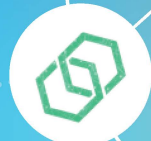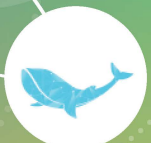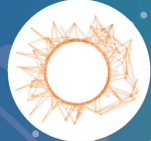NSF Convergence Accelerator

2023 PORTFOLIO GUIDE

This page is left intentionally blank

TABLE OF CONTENTS

TIP DIRECTORATE OVERVIEW

For more than seven decades, the U.S. National Science Foundation has been at the forefront of the research, innovation and education that has transformed American lives, powered the economy, and elevated the nation's competitiveness on the global stage. NSF investments have given the world tangible solutions such as bar codes, the modern internet, laser eye surgery, and DNA analysis. Now, the Foundation is looking to do more to speed the development and deployment of future technological advancements and focus on addressing the foremost challenges that society and the economy face today–from climate change to equity to critical infrastructure–affecting every corner of the country.

In March 2022, NSF launched the Directorate for Technology, Innovation and Partnerships (TIP), NSF's first directorate in 32 years. The TIP directorate's mission is to maximize NSF's impact by harnessing the nation's vast and diverse talent pool to advance critical and emerging technologies, addressing pressing societal and economic challenges, and accelerating the translation of research results from the lab to market and society. TIP will improve U.S. competitiveness, grow the U.S. economy, and train a diverse workforce for future high-wage jobs.

Through the TIP directorate, NSF is seizing a generational opportunity to focus on pivotal challenges and is doubling down the Foundation's support of use-inspired research and the translation of research results to the market and society. In doing so, the directorate strengthens the intense interplay between foundational and use-inspired work, enhancing the full cycle of discovery and innovation, the development of new technologies and solutions and provides opportunities for all Americans to contribute to the workshop in science, technology, engineering, and math jobs.

Accelerating Research and Innovation to Impact

TIP meets the nation's priorities by providing researchers and innovators with education, tools, and funding to spur innovation, accelerate the development of breakthrough technologies, and speed solutions forward. The directorate works closely with the entire agency to leverage ongoing research investments and grow them at speed and scale—leading more rapidly to economic and societal benefits across the nation.

- **Fostering Innovation and Technology Ecosystems**—Nurtures regional and national innovation and technology ecosystems to support researchers and innovators to converge, develop and accelerate use-inspired research for societal impact.

- **Establishing Translational Pathways**—Supports startups through a lab-to-market platform and establishes new pathways for translating research results for society.

- **Partnering to Engage the Nation's Diverse Talent**—Advances and deepens high-impact, public and private partnerships across all areas of science, engineering, and education to cultivate innovation ecosystems, create technology solutions, and support future STEM leaders.

TIP Programs

TIP's impact is embodied in its dynamic innovation programs to advance use-inspired and translational research in all fields of science and engineering, giving rise to new industries and engaging all Americans—regardless of background or location—in the pursuit of new, high-wage jobs in STEM.

TIP integrates with NSF's existing directorates and fosters partnerships—with government, industry, nonprofits, civil society, and communities of practice—to leverage, energize, and rapidly bring to society use-inspired research and innovation. TIP programming has three primary foci:

- Cultivate innovation ecosystems throughout the U.S. to advance use inspired research with a focus on the breakthrough technologies and societal and economic challenges.

- Enhance the translation of emerging technologies to the market and to society more generally.

- Leverage partnerships that bring researchers and practitioners together.

To learn about the TIP directorate, including the latest funding opportunities and information about ways to partner across its portfolio of technology, innovation, and translation, visit new.nsf.gov/tip/latest.

CONVERGENCE ACCELERATOR OVERVIEW

Solutions for today's national-scale societal challenges are hard to solve within a single discipline. Instead, these challenges require convergence to merge ideas, approaches, and technologies from a wide range of diverse sectors, disciplines, and experts.

Launched in 2019, the U.S. National Science Foundation's Convergence Accelerator builds upon research and discovery to accelerate use-inspired convergence research into practical application. The program funds a cohort of teams to work interactively toward solving grand societal challenges that impact thousands of people positively. In March 2022, NSF launched the Directorate for Technology, Innovation, and Partnerships and aligned the Convergence Accelerator program to the directorate. Fiscal year 2023 has shown the largest expansion of the program to date and showcased partnerships between the NSF and the Department of Defense (DOD), as well as the governments of Australia and Sweden.

Funded teams begin in Phase 1; a fast-paced nine-month hands-on journey, which includes the program's innovation curriculum, formal pitch, and Phase 2 proposal evaluation. The innovation curriculum includes customer discovery, human-centered design, team science, communication skills, and pitching. Teams apply the curriculum to help develop their use-inspired solution, create communication and outreach products to connect with partners and stakeholders, and prepare teams for the next phase. The program's team-based approach creates a co-opetition environment; stimulating cooperation by the sharing of innovative ideas toward solving complex challenges together, while also working in a competitive environment to try and progress to Phase 2.

Teams are composed of disciplines and expertise from academia, industry, government, nonprofit, and other communities of practice. Disciplines include science and engineering fields as well as other disciplines like law, healthcare, communications and media, and

business management to accelerate the solutions forward. As teams apply the Program's convergence research fundamentals and innovation processes, the teams' pioneering ideas are transformed along the journey—converting it to a low-fidelity proof of concept, then prototype, and finally a solution. Catalyzed partnerships are also vital to the teams, providing end-user insights, resources, services, infrastructure, and transition-to-practice pathways. Teams foster and nurture partnerships to support their solutions toward sustainability and societal and economic impact.

The Convergence Accelerator is a unique NSF program. While the program is focused on advancing research toward societal impact; the program is intentionally designed around four key components to provide the highest impact. The four components include a convergence research approach, strong multi-organization partnerships, high-impact deliverables, and track alignment.

- **Convergence Research**—Each research effort includes a multidisciplinary approach to accelerate use-inspired research into practice in ways that benefit society at scale.

- **Partnerships**—Funded teams must create partnerships with many types of organizations and sectors to ensure that the research efforts are use-inspired and have a clear transition path. Each partnership is unique and may provide needed expertise, represent end-users; or provide resources, services, and infrastructure to advance the NSF-funded solution forward.

- **Deliverables**—Deliverables or solution outputs can take many forms such as hardware, software, data, services, processes, protocols, standards, and more, but each solution must provide a positive impact on society at scale.

- **Track Alignment**—Each funded effort must align to the program's identified convergence research track topics and have the potential for strong integration with other efforts.

To date, the Convergence Accelerator program is composed of four cohorts. The 2019 Cohort, launched in September 2019, is the pilot cohort, funding 42 Phase 1 teams and seven Phase 2 teams to develop solutions

in Track A: Open Knowledge Networks and Track B: AI & the Future of Work. Currently, the cohort has brought their solutions and research outcomes to the public as they are the first teams to have completed both phases of the Convergence Accelerator program. All teams have strong partnerships and are focusing on finalizing their sustainability plans to ensure the solutions' impact beyond NSF support. The 2020 Cohort, awarded in September 2020, included 29 Phase 1 teams and features 10 Phase 2 teams developing solutions in two transformative research areas—Track C: Quantum Technology and Track D: AI-Driven Innovation via Data and Modeling Sharing. The 2020 Cohort is finishing their 24-month Phase 2 process. Teams are beginning to bring their solutions and research outcomes to the public and implement their partnerships and sustainability plans for the future.

The 2021 cohort, awarded in September 2021, included 28 Phase 1 teams focusing on Track E: Networked Blue Economy and Track F: Trust & Authenticity in Communication Systems. In September 2022, the program awarded 12 teams to Phase 2. The 2021 Cohort is entering the final stages of Phase 2 where they are creating their solutions, conducting focused research, building partnerships with stakeholders and organizations, and creating a go-to market and sustainability strategy.

The 2022 cohort includes four convergent track topics, kicking off the first track, Track G: Securely Operating Through 5G Infrastructure, partnering with the DOD's Office of the Under Secretary of Defense for Research and Engineering, OUSD(RE), awarded 16 Phase 1 teams in August 2022. The 2022 cohort was completed in January 2023 with the awarding of 49 additional teams for Track H: Enhancing Opportunities for Persons with Disabilities; Track I: Sustainable Materials for Global Challenges; and Track J: Food & Nutrition Security. Additionally, the Convergence Accelerator is excited to have partnered with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), an Australian Government agency responsible for scientific research, on Track I. Over the last nine months, the teams built proof-of-concepts, fostered partnerships, participated in the program's Innovation Curriculum, and completed the formal pitch and Phase 2 proposal evaluation. In Fall 2023, 24 teams across Tracks G, H, I, and J advanced to Phase 2 of the program. Phase 2 teams will continue to apply the Program's fundamentals to develop use-

inspired solutions and build sustainability plans to continue to deliver impact.

Within the 2023 fiscal year, the program also coordinated the preparation of the 2023 Cohort, which included a funding opportunity, issued in May 2023 with proposals due August 2023, on three research tracks: Track K: Equitable Water Solutions, Track L: Real-World Chemical Sensing Applications, and Track M: Bio-Inspired Design Innovations. The Convergence Accelerator is proud to have partnered with two Swedish Research Agencies: the Swedish Research Council and Vinnova, for Track L. The 2023 cohort will kick off Phase 1 in January 2024.

To learn more about the NSF Convergence Accelerator, visit new.nsf.gov/funding/initiatives/convergence-accelerator.

TRACK A: OPEN KNOWLEDGE NETWORKS

Vast amounts of data are produced every day, yet many organizations lack the ability to draw insights from the data and make data-driven decisions. Knowledge networks (or repositories) with massive amounts of world knowledge help to power the next wave of artificial intelligence exploration, driving innovations from scientific research to the commercial sector. Knowledge networks/graphs provide a powerful approach for data discovery, integration, and reuse, but require an investment in their creation and maintenance.

To enable data to be freely accessible, especially to government, academia, small business, and nonprofit organizations, the U.S. National Science Foundation Convergence Accelerator funded the creation of nonproprietary infrastructure for building Open Knowledge Networks (OKNs) from 2019 to 2022. Using AI and machine learning, teams built infrastructure, tools, and applications to identify data, link data points, describe relationships, and gather information at speed and scale—providing data to knowledge, knowledge to insights, and insights to understanding.

The OKNs connect people, events, places, environments, health, and more. They remove domain boundaries in order to link data, its attributes, and relationships to other data to be accessible for decision-makers, analysts, researchers, and the American public to answer interesting and pressing questions. The teams aligned to Track A: Open Knowledge Networks focused on urban flooding, judicial court records, biomedical health, geospatial information, and technology infrastructure for knowledge network creation and use.

Open Knowledge Networks teams include:

AI and Machine Learning Infrastructure Tools and Applications

KnowWhereGraph—Led by University of California, Santa Barbara, KnowWhereGraph provides knowledge graph and geo-enrichment services for environmental intelligence applications. The solution enriches data with pre-integrated custom-tailored knowledge about any locale of interest, thereby reducing the time to find, combine, and reuse data. The initial application

areas are focused on decision support related to food systems, supply chains, and humanitarian aid, but can easily be expanded to other application areas as well.

OKN Infrastructure—Led by Massachusetts Institute of Technology, the OKN Infrastructure is building infrastructure for constructing novel OKNs and OKN-powered applications. This solution provides tools to make the creation and maintenance of high-quality datasets and apps more cost-effective and more widely accessible.

Domain-based Open Knowledge Networks

Biomedical Open Knowledge Network—Led by University of California, San Francisco, the Biomedical Open Knowledge Network, features SPOKE, an OKN connecting millions of biomedical facts including molecules, pharmacological compounds, organs and diseases, food nutrients, and more. Centered around knowledge representation and reasoning, the team is developing applications using graph theory, advanced visualizations, and real-world clinical evidence to advance drug development and precision medicine.

SCALES—Led by Northwestern University, the SCALES (Systematic Content Analysis of Litigation Events) open knowledge network is designed to be a public resource to help provide insights based on judicial court records. SCALES is creating tools to decode court records and transform this data into actionable information that aids a variety of uses, including legal scholars, journalists, policymakers, judiciary, and citizens.

Urban Flooding OKN—Led by University of Cincinnati, Urban Flooding Open Knowledge Network (UF-OKN) is addressing urban flooding impacts to assist decision-makers and urban planners in real-time response and long-term planning.

Integrating the Knowledge Networks

Data2Knowledge Consortium—Knowledge graphs are rapidly emerging as key infrastructure to integrate the diverse information needed to solve complex societal challenges—from climate change and human health to capturing business value from the AI revolution. The Open Knowledge Network Phase 2 teams have collaborated" to create the Data2Knowledge Consortium to ensure that the Track A outcome is "greater than the sum of the parts". Composed initially of the current Open Knowledge Network Phase 2 teams, the objective of the Data2Knowledge Consortium is to facilitate a thriving ecosystem for open knowledge graph development and use.

TRACK OUTCOMES:

- The Biomedical Open Knowledge Network team established a startup, MATE Bioservices, in 2021, harnessing the power of SPOKE to support academic, clinical, and pharmaceutical researchers in their efforts to better understand diseases, biological complexity, and bring new products to the market. The startup is co-owned by University of California, San Francisco Innovation Ventures (UCSF Ventures).

- The SCALES team is establishing a nonprofit entity focused on promoting the transparency and accountability of the U.S. legal system by making data about its operations and participants accessible and free to the public.

- Inspired by Track A, NSF Convergence Accelerator hosted an OKN Innovation Sprint to gather input to design a roadmap to build a proof of concept or prototype OKN (Proto-OKN). The Sprint collected insights from more than 150 experts across 24 academic institutions, 15 Federal agencies, 3 nonprofit organizations, and 20 private sector companies.

  - **September 2022**: NSF released the Open Knowledge Network Roadmap, outlining a strategy for establishing an open and accessible national resource to power data science and next-generation AI.

  - **March 2023**: NSF issued a program solicitation, NSF-23-571 'Building the Prototype Open Knowledge Network', in coordination with five federal agencies, to continue the development of the proto-OKN.

  - **September 2023**: NSF invested $26.7 million in 18 multidisciplinary, cross-sector teams to build the first-ever prototype OKN.

Biomedical Open Knowledge Network

Connecting the Dots to Advance Precision Medicine for Everyone

Lead PI: Sergio Baranzini
Sergio.Baranzini@ucsf.edu

Sui Huang
Sui.Huang@isbscience.org

Sharat Israni
Sharat.Israni@ucsf.edu

Overview

The human brain cannot possibly integrate the vast and rapidly growing amount of information modern societies have been able to amass. This hampers the generation of new knowledge, specifically in the biomedical sciences and human health, where the subject complexity is vast, and stakes are high. This project's knowledge network, SPOKE, incorporates a significant proportion of all known factual relationships among biomedical concepts, providing a discovery engine that will enable doctors, researchers, the pharmaceutical industry and the citizen scientist to explore biomedicine in its whole might.

Description

Human health has become so complex that even doctors turn to Google, and now even large language models (LLMs, such as GPT-4), to understand difficult cases. Then, based on their extensive training, they can better interpret, diagnose and treat illnesses. Clearly, Google is neither based purely on accepted science nor is it specialized enough to handle rare or complex conditions, find a cure for a given disease, or discover the root of a biological process. For those cases, specific information needs to be integrated by skilled researchers into formulating the right hypothesis (consistent with previous evidence and maximizing utilization of current knowledge), which then needs to be tested experimentally.

The response to each of the previous scenarios requires navigating a deluge of complex data and information and connecting the dots in a meaningful way. SPOKE integrates hundreds of millions of biomedical concepts into a knowledge engine to enable doctors, drug developers and citizen scientists to connect the dots and produce a biologically meaningful answer to these questions. Healthcare and related industries represent 1/5 of the entire U.S. economy. The team recently incorporated Mate Bioservices, a company that commercializes applications of SPOKE. The team anticipates extensive adoption of this platform will have a significant societal impact by reducing healthcare costs, health disparities and accelerating therapeutics, ultimately improving the quality of life for every American.

Differentiators

Even as high-throughput modern technology in biomedicine has facilitated the acquisition of vast amounts of data, it has greatly widened the chasm between its generation and its interpretation. Those approaching such a complex task based only on individual strengths are bound to fail. While few efforts have been devoted to addressing this vacuum, the team is pioneering the paradigm of knowledge networks in biomedicine-a paradigm amply proven in Web Search-into a discipline that is inherently graph-theoretic. The team's experience with systems biology and graph theory, Principal Investigator participation in National Institute of Health (NIH), National Center for Advancing Translational Sciences (NCATS) Biomedical Translator, and the long track record of creating SPOKE, are testaments to their vision and commitment to transforming data into knowledge. This has been acknowledged even by the NIH Office of Data Science Strategy.

The team's commercialization vehicle, Mate Bioservices, aims to revolutionize the way research is conducted in the healthcare industry through: i) harmonizing biomedical research into a central knowledge network; ii) designing the artifical intelligence and machine learning (AI/ML) tools needed to answer complex scientific questions; and iii) integrating knowledge networks and AI/ML tools into sophisticated user interfaces that are specifically designed for various customer profiles.

Road Map

Throughout the team's participation in the NSF Convergence Accelerator program, they have developed and made available a fully functional biomedical knowledge network. They have established a governance committee for SPOKE, guiding expansion of the knowledge networks with additional knowledge sources; and developed an open access

network visualization tool. They have completed various analyses and published results validating the network's quality and utility. They secured rights for the commercialization of SPOKE-powered products, and established a company to support commercialization of four products powered by the knowledge networks. In the near future, the company, Mate Bioservices, will:

Q3, 2023: Increase the number of daily active users on SPOKE Cloud by 20%

Q4, 2023: Partner with proprietary data producers to sell data through SPOKE Cloud

Q4, 2023: Secure additional seed funding

Q1, 2024: Deploy SPOKE Cloud in additional graph databases

Q4, 2024: Launch SPOKE Cloud Fabric

Partnerships

Institute for Systems Biology (ISB): The team continues to work with ISB investigators both in the scientific development of the knowledge network and with resources to expand its utility and reach.

Lawrence Livermore National Labs: Leveraging its extraordinary computing power and technical knowhow on graph theory and analytical approaches the team works to derive insights from the structure of the graph.

Indiana University (IU): A partnership sparked by the Convergence Accelerator Phase 1, Katy Börner's team at IU used their world-class expertise in complex graph visualizations and analysis to develop an open access network visualizer aimed at citizen scientists.

University of California, San Diego (UCSD): Another partnership formed in Phase 1 of the Program, Peter Rose from the San Diego Supercomputer Center is using his expertise in protein domain and structure, as well as geolocation information, to further expand the network.

University of California, San Francisco (UCSF) Innovation Ventures: Having already provided seed funding for the establishment of Mate Bioservices, they will continue to provide support for the handling of intellectual property matters.

National Center for Advancing Translational Sciences (NCATS): The team's knowledge network is an active participant of the NCATS Translator Program as an Autonomous Relay Agent Team.

UCSD and Elchemy: The team partnered with Camille Nebeker (UCSD) and Erin Kenneally (Elchemy) to formally advise on ethical, legal and social implications of the project.

National Aeronautics and Space Administration (NASA): The team has established a strategic partnership with NASA's GeneLab to process biological datasets acquired during spaceflight with SPOKE and will programmatically link the two platforms.

Intellectual Property

Invention disclosures related to uses of the network (not the network itself) have been filed with UCSF Innovation Ventures. This will ensure proper documentation of the resulting intellectual property from this project for those application areas.

KnowWhereGraph

Enriching & Linking Cross Domain Knowledge Graphs via Spacially Explicit AI

Lead PI: Krzysztof Janowicz
janowicz@ucsb.edu

Pascal Hitzler
hitzler@ksu.edu

Wenwen Li
wenwen@asu.edu

Dean Rehberger
rehberge@msu.edu

Mark Schildhauer
schild@nceas.ucsb.edu

Overview

The KnowWhereGraph team is developing a cross-domain knowledge graph for environmental intelligence applications. KnowWhereGraph supports data-driven analytics and decision-making by answering questions such as "What is here?" or "What happened here before?" anywhere on Earth within seconds. The team developed multiple geospatially aware graph analytics services, e.g., for graph integration, geo-enrichment, and visualization, to support pilots in disaster relief, agriculture and food supply chains, and finance. However, the openly available knowledge graph (consisting of 3 billion statements) and services generalize to all application areas that benefit from rapid access to contextual information about people, places, and the environment.

Description

Geospatial data, be it about people, places, or events, are critical to understanding where and when things happen and, more importantly, why they happened or will happen. Today, nearly 80% of the resources invested in any data-intensive project are still spent on data discovery, retrieval, entry, integration, cleaning, and apportionment. Hence, only 20% of a project's overall resources are left for the analytics that will ultimately determine the quality of the derived insights. This significantly hinders the rate and cost of data-driven decision-making in industry and government. KnowWhereGraph addresses this challenge by providing (1) a 13 billion facts-strong open knowledge graph that interlinks over 30 cross-domain data layers, and (2) a set of geo-enrichment services that enable rapid access to well-curated location-aware data from the graph.

The team made significant progress over the past years in developing the graph using expressive knowledge graph schemata to connect multi-source data in terms of disaster, air quality, climate hazards, crop history, soil

characteristics, experts and expertise, administrative boundaries, health, transportation infrastructure, etc. Overall, the graph provides 10 different kinds of geographic identifiers and over 20 data layers that provide millions of past and present facts about any of these regions. This number is expected to continue growing as more automated graph generation and integration approaches are being developed.

Team members are also pioneers in developing spatially explicit machine learning models to provide GeoAI-ready data to empower intelligent decision-making. In the last phase of the project, the team centered their efforts on supporting project verticals, including the disaster relief subteam, to assemble quickly needed datasets for rapid disaster response and evacuation after major devastating events, such as hurricanes, have occurred. They are also developing graph solutions for understanding and sustaining food supply chain resilience. As a technology-driven project, the goal is to demonstrate how novel geospatial solutions can inform downstream stakeholders from industry, nonprofits, and government agencies.

Differentiators

Spatial is special. The KnowWhereGraph team provides unique expertise in representing and integrating geospatial data using knowledge graph technologies and GeoAI-based services: the team has contributed to international semantic standards; project partner Esri offers the market's most advanced spatial analytics technology, while Oliver Wyman and partner companies provide expertise in applying remotely sensed imagery and machine learning models to global food markets, supply chains, and farms. The academic team has a track record in technology transfer, the development of vocabularies, and lifting geospatial data to the graph, while partners National Center for Ecological Analysis and Synthesis (NCEAS), U.S. Geological Survey (USGS), and U.S. Department of Agriculture (USDA) are among the largest providers and integrators of geospatial data.

This combination enables the team to develop services rapidly, connect them to vast amounts of data, and apply them to real-world applications, including disaster relief and food supply chains.

Road Map

In its final project year, the team's main focus is on (1) making the graph sustainable to serve it openly to the public for years to come, (2) building a community of contributors and users around it, (3) ensuring a high quality of data and schemata, and (4) developing means to keep the graph growing automatically when new data becomes available in contrast to the fixed releases (snapshots) currently published about every six months. Further, the team would like to broaden the use cases KnowWhereGraph can be applied to. Hence, they encourage potential contributors, users, developers, ontology engineers, and others from industry, government agencies, and academia to reach out.

Partnerships

Academia Partners: University of California, Santa Barbara's Center for Spatial Studies, NCEAS, Kansas State University's Center for AI and Data Science, and Arizona State University offer expertise in knowledge engineering, GeoAI, data synthesis, and environmental modeling. Michigan State University contributes expertise in precision and digital agriculture and graph-based applications for the humanities. University of South Carolina provides expertise in environmental economics.

Industry Partners: Esri provides expertise for developing and testing knowledge graph-based geo-enrichment services. Oliver Wyman and start-ups test project capabilities with its customers in supply chain optimization and commodity markets.

Nonprofit Partners: The Food Industry Association provides access to the food industry with a focus on sustainable agriculture. Direct Relief applies project work to humanitarian aid supply chains.

Government Partners: USGS provides expertise in lifting its National Map portal data to the graph, while USDA Agricultural Research Service (ARS) & Natural Resources Conservation Service (NRCS) provide data and expertise about sustainable agriculture and soil data.

Intellectual Property

The team is committed to openness and international standards. While encouraging the least restrictive licensing, data or software licensed under more restrictive conditions will be accommodated to allow for broad industry participation.

Lead PI: Michael Cafarella
michjc@umich.edu

Doug Downey
ddowney@allenai.org

Matthew Shapiro
shapiro@umich.edu

Overview

Knowledge networks are a novel and potentially transformative form of data, but building applications on top of them is too difficult, time-consuming, and expensive. OKN Infrastructure has built a range of resources to make these applications easier to build, including a Knowledge Network Programming System for data provenance and debugging; and a range of information extraction systems that improve the knowledge resources themselves.

Description

Knowledge networks like Wikidata are a compelling new type of data–akin to a "structured world wide web"–that have enabled new applications, such as structured web search and voice assistants. Unfortunately, only the most technically sophisticated organizations have had the resources to build these difficult-to-engineer applications. As a result, most of these next-generation applications never actually get built, and users cannot benefit from them. The team's Knowledge Network Programming System dramatically reduces the cost of building knowledge-powered applications by combining programming tools with recent advances in data management and machine learning. This happens in three ways. First, it makes knowledge network data easy to use by turning today's knowledge networks into useable built-in Python types and program values, thereby avoiding the endless data janitor work that comes with conventional programming. Second, it makes knowledge applications easy to debug by automatically recording all data operations for future examination; crucially, these recordings can be shared across institutional boundaries. Third, it can make knowledge application development more collaborative by making data sharing a basic language primitive, thereby including in the development process not just programmers, but also end-users, crowd workers, data field workers, analysts, and even news article readers: anyone who creates, manipulates, or consumes knowledge can make an application better.

OKN Infrastructure has also built several knowledge networks as part of this effort, both for their own value and to test the programming system. The most notable is the CORD-19 knowledge network, which described 40,000 scientific papers about COVID-19 and related historical coronavirus research. Upon completion of this network in mid-2022, it described more than one million papers. This knowledge network has been covered in the Wall Street Journal, the New York Times, and elsewhere.

One important way the team accelerates application development is via software that automatically produces provenance knowledge networks by observing data processing activity. The team has used this method to create networks that reflect data production processes in economics data handling and in scientific data applications.

Further, this project has yielded a range of software packages and novel technical methods that make it easier to accurately extract knowledge networks from raw sources. For example, the work has improved ingesting PDFs, performing concept coreference, performing scientific paper author disambiguation, and in accelerating neural model operations by recycling previously seen embeddings.

Finally, the team has introduced user-facing tools that demonstrate novel user interactions, such as guided synthesis of data extractors for web pages.

Differentiators

All knowledge network applications that the team is aware of rely on traditional software engineering tools. The team is unaware of any system that addresses knowledge network application development per se, even though other data types (say, relational databases) have extensive dedicated tooling.

OKN Infrastructure's work has also been unusual in the ability to handle provenance evidence from multiple institutions without a domain-specific provenance standard. Most past data provenance collection efforts have either been very limited in terms of

topic, or they stop collecting data at the institutional boundary. In almost all cases, these past methods have been expensive to adopt. OKN Infrastructure's approach enables organizations to incrementally adopt provenance data gathering methods, to incrementally benefit as their partners share provenance data, and to do so at low deployment cost.

The team's work in producing the CORD-19 knowledge network was notable in its speed to first deployment (just weeks after the COVID-19 virus came to widespread attention), in the very regular updates made over more than a two-year span, and the large size of the ultimate product.

Finally, the team's work has been unusual in not focusing exclusively on one element of the knowledge network application development stack but has instead yielded software or novel scientific results that improve knowledge application development at many different layers: improved extraction quality, improved collection of debugging information, faster model training, better data cleaning methods, and others.

The research team has been unusual in its level of experience with shipping data development systems, knowledge network production, and relevant domain expertise.

Principial Investigator (PI) Michael Cafarella is a principal research scientist at Massachusetts Institute of Technology's Computer Science and Artificial Intelligence Laboratory. He has published on information extraction systems and data-intensive programming systems. He is also one of the co-creators of the Hadoop framework for managing big data.

PI Doug Downey is a Senior Research Scientist at the Allen Institute for Artificial Intelligence. The Allen Institute is one of the largest nonprofit research organizations in AI, and arguably employs the largest set of Knowledge Network engineers outside the major technology firms.

PI Matthew Shapiro is the Lawrence R. Klein Collegiate Professor of Economics at Michigan, and an expert in macroeconomics and public finance. He serves as chair of the Federal Statistics Advisory Committee.

Road Map

This Track A project has ended. The work in this project is reflected in a wide range of published scientific research papers, the CORD-19 dataset, the Knowledge Network Programming System open-source project, and a wide range of tools for extracting knowledge networks from raw documents.

SCALES

Transform the Transparency and Accessibility of Court Records
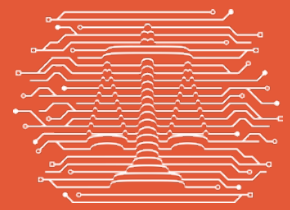
Lead PI:

Luis A. Nunes Amaral
amaral@northwestern.edu

Charlotte S. Alexander
calexander@gsu.edu

Rachel D. Mersey
rdmersey@northwestern.edu

Adam R. Pah
a-pah@kellogg.northwestern.edu

David L. Schwatrz
david.schwartz@law.northwestern.edu

Overview

The U.S. court system produces millions of records per year. These records are supposed to be open to the public, but in practice they are trapped behind paywalls and dysfunctional, outdated software. This project's goal is to enable a broad spectrum of public stakeholders to efficiently access, evaluate, engage with, and understand the work of the courts. The team's mission is to create an Open Knowledge Network (OKN) that will serve as a foundation for advocates and researchers to analyze court data systematically. The platform will also enable data gathering and integration that, in turn, supports intelligent analysis and meaning extraction so all citizens, entrepreneurs, journalists, lawyers, potential litigants, policy makers, scholars, and even the judiciary itself, can better understand and evaluate how the courts function.

Description

Data drives information and insight. Government agencies, central banks, health organizations, and law enforcement agencies all gather data in order to better understand and communicate the events, trends, and relationships between them that define the world. All of this is in service of the twin goals of understanding and transparency.

While the U.S. court system collects similar data sets, those data are rarely used in support of the goals of understanding and transparency. This shortfall is the result of three features: availability of data, lack of data integration, and limited tools that support intelligent information analysis for non-technical users. Availability is hampered by the fact that much of the relevant court data resides behind a federal pay-for-use firewall. While individual case information is affordable, the data needed to do system level analysis would cost tens of millions of dollars to access. Integration is limited by data availability as well as the tools and skills required to support this work at scale. Understanding and insight, even if one had full access to the documents,

is thus hindered by the lack of available tools for the journalists, legal scholars, and decision-makers who most need it.

With these issues in mind, the team has brought together data scientists, legal scholars, journalists, and policy experts, to develop a suite of tools to enable access to court records and analytics. The Systematic Content Analysis of Litigation EventS (SCALES) OKN provides access to both the data and the insights contained within them to a broad range of users with diverse technical skills.

This project encompasses five complementary elements.

- **Data Access:** The team makes all of the data incorporated into SCALES and the integration of such data freely accessible to the public.

- **Data Integration:** The team will provide tools that integrate data sets (e.g., judicial, firm, and corporate profiles) and support data cleaning, normalization, and integration. These tools include intelligent data interpretation supported by natural language processing and machine learning.

- **Extraction of Insight:** The team has developed a public facing data platform that allows users to explore the data to answer questions about trends, comparisons, and correlations by simply asking questions. Expanding on work in language processing, information goals, and intent guided analytics, the system provides access to not just the data, but the information and insight contained within.

- **Education:** The team has developed extensive materials aimed at providing users with an understanding of both the data, the integration, and analytics methods. This includes both reports, which describe features of the data and are publicly available at livingreports.scales-okn.org, as well as supporting documentation for their software, tools, and data.
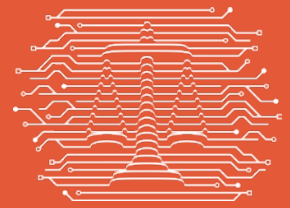
- **Community:** The team has fostered the nucleation and organic growth of a community of stakeholders that both add to and use the data and the system supporting it through annual Open Justice Research Workshops.

Differentiators

There are limited alternative sources of judicial records and none that enable systematic access and analysis for the public. Commercial legal services such as Westlaw, LexisNexis, and others have purchased many judicial records, but they limit access through their own fees and prohibit bulk downloads—foreclosing systematic analysis even for those who pay the hefty fees. A pioneering open alternative, The Free Law Project, maintains a user-generated free repository of court records, but it is not designed to support systematic analysis.

SCALES is unique in that it is providing users with not just access to raw data but also the meaning that it supports through access to intelligent analytics learned from across the legal system.

Road Map

During year one of Phase 2, the team conducted extensive user tests and refined the user interface of the prototype based on that feedback. They also implemented named entity recognition to further enrich the court record data with links to judge characteristics, nature of entity (i.e., business or government), and statutes—to aid in contextualizing the entities within these records. Further, the team is developing an ontology of litigation events in order to systematically identify what occurs in a case.

In the following years, they used user feedback to inform the continued effort to develop models and ontologies that provided the additional context that was needed to understand what events were transpiring in the court records and how that related to the parties that were a part of the case. The team developed ontologies for civil and criminal litigation events as well as recognizing different types of entities that are involved in the cases.

Partnerships

During Phase 2, the SCALES team engaged with partners across academia, law, industry, and journalism. They hosted an annual Open Justice Research Workshop, which brought together researchers from across disciplines to ideate on new research topics and form new collaborations. They also worked with legal aid clinics to develop reports that examine how the federal courts function and broadly shared their insights about developing the SCALES OKN to various communities and partners.

Intellectual Property

The team licenses all intellectual property created under the GNU General Public License v3.0.

Urban Flooding OKN

Flood Info for AnyOne & AnyTime

Lead PI:

Lilit Yeghiazarian
lilit.yeghiazarian@uc.edu

Sankar Arumugam
sankar_arumugam@ncsu.edu

Ximing Cai
xmcai@illinois.edu

Torsten Hahmann
torsten.hahmann@maine.edu

Venkatesh Merwade
vmerwade@purdue.edu

Overview

Flooding causes more than $100 billion in economic loss and 500 deaths in the U.S. every year. Some of this could be avoided if people had access to flood-related information such as flood inundation depth at any location or optimal evacuation routes during a flood event. The team is developing an open knowledge network that people can use to find out how flooding impacts them so they can take actions to mitigate it.

Description

Recent studies have shown that approximately 41 million people (~13% of the population) are at risk of severe flooding in the U.S. Despite such high risk of flood exposure, it is hard to find answers to questions such as "What is the total impact of flooding on a city?" This is because while urban infrastructure is connected, data and models that describe them are not. Urban Flooding Open Knowledge Network (UF-OKN) calls this connected urban infrastructure the Urban Multiplex. It includes the power grid, transportation network, surface water and groundwater systems, storm water and sewage systems, drinking water systems, inland navigation and dams, all intertwined with the socioeconomic and public health sectors that form the fabric of modern cities. So, when one part of the Urban Multiplex fails from a flood, its cascading impacts across the city are unknown.

This project aims to address the issue of quantifying flood impacts on an Urban Multiplex by developing a publicly accessible national-scale UF-OKN. The proposed UF-OKN will connect multiple datasets, tools and models across the Urban Multiplex to ascertain and forecast the true impact of flooding.

Product design, implementation and delivery are guided by user needs and partnerships with local, state and federal agencies and private industries. The UF-OKN can be used to answer questions such as:

"Which roads are expected to flood during a storm?" or "Is my house likely to lose power?" At an organizational level, a decision maker can ask questions such as: "To minimize human loss, which neighborhoods should be evacuated and when?" or "How flood risk will change in my city in the next 20-30 years?"

The team expects that the UF-OKN will directly and indirectly serve millions of impacted people—by providing the necessary tools and resources to enable real-time response and long-term planning and decision making.

Differentiators

Currently, flood-related information is available from different sources and in different forms. The two most common sources are flood insurance rate maps (FIRMS), produced by Federal Emergency Management Agency (FEMA) and available as static GIS files or paper maps; and dynamic flood forecasts and water levels provided by the U.S. Geological Survey (USGS) and the National Weather Service. All these datasets are available only through the respective agencies and require some knowledge of how to navigate their systems. Additionally, these datasets cannot be easily integrated to create a holistic view of a flood impact on an Urban Multiplex at different temporal and spatial scales.

UF-OKN integrates flooding information with other related datasets in an Urban Multiplex so users ranging from an individual homeowner to decision makers at state or federal levels could get answers to their questions.

Road Map

UF-OKN is delivering key technologies and products to serve the needs of two user archetypes representing emergency responders and federal agencies involved in planning and coordination to mitigate flood impacts. The Strategic Framework consists of five planes:

User Relations & Product Development; Technology Development; Research & Development; Transfer to Practice & Sustainability Model Development; and Urban Flooding Scientific Community Development. Activities and milestones achieved in each plane inform decisions throughout the Strategic Framework.

Deliverable 1: A national scale UF-OKN data fabric which is designed to be flexible in accommodating static geospatial data as well as dynamic flood forecasts. A key deliverable is the Urban Multiplex Inventory (UrMI) which is the geospatial data warehouse for indexing and describing over 140 million features of the urban infrastructure.

Deliverable 2: A national-scale flood forecasting service that provides flood depth predictions across UrMI features leveraging the National Water Model (NWM) hydrologic forecasts.

Deliverable 3: Climate-informed future flood predictions for long-term planning.

Deliverable 4: Business canvas and market evaluation.

Deliverable 5: API-based access and/or user-interfaces around UrMI, socioeconomic impacts of floods, future flood predictions, and real-time flood forecasting services. Soft launch.

Final Deliverable: Viable products and services.

Partnerships

UF-OKN's partners contributed personnel time, data, model results, testing, evaluation, and feedback. Many Phase 1 partners will adopt UF-OKN for their operations, thus becoming the project's first users.

Phase 2 partners will contribute at the same level as Phase 1 partners. They include U.S. Environmental Protectional Agency (National repository of underground and above ground fuel storage tanks; National drinking water infrastructure data; Joint modeling of flood impacts in these critical facilities; real-time sensing data); USGS (real-time sensing data); and National Oceanic and Atmospheric Administration (personnel time).

Intellectual Property

The team anticipates that significant intellectual contributions will result from this project. Participating project team members have agreed to work together on the protection, maintenance, and commercialization of any jointly owned intellectual property according to applicable laws and policies. As the lead institution, the University of Cincinnati will coordinate these efforts.

Luis Nunes Amaral
amaral@northwestern.edu

Sergio Baranzini
Sergio.Baranzini@ucsf.edu

Mike Cafarella
michjc@csail.mit.edu

Krzysztof Janowicz
jano@geog.ucsb.edu

Lilit Yeghiazarian
yeghialt@ucmail.uc.edu

Overview

Knowledge graphs are rapidly emerging as key tools to integrate the diverse information needed to solve complex societal challenge–from climate change and human health to capturing business value from the artificial intelligence revolution. The Data2Knowledge collaboration of the five Open Knowledge Network (OKN) projects in Track A of the U.S. National Science Foundation Convergence Accelerator seeks to facilitate an open ecosystem for knowledge graph development, use, and maintenance–helping to build a Prototype OKN (Proto-OKN) for the American industry, government agencies, and the broader public. The goal of Data2Knowledge is to facilitate an open system approach that helps deliver the power of knowledge graphs across sectors.

Description

OKNs, powered by domain-specific knowledge graphs, are poised to fuel the next wave of AI exploration-enabling insights from massive amounts of world knowledge and driving innovations from scientific research to the commercial sector.

The OKNs Track of the NSF Convergence Accelerator—including the Data2Knowledge track integration effort—envisions an open, inclusive, community-oriented graph structure as a trustworthy knowledge infrastructure that facilitates and empowers a host of applications and opens new research avenues. Proto-OKN is the next stage of this interconnected infrastructure.

The 2021 Final Report from the National Security Commission on AI calls for the establishment of "a National AI Research Infrastructure composed of cloud computing resources, test beds, large-scale open training data, and an open knowledge network that will broaden access to AI and support experimentation in new fields of science and engineering." The Data2Knowledge effort is a key building block for realizing this vision.

Each of the Track A OKN projects brings together data from specialized information sources, including government data platforms, and enriches them to infer knowledge and context. From February to June 2022, NSF and the White House Office of Science and Technology Policy hosted the OKN Innovation Sprint, building on the ongoing work of Track A and Data2Knowledge, to define public-sector use-case opportunities and parameters for a proto-OKN infrastructure. The OKN Innovation Sprint use-cases have envisioned tools and communities of users that could be developed if resources are allocated to build the Proto-OKN.

Differentiators

While massive knowledge graphs have been created and are in use in proprietary applications, an open platform for heterogeneous data integration using knowledge graph technologies–the Proto-OKN–does not yet exist. This track integration activity brings together the complementary knowledge networks, tools and technologies being created by the five teams in Track A of the Convergence Accelerator to create the beginnings of an integrated Open Knowledge Network.

User-centered design is central to this vision. Efforts are driven by use cases and users, rather than being technology driven.

Road Map

The Data2Knowledge effort seeks to facilitate the development of an integrated, continuously updated OKN that hosts open, curated data to support development of AI applications; provide open, transparent access to data; empower the larger community to extend the OKN with additional information and knowledge from new sources and new domains; and facilitate training in the development and use of knowledge graph technologies.

The Data2Knowledge effort is leveraging the Track A projects, with their extensive expertise and networks, to enable the development of the Proto-OKN described by the [OKN Innovation Sprint Roadmap Report](). The overall Proto-OKN seeks to ensure the sustainability of each application use-case and of the overall infrastructure through a variety of partnerships, including public-private efforts, so that the Proto-OKN can persist well into the future, for as long as it is needed.

Partnerships

Each Track A team has an extensive network of partners and collaborators available to contribute to Data2Knowledge efforts and to the overall goal of creating a Proto-OKN. National and international partners from all sectors interested in creating the OKN–from academia, industry, government, nonprofit, and others–are welcome and encouraged to join the movement!

Intellectual Property

Each entity participating in Data2Knowledge and the OKN Innovation Sprint maintains all claims to existing intellectual property (IP), including proprietary data, and to IP developed as part of their individual efforts. As the Proto-OKN is developed, the intention is that most tools and resources will be posted publicly, with the end goal of creating a shared resource that anyone can build upon.

TRACK B: AI & THE FUTURE OF WORK

The world's technological advancements in artificial intelligence, machine learning, and robotics are shifting the future of work in unanticipated ways. The U.S. National Science Foundation Convergence Accelerator's Track B: AI & the Future of Work is focused on solutions to train, reskill, upskill, and prepare the current and future workforce with industry needs and jobs of the future, as well as build a national talent ecosystem to stimulate the U.S. workforce and ensure continuing global competitiveness.

Funded from 2019 to 2022, teams composed of academia, industry, nonprofits, and end-user partners converged together to develop disruptive future of work solutions to create a STEM talent pipeline relevant to industry needs, keep workers safe and help them perform their jobs better, create new jobs, and facilitate accessibility and inclusivity. Solutions include the development of the U.S talent pipeline through competency-based training, intelligent tools to connect academic institutions with industry needs to prepare students for the workforce, improvements to workforce training and safety for emergency responders through human augmentation, and the creations of virtual reality and augmented reality (VR/AR) tools to identify unique skills of neurodiverse individuals thus preparing them to thrive in the workforce.

The AI & the Future of Work teams include:

LEARNER—Led by Texas A&M, LEARNER (Learning Environments with Augmentation and Robotics for Next-Gen Emergency Responders) is an agile and adaptive Human Augmentation Technologies

(HAT) integrated Emergency Response (ER) training platform that accelerates HAT adoption for safer and more efficient ER work, supports adaptive learning sensitive to ER workers' socio-technical opportunities and budgetary constraints, builds and retains skilled ER personnel, and accelerates next-gen workforce development.

SkillSync—Industry 4.0 is changing the skills that workers need and companies require, leaving businesses vulnerable and colleges behind. SkillSync, led by Eduworks Corporation, uses AI and national skills data to help companies identify required skills, connect them with college continuing education departments, and enable colleges to respond with efficient, effective, and equitable reskilling programs.

Integrating the Future of Work Ecosystem

STEP-UP—Skills-Based Talent Ecosystem Platform for Upskilling (STEP-UP) was created by integrating the main themes of Track B into one project that utilizes the strengths of all Track B teams. Composed of

members of the AI and Future of Work teams, STEP-UP connects the skills and talents of individual workers to the opportunities that most need them. By inclusively engaging America's human skill and talent, and the technologies that support, augment, and develop that talent, the group is ensuring every American may partake in the benefits of a thriving economy and the dignity of meaningful work. STEP-UP is designed to address under-served populations and to enable the talent ecosystem to respond to new skills, needs, and unforeseen events.

TRACK OUTCOMES:

- The STEP-UP platform will allow workers to generate skills profiles from résumés, employers to generate job skills profiles from job descriptions, and training providers to generate skills profiles from course materials. STEP-UP (v1) will be released in 2023. A live online demo is expected to be available in the first quarter of 2024.

- The Track B integration effort will include the development of guidelines for selecting the most appropriate training modality, ranging from basic eLearning to immersive learning environments. These guidelines are being incorporated into the training recommender system.

- The curriculum developed for STEP-UP proof-of-concept includes Extended Reality (XR) and Simulation-based training based on validated cognitive research that addresses emergency response preparedness for mental health crisis, an area of national concern.

- The existing STEP-UP technology is being incorporated in the US Chamber of Commerce Foundation's Talent Pipeline Management (TPM) initiative via a Job Skills for In-Demand Employment (JobSIDE) application that is currently in alpha testing and will go into beta testing early in 2024. The TPM initiative has involved over 3,000 employers in their collaboratives.

LEARNER

Learning Environments For Augmenting Next Gen Emergency Responders

LEARNER

Lead PI: Ranjana Mehta
rmehta@tamu.edu

E. Du
eric.du@essie.ufl.edu

J. Gabbard
jgabbard@vt.edu

D. Srinivasan
sdivya1@v.edu

Overview

Emergency Response (ER) workers do dangerous work while adapting to novel situations. Training institutes and organizations have reported a steep decline in ER trainings that are essential to the nation's critical infrastructure. A critical need exists to accelerate ER expertise development through adaptive, personalized learning platforms that deliver next-generation skills while integrating emerging human augmentation technologies (HATs). Learning Environments with Augmentation and Robotics for Next-Gen Emergency Responders (LEARNER), an agile and adaptive HAT-integrated ER training platform, will accelerate HAT adoption for safer and efficient ER work, support adaptive learning sensitive to ER workers' socio-technical opportunities and budgetary constraints, build and retain skilled ER personnel, and ultimately accelerate next-gen workforce development across other industry domains.

Description

LEARNER is a novel mixed-reality learning platform that has physical, augmented, and virtual reality components, where ER personnel learn to work effectively with two HAT classes: exoskeletons (EXO) and head-worn AR interfaces (AR) for two ER skills curricula (e.g., Triage and Patient Handling). These HATs showcase the modularity of LEARNER across physical and cognitive augmentation that have distinct learning requirements. The team has developed, integrated, and assessed EXO and AR learning modules into the LEARNER system across different access levels (home to field house to training centers). LEARNER's industry partner SARCOS Robotics have designed an upper-body EXO emulator interface integrated into the core LEARNER system. Concurrently, the team remains engaged with their other industry partner Knowledge Based Systems, Inc. (KBSI), who are developing a working LEARNER prototype that utilizes a unique paradigm for learning by adapting to a variable set of learners' characteristics and contexts,

through the incorporation of physiological, neural, and behavioral markers of learning into real-time AR/VR scenario delivery. Finally, the team has tested and evaluated the HAT-integrated LEARNER prototypes at a National ER Training Center (Texas A&M Engineering Extension Service; TEEX) with close guidance from their government partner National Institute for Standards and Technology (NIST).

Customer/market needs assessment and determination of LEARNER business model will inform achieving scale in the ER community. The team is working with existing and interested partners to submit non-dilutive grants and to license copyrights to the LEARNER curriculum across ER and broader industry domains. LEARNER serves responders by building a more capable and skilled ER workforce, safeguarding their health, improving their career longevity and ensuring the nation's emergency preparedness.

Differentiators

Current VR based training platforms in ER are focused on extensively simulating the environment. LEARNER affords quick integration of emerging HATs (EXO and AR) into its platform enabling an individual or a group of users to learn and collaborate in tomorrow's human-technology ER teams. Access to training resources (i.e., facilities, technology, budget, time away from duty) remains a critical barrier for effective and continued ER training. LEARNER provides multiple training delivery methods, from the home to embodied immersive training, that offer affordable and abundant opportunities for rapid repetition and skills refinement. ER workers are diverse in their makeup, in terms of their demographics, experiences, trust, and learning rates. In contrast, current ER training paradigms are static, with a one-size-fits-all approach. LEARNER utilizes personalized learning algorithms to reduce skills gaps across ER teams that enhance team operations. LEARNER is scalable across other work domains and industries, thereby creating opportunities for broader industry adoption.

Road Map

Milestones: The team successfully completed the Minimal Viable Product (MVP) evaluation of the LEARNER platform in July 2023, where eight public safety agencies from Texas and neighboring states participated in a daylong event at the Disaster City in College Station. They are currently analyzing key stakeholder feedback and developing customer models for sustainability, which should be completed by December 2023.

Key deliverables: ER-based training curricula, personalized learning algorithm for ER training and AR/EXO learnings, AR/EXO-specific learning modules, and a functional LEARNER prototype.

Partnerships

LEARNER has assembled a team of academic researchers across three universities, industrial (SARCOS Robotics; EXO integration), government (NIST; training standards/ testing), and nonprofit ER workforce development (TEEX; ER training and evaluation) partners. The advisory board is composed of leaders from ER stakeholder organizations (International Association of Fire Chiefs, National Volunteer Fire Council, National Fire Protection Association; to advise on ER training needs/constraints), government institutions (Federal Emergency Management Agency, U.S. Naval Research Lab, Texas Division of Emergency Management; to guide on achieving scale in ER), and industry partners (Eksobionics, Boeing, Ford, and American Society for Testing and Materials); to share experiences in transition to practice, commercialization, and training and assessment in diverse industrial sectors).

Intellectual Property

The intellectual property (IP) will include the LEARNER training platform, ER training scenarios, personalized learning algorithm, and EXO/AR learning modules that would be protected in the form of copyrights and trademarks, registered through filings with the U.S. Patent and Trademark Office to minimize infringement and illegal copying of materials. Licensees will be responsible for preventing infringement or illegal distribution of IP.

Lead PI:

Robby Robson
robby.robson@eduworks.com

Myk Garn
michael.garn@pe.gatech.edu

Jeanne Kitchens
jkitchens@credentialengine.org

Elliot Robson
elliot.robson@eduworks.com

Jennifer Thornton
jennifer.thornton@bhef.com

Sandra von Doetinchem
sandravd@eduworks.com

Overview

Managing America's talent pipeline in a way that is equitable and responsive to changing demands requires knowing what skills are needed for jobs, enabling workers to identify their own skills, and enabling them to find training that fills their gaps. This sounds simple, but it is not possible without a shared understanding of the skills in question and without tools that help employers, training providers, workers, students, and job seekers connect to with each other using skills as a common language. SkillSync uses leading-edge artificial intelligence and national-scale data to achieve this shared understanding and provide those tools.

Description

SkillSync was motivated by the observation that colleges are underutilized to upskill incumbent workers. There are reasons for this. Companies have needs that must be met in months while colleges offer multi-year programs; companies struggle to express their needs in terms that colleges can understand; college courses are often general and not designed to teach the specific skills; and companies and colleges communicate via relationship-based ad hoc processes, if at all.

This observation led to a SkillSync web app that connects companies and colleges for the purpose of upskilling incumbent workers. Using the app, companies can formulate and publish training requests that include prioritized lists of desired skills, and colleges can align their offerings with those requests and offer training. SkillSync uses AI to extract skills from job descriptions, to score the alignment between a set of courses and a set of skills, and to detect skills trends in job postings provided by the National Labor Exchange. Multiple techniques are used to reduce unwanted bias in the AI and its underlying language models.

Although SkillSync was designed with input from professional development and continuing education programs and two-year colleges, the team has found that these institutions are not ready to adopt the tool. Those institutions have a strong desire to boost employability for their students, but their immediate needs are for tools that help their students acquire in-demand skills rather than for tools that connect programs with employers. They also have a general need to align their courses with skills. This led SkillSync to focus more on individual workers and students and to seek opportunities for achieving scalable impact by using the AI in third party applications.

The first such opportunity is a Job Skills for In-Demand Employment (JobSIDE) application SkillSync is creating for the U.S. Chamber of Commerce Foundation Talent Pipeline Management (TPM) initiative and that will be available to participants in 40 states. The team is also working with partner organizations to provide tools and services that identify the skills taught by courses, help schools develop micro-credentials that offer in-demand skills, and allow students to analyze their skills, identify gaps, and find courses to fill them.

Differentiators

SkillSync has two crucial differentiators–its AI and its end-user features. Its AI uses a purpose-built large language model (LLM) that out-performs general models such as GPT-4 on skills extraction, alignment, and related tasks. This model is quickly trainable on new content domains and on custom output formats using small amounts of data. This gives the team a competitive edge when responding to third party requirements and enables them to deploy SkillSync AI in new ways at low cost. In addition, the work done de-biasing SkillSync's LLM propagates to all applications and services that it supports. There is increasing concern in all sectors about bias in AI, and the fact that the team addresses this in multiple ways is a significant selling point.

SkillSync has many features that set it apart from typical skills matching and skills management products. It uses skills that have been curated, properly contextualized, and are written in ways that conform to standards and best practices, e.g., from Institute of Electrical and Electronics Engineers, the Credential Engine, and the Open Skills Network. SkillSync can auto-generate skill profiles from job descriptions, résumés, and course materials, and when users write their own skill definitions, SkillSync suggests curated skills they might use instead. When associating skills with jobs, SkillSync rates the importance of skills, and SkillSync considers the required level and the importance of skills when aligning courses with jobs or with individual skill profiles. Other products rarely do this. All SkillSync data are available to other applications as linked data and are stored in a system that has passed U.S. Department of Defense security requirements. These architectural features meet IT requirements that many related products do not meet.

Road Map

The SkillSync product roadmap includes updates to user interfaces and AI services; integration with new sources of skills frameworks and job market data; user management and multi-tenant features that make it possible for colleges to offer branded versions of SkillSync to their students; and features that help colleges develop skills-based micro-credentials. The team is adding features that focus on individuals and that come from the Skills-based Talent Ecosystem Platform for Upskilling (STEP-UP) application developed for a Convergence Accelerator Track B Integration effort. These STEP-UP features empower individual users (as opposed to companies) to analyze their skills, create training requests, find training, and get credit for the skills they acquire. They improve the ability of students to find higher paying jobs with attractive career paths, and they meet needs that colleges have expressed.

Partnerships

SkillSync partners include the Business Higher Education Forum (BHEF), the Credential Engine, the National Association of State Workforce Agencies (NASWA), Georgia Tech Professional Education (GPTE), the DXtera Institute, the University Professional and Continuing Education Association (UPCEA), WorkCred, and the U.S. Chamber of Commerce Foundation

(USCCF). All have helped define SkillSync. NASWA provides access to the National Labor Exchange. The USCCF is sponsoring JobSIDE, while the GPTE Center for the 21st Century University is a likely customer. The DXtera Foundation, WorkCred, and BHEF are channels for SkillSync via joint proposals, and UPCEA has served to introduce SkillSync to its members.

Intellectual Property

The software used to manage skills and other data was developed and is copyrighted by Eduworks, the SkillSync awardee. SkillSync AI services were developed under this project and are owned by Eduworks subject to applicable laws and National Science Foundation policies. Partner data is licensed under data agreements, and data produced by users belongs to the users who produced it. The team expects to protect proprietary methods with patents.

Additional Information

Please contact Dr. Robby Robson (Principal Investigator) or Dr. Sandra von Doetinchem to request demos and further information.

Ranjana Mehta
rmehta38@wisc.edu

Robby Robson
robby.robson@eduworks.com

Overview

STEP-UP (Skills-based Talent Ecosystem Platform for Upskilling) connects workers, employers, and training providers based on skills. Its goal is to provide diverse populations with equitable access to jobs and training and to help employers find, train, and hire workers in a skills-based economy. STEP-UP uses leading-edge AI to help users create and match skills profiles for jobs, learning opportunities, and themselves and provides access to innovative training.

Description

STEP-UP grew out of two U.S. NSF Convergence Accelerator Track B projects–Learning Environments with Augmentation and Robotics for Next-gen Emergency Responders (LEARNER), which has developed VR and simulation-based training for first responders that is informed by research into the effects of stressors on learning–and SkillSync, which has developed AI services for extracting skills from unstructured text and for aligning prioritized sets of skills with curricula. These are combined in a web application called STEP-UP. STEP-UP allows workers to generate skills profiles from résumés, employers to generate job skills profiles from job descriptions, and training providers to generate skills profiles from course materials. STEP-UP permits users to add skills from curated skills frameworks and to prioritize skills and identify skill levels. With STEP-UP, workers can search for jobs, determine skill gaps, and find training to fill those gaps; employers can post job skills profiles and search for workers who might be a good match; and training providers can analyze job skills trends to inform their curriculum development.

The Track B integration effort also includes the development of guidelines for selecting the most appropriate training modality, ranging from basic eLearning to immersive learning environments. These guidelines will be incorporated into the training recommender system. A STEP-UP proof of concept will be available online. It, and the training available through it, will help public safety workers successfully interact with individuals going through mental health crises and will be based on a skills framework developed for this purpose.

A National Talent Ecosystem Council (NTEC) will inform the STEP-UP project and is intended as a resource for other workforce-related efforts.

Differentiators

The talent pipeline ecosystem includes three main components: individuals (incumbent workers, job seekers, and students), employers, and training and education providers. Most products on the market address only one of these components or connect at most two of them. STEP-UP connects all three. By treating the complete talent pipeline ecosystem triangle, STEP-UP fully supports skills-based hiring, skills-based training, and skills-based career management. This allows individuals to be represented and evaluated by what they know and can do rather than by their educational attainment and past employment. This approach is far more equitable, more accurate, and necessary to provide opportunities to underserved groups.

STEP-UP uses a large language model and associated AI techniques that were developed for workforce and training applications and that out-perform commercially available AI solutions in this area. This AI enables skills profiles to be largely auto-generated, greatly reducing the time and effort required by users and thus lowering the barriers to skills-based talent pipeline ecosystem management. In addition, the use of curated skills frameworks provides depth and detail that are not available in competing applications and that increases the efficacy of skills-based approaches.

Finally, the curriculum developed for STEP-UP will include Extended Reality (XR) and Simulation-based training based on validated cognitive research that addresses an area of national concern. The team will review existing relevant guidelines and best practices and create a resource for documenting properties of training that can be used to characterize different training modalities that are afforded through

desktop eLearning, XR-based simulations, or physical interactions (smart objects, robotics, etc.).

Road Map

The STEP-UP proof of concept, without the full complement of training, will be available online by the end of 2023. Training will continue to be developed through the first two quarters of 2024.

Other outputs of this Track Integration effort include guidelines for training development, due to be released by November of 2023; NTEC symposia, scheduled for September of 2023 and January/February of 2024, and a skills framework that is significant both for its content and for the method used to create and validate it, which is a separate research output.

STEP-UP technology is being incorporated in the U.S. Chamber of Commerce Foundation's Talent Pipeline Management initiative and is being evaluated for inclusion in partner projects.

Partnerships

Each Track B project has its own extensive network of team members and partners. All are available to contribute. Key partners include the Texas A&M Engineering Extension Service (TEEX), National Institute of Standards and Technology (NIST), the Credential Engine, the National Association of State Workforce Agencies (NASWA), the Business Higher Education Forum (BHEF), WorkCred, the DXtera Foundation, the U.S. Chamber of Commerce Foundation, and the University Professional and Continuing Education Association (UPCEA).

Intellectual Property

STEP-UP is based in part on the open-source Competency and Skills System (CaSS). The copyright is owned by the SkillSync performer. The AI used in STEP-UP is proprietary and uses some open-source models. The training used in the STEP-UP proof of concept is either existing training that is available for this purpose or will be copyrighted by the LEARNER team. The IP for the application belongs to the SkillSync performer.

Additional Information

STEP-UP, as well as other artifacts and research produced by LEARNER and SkillSync, will be available online at www.talentecosystem.org.

TRACK C: QUANTUM TECHNOLOGY

Many of today's technologies rely on computers to help with sensing, networks, data, decision making and more, but advancement in quantum technologies has become a focus for research and industry organizations, including the U.S. National Science Foundation. As a longtime supporter of quantum technologies, NSF is building upon its investment of basic research and discovery to develop and accelerate solutions through the Convergence Accelerator's Track C: Quantum Technology.

Quantum technology has the potential to solve large-scale challenges and at an even faster rate; however, scaling is critical. Teams within the NSF Convergence Accelerator Quantum Technology track are developing quantum sensors, networks, and simulations to deploy new technologies for a variety of applications, such as the hardware and software that will be needed to deploy the new quantum internet, as well as applications in many areas including autonomous vehicles and healthcare. Educating and developing

the current and future workforce is also vital to ensuring a pipeline of future scientists and engineers are prepared to meet the rapidly growing workforce and education needs associated with the expected growth in quantum technology and application areas it would enable. In this regard, the Quantum Technology track teams are also working on creating innovative curriculum by leveraging strong industry-university partnerships that are diverse and inclusive.

Quantum Technology funded Phase 2 teams include:

Quantum Sensors

PEAQUE—Led by University of Washington, PEAQUE (Photonic Engine Accelerating Atomic Quantum Engineering) is addressing quantum computing scalability by innovating a chip-scale, multi-beam optical control system that empowers cold-atom quantum computing with 1000s of qubits. The use-inspired research on integrated photonic control engine can

help scaling down of quantum computing hardware. This translational research could prove valuable for many other emerging areas of technology including LIDAR and holographic displays.

Quantum Sensors—Led by University of Michigan, Quantum Sensors is developing an entanglement-enhanced sensing architecture to benefit multitudes of domains, including secure inertial navigation, space and planetary terrestrial control.

Quantum Networks/Simulations

QuaNeCQT—Led by University of Maryland, QuaNeCQT (Quantum Networks to Connect Quantum Technology) is developing hardware to transform the internet into a quantum internet, which is essential to connecting the anticipated rapid expansion of the use of quantum computers The quantum network will be able to interconnect different kinds of quantum computers and can enable opportunities to harness the power of networking and thus the ability to solve very complex and large-scale problems that cannot be handled by classical computers and networks.

Workforce/Education

QuSTEAM—Led by Ohio State University, QuSTEAM (Quantum Information Science, Technology,Engineering, Arts, and Mathematics) is a transformational undergraduate curricula aimed at addressing critical workforce needs in quantum information science and engineering. QuSTEAM is developing a curricular structure that is focused on a commitment to diversity, equity, inclusion, and justice. The structure is being built from ground up to address structural barriers that have limited diversity and inclusiveness.

Integrating Quantum Technology

PhoTeQ-C—Quantum photonics plays a pivotal role in future scalable quantum technologies for computing, communication, and sensing. Cutting-edge research conducted in labs needs to be exported to large-scale manufacturing facilities to impact the whole quantum industry and society. The Quantum Technology Phase 2 teams are collaborating on "track integration" to create PhoTeQ-C (the Quantum Photonic Technology Consortium) to establish quantum photonic device manufacturing standards and knowledge that will be adopted by industry, academia and will facilitate convergence to share know-how and infrastructure to accelerate lab to market translation.

TRACK OUTCOMES:

- The development of quantum computing educational coursework is in progress and is intended to prepare the future quantum workforce. Each course includes approximately five modules featuring topics like physical basis for different qubits, networking and teleportation, and sensing. To date, 3 of the 4 complete courses and an estimated 15 modules from all 4 have been piloted at 11 campuses within the project's network. The course materials will be used by students across universities and colleges, including tribal colleges, Hispanic-serving institutions, historically black colleges and universities, and community colleges.

- Demonstration of the first-generation modem and hardware, including quantum repeaters and router, for a quantum internet called the MARQI network. A next-generation modem is in development and will significantly reduce the consumption of power while achieving a higher efficiency.

PEAQUE

Enabling Scalable Cold Atom Quantum Computing with Integrated Photonics

Lead PI: Mo Li
moli96@uw.edu

Ben Bloom

Adam Kauffman

Arka Majumdar

Birgitta Whaley

Overview

Quantum computing promises to solve critical problems that are intractable by classical computers, but currently, it faces many scaling bottlenecks. The PEAQUE (Photonic Engine Accelerating Atomic Quantum Engineering) team is developing a scalable optical quantum control system, programmed with quantum software to empower quantum computing using 1000s of cold-atom qubits and metrology with entangled atomic clocks. Dissemination of the system to the quantum research community will accelerate the realization of full-scale quantum computers capable of solving challenging problems from optimization algorithms to computational chemistry for drug discovery. The project also spins off optical technologies for light-detection and ranging (LiDAR) that is critical for autonomous vehicles and robotics.

Description

PEAQUE addresses scalable quantum computing by developing a powerful optical control engine that interfaces cold-atom qubits with quantum software. The core of this engine is a chip-scale Multi-Beam Illumination and Steering (MBIS) system, which leverages the latest advances in integrated photonics to generate arrays of laser spots and precisely focus them on a dense atom array. Each MBIS module includes a pixel array of 8 lithographically patterned devices each capable of emitting 16 individually steerable laser beams, creating a module with 128 beams from a package sized only ~10 cm^3, 3 orders smaller than existing technology. Multiplexed arrays of MBIS modules will perform high-speed, parallel gate operations on large 2D or 3D lattices of cold-atom qubits. The MBIS engine will power the execution of quantum error correction codes specially designed for cold atom qubits toward fault-tolerant computing. The technology can also be applied to entangle atomic clocks to advance quantum metrology. The complete PEAQUE solution package will accelerate the building of cold-atom quantum computers in both industry and academia.
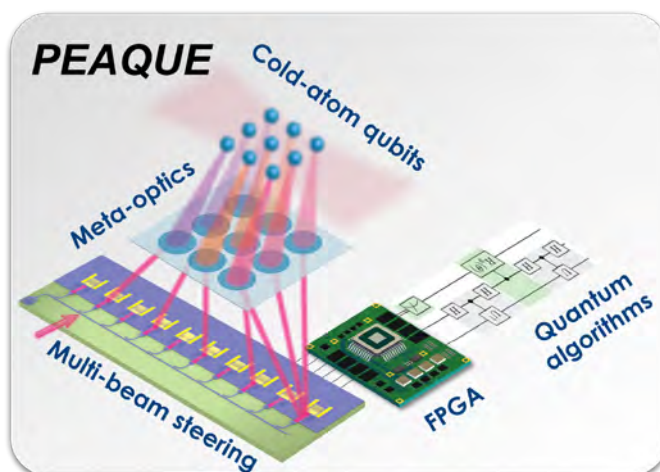
PEAQUE's solution package includes a full stack of hardware and software to enable scalable cold-atom quantum computing and metrology.

Differentiators

Compared with other qubits (e.g., superconducting circuits, trapped ions, solid-state spins, or photons), cold-atom qubits have the decisive advantage of the ease of creating a large number of naturally identical qubits. To use them for quantum computing, optical control of each qubit in a large array is indispensable but has been a challenge to the current technology. PEAQUE will overcome this bottleneck with MBIS's unprecedented multibeam control and modulation capability. The PEAQUE hardware will be mass-produced at wafer-scale using industrial-scale foundries (Sandia National Laboratories (SNL)) and disseminated, along with electronics and software, in a solution package to the quantum community. To achieve the use-inspired research goals, the PEAQUE team consists of multidisciplinary experts in atomic physics, integrated photonics, micro-electromechanical systems, materials science, and quantum software.
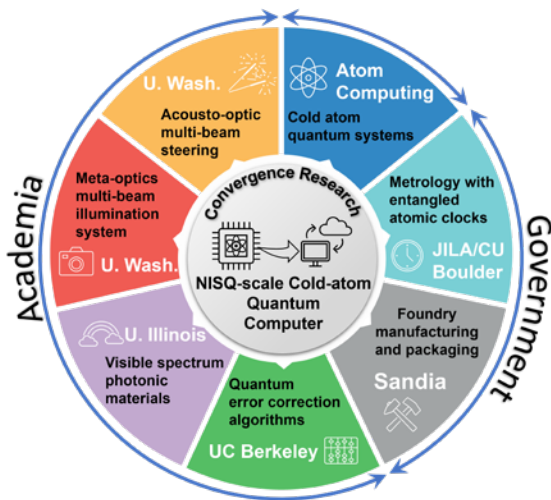
PEAQUE's multi-disciplinary, trans-sectorial effort to eliminate a bottleneck in scalable quantum computing.

Road Map

In Phase 1, the team finalized the system design, developed the fabrication processes, and established a partnership with Sandia for foundry processes.

In Phase 2, key milestones and deliverables include prototype MBIS modules, scalable manufacturing at foundries, control electronics systems, quantum software, and final atomic system demonstrations, in a timeline as listed below. The project also spun off a new LiDAR technology that is already in the process of commercialization.

Q3, 2021: MBIS integration with cold atom quantum system

Q4, 2021: Prototypes of single pixel MBIS

Q2, 2022: Fault-tolerate color code algorithms

Q2, 2022: Field-programmable gate array control system with customized algorithm

Q2, 2022: Prototype of 10 pixel MBIS

Q3, 2022: Error correction executed in cold atom quantum system

Q4, 2022: Foundry process integration completed

Q4, 2022: Wafer-scale process completed

Partnerships

PEAQUE's key partners include researchers across three universities (University of Washington: acousto-optics, nanophotonics, nanofabrication; University of Illinois Urbana-Champaign: wide bandgap materials, University of California, Berkeley: quantum error correction), two national labs (SNL: foundry services for wafer-scale MBIS fabrication; Joint Institute for Laboratory Astrophysics: metrology and atomic clocks), and one key industrial partner (Atom Computing: cold atom systems for quantum computing and simulation).

Intellectual Property

The team has established a comprehensive intellectual property (IP) management plan that delineates the treatment of background IP, new IP generated through this project, licensing negotiation options, and confidentiality. The University of Washington team is also planning to start-up a company to commercialize the LiDAR technology.
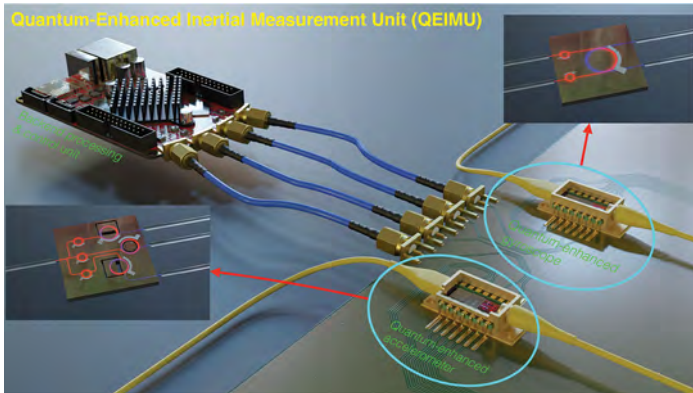
Li, B., Lin, Q. & Li, M. Frequency–angular resolving LiDAR using chip-scale acousto-optic beam steering. Nature 620, 316–322 (2023)

Quantum Sensors

Advanced Navigation and Sensing

Lead PI: Zheshen Zhang
zszh@umich.edu

Jianfeng Wu
Jianfeng.Wu@Honeywell.com

Jon Pratt
jon.pratt@nist.gov

Nan Yu
nan.yu@jpl.nasa.gov

Quantum-Enhanced Inertial Measurement Unit (QEIMU)

Overview

In this Track C Convergence Accelerator Phase 2 project, Quantum Sensors' highly interdisciplinary and cross-sectoral team will develop a quantum-enhanced inertial measurement unit (QEIMU) for positioning and navigation at a performance level well beyond the current state-of-the-art inertial sensors. Phase 2 will build upon the Phase 1 results, inputs from user interviews, and the concepts conceived with partners through prototyping meetings. The expected outcome of this project will be a landmark example of how quantum technologies can yield near-term societal impacts within a 5 to 10-year timeframe in diverse realms, such as aerospace navigation, self-driving cars, and space exploration.

Description

Phase 2 core team members are University of Michigan (UM), Honeywell, NASA Jet Propulsion Laboratory (JPL), National Institute of Standards and Technology (NIST), Purdue University, and Texas A&M University (TAMU). The QEIMU prototype will comprise three principal pillars: 1) a quantum-enhanced gyroscope for angular velocity sensing (Honeywell, UM); 2) a quantum-enhanced accelerometer for linear acceleration sensing (Purdue, TAMU, UM); and 3) a backend processing unit for central control (UM). JPL will integrate the QEIMU components. Honeywell, JPL, and NIST will

verify the QEIMU in their state-of-the-art calibration and environmental test facilities. The projected QEIMU performance for sensitivity, angle random walk, and bias is one-to-two orders of magnitude superior to the state-of-the-art classical inertial sensors. Therefore, QEIMU will enable unprecedented capabilities, including 1) spacecraft control and planetary terrestrial applications without a GPS-like system; 2) secure navigation for self-driving cars; and 3) precise measurements with entangled arrayed-weak force sensors for gravity, gravitational waves, and dark matter and energy, which have previously been scientifically unmeasurable. Since precise navigation and sensing are widely desirable and affect the daily lives of the general populace, the team anticipates QEIMU will create a $2.5 billion market by 2035 and impact 700 million people.

Differentiators

The high cost and large size, weight, and power (SWaP) of commercial optical gyroscopes and accelerometers prevent their market penetration for self-driving vehicles, autonomous robots, and various small-position and navigation platforms. While immense efforts have been dedicated to developing on-chip gyroscopes and accelerometers with reduced SWaP and production costs, their performance remains inferior to the navigation grade due to weak signal-to-noise ratios. The performance improvement from fabricating larger photonic components to strengthen the inertial sensing signal is saturated by material properties constraints. The noise floor is deemed a barrier dictated by the fundamental quantum noise.

This Phase 2 project will harness the revolutionary quantum-sensing technology to break this noise barrier. The team will miniaturize their quantum-sensing platform into a chip scale and integrate squeezed and entangled light sources with gyroscopes and accelerometers. Such differentiation will lead to the QEIMU prototype and a paradigm shift in inertial navigation and sensing.

Road Map

The two-year Phase 2 timeline comprises parallel development of three key project components: 1) quantum-enhanced gyroscope; 2) quantum-enhanced accelerometer; and 3) a backend processing and control unit. The completion of calibration and testing deliverables for the quantum-enhanced gyroscopes and accelerometers will converge all three components into the integrated and verified QEIMU prototype as the final, end-of-project deliverable.

Intellectual Property

Partnerships

The successful Phase 1 outcomes underpin Phase 2. In particular, UM's entanglement-enhanced optomechanical sensing proof-of-concept laid the foundation for the QEIMU prototype. In parallel, the Phase 1 team developed on-chip quantum-light sources (UM), wafer-scale optomechanical sensor arrays (Purdue), a test and calibration platform (TAMU and NIST), a backend processing and control unit (UM), and a modeling tool (USC). Phase 2 will readily integrate these functional modules to demonstrate QEIMU. Specifically, UM and Honeywell will develop a multilayer silicon-nitride platform to assemble QEIMU components. Honeywell will use its world-leading navigation sensor expertise to build quantum-enhanced gyroscope while Purdue and TAMU will collaborate to make triaxial accelerometers. Honeywell, a certified electronics manufacturer for defense and civilian applications, will deliver a gyroscope test platform for QUIMU. JPL will then integrate the individual components into the QEIMU prototype. The QEIMU calibration at NIST will be followed by environment tests at JPL to evaluate performance in future space-borne and aerospace applications.

Quantum Sensors has developed a jointly owned intellectual property (IP) for an on-chip squeezed-light generation method and entangled radio-frequency photonic sensors. They have filed patent applications for on-chip large-scale entanglement generation and other technology. Honeywell owns IP for integrated photonics and gyroscopes. The team is coordinating with the tech transfer offices of each party to facilitate the success of the project.

Contribution to Quantum Ecosystem

Quantum Sensors' project will help build a quantum ecosystem by distributing turnkey quantum-source modules to Convergence Accelerator teams and the broader community. Their contributions will include collaborating with other Convergence Accelerator teams, government labs, and the industry on customized quantum photonics and working with other Convergence Accelerator Track C teams on quantum education and organizing workshops to engage stakeholders.

QuaNeCQT

Quantum Networks to Connect Quantum Technology

QuaNeCQT

Lead PI: Edo Waks
edowaks@umd.edu

Dirk Englund
englund@mit.edu

Saikat Guha
saikat@optics.arizona.edu

Norbert Linke
linke@umd.edu

Tripti Sinha
tsinha@umd.edu

Overview

The internet fundamentally changed every aspect of life by enabling computers to communicate with each other over long distances. But the current internet is not compatible with emerging quantum computers that store and process quantum information. QuaNeCQT (Quantum Networks to Connect Quantum Technology) will develop hardware that will enable the current Internet to communicate quantum information over a vast network infrastructure, an essential requirement for the emerging quantum ecosystem.

Description

The current internet cannot transmit quantum information. This limitation relegates emerging quantum technologies, which are currently limited in their computational power, to be stand-alone systems that cannot be expanded or reach a broad user base. A quantum information transmitting internet would significantly boost quantum computing power by connecting multiple small quantum computers into powerful distributed quantum computers that can solve problems with major societal impact. It would revolutionize numerous industries that take advantage of quantum computing including banking, chemistry, medicine, and data analytics. A quantum network would also greatly increase the user base for quantum computers by providing secure access to end-users (blind quantum computing) as well as certifying the legitimacy of quantum computing providers (quantum verification).

QuaNeCQT will enable internet service providers and networking companies to immediately transform their classical networks into the next generation quantum internet that delivers unprecedented security, data rates, and performance. The team will do so by developing a comprehensive hardware solution composed of two modules, the quantum modem and the quantum router.

The quantum modem and router modules provide a complete quantum networking solution that handles both the quantum data and classical data required to run a quantum network. They will be fully integrated and equipped with a user-friendly software interface for ease of operability. By connecting them to various peripherals (quantum computers, quantum sensors, detectors, etc.) the team can build quantum networks that directly connect emerging quantum technology and can be easily expanded. The two modules convert a classical fiber network into a fully-functional quantum network that can transmit quantum information and connect quantum computers. They therefore allow the quantum industry to immediately take advantage of the vast existing infrastructure that is the current internet. The team will deploy and test these modules in the MARQI network, University of Maryland, and the Washington, D.C. area's local quantum network footprint, which was established in Phase 1.

Differentiators

Currently, a quantum internet that connects quantum computers does not exist. Emerging quantum networks have focused almost entirely on secure point-to-point communication using quantum key distribution. These networks use quantum signals to exchange classical information with security guaranteed by quantum physics, but cannot transmit quantum information between quantum computers. They therefore cannot interconnect them to scale computation power. A quantum internet that transmits quantum information would provide this essential and currently missing component.

The team's hardware solution will establish the first interconnection of quantum computers over the internet. It will allow quantum computers to work collectively to increase their processing power, and provide quantum links to end-users for blind quantum computing and quantum verification. The team will achieve this unprecedented objective by combining the

most viable quantum computing architectures with advanced reconfigurable quantum photonic devices that can convert and route quantum signals in a network. It will also enable internet service providers to leverage existing classical internet infrastructure and coordinate with leading ISP and network companies.

Road Map

In Phase 2 the team is developing compact packaged quantum hardware and deploying it in the MARQI network.

Q1, Y1: Begin development of the qFC and qROADM modules.

Q2, Y1: Test hardware components and integrate hardware delivered from industry partners.

Q3, Y1: Package and integrate hardware modules.

Q4, Y1: Develop software interface for qFC and qROADM modules. Establish plan for expansion and future connectivity of the MARQI network.

Q1, Y2: Deploy hardware modules into the MARQI network. Install ion traps in MARQI end-nodes.

Q2, Y2: Establish a connected network of ion traps over the MARQI network.

Q3, Y2: Distribute entanglement over end-nodes.

Q4, Y2: Demonstrate quantum communication between ion trap quantum computers with reconfigurable connectivity.

Partnerships

As part of the U.S. National Science Foundation Convergence Accelerator, Team QuanNeCT is forming a startup company that will take over the development effort. The team also has several additional core partners: (1) Cisco is helping to develop compatible hardware packaging and integration for a potential future product line; (2) IonQ is building the ion trap and will serve as a node on the MARQI network; (3) Brain Holding Ventures continues to guide the commercialization and use case scenarios; (4) Shinkuro's CEO serves as the Chair of the MARQI advisory board with expertise in the development of the internet (5) Army Research Laboratory (Department of Defense) provides one of the central nodes of the

MARQI network; (6) Qrypt provided secure networking expertise, and will guide the secure internet use case during Phase 2.

(7) Ciena advises on networking and software. (8) Juniper Networks serves on the MARQI Advisory Board and advise on the general direction of the telecommunication industry (9) NTT Electronics and ADVR are providing customized quantum frequency conversion crystals, and (10) AIM and LionIx will fabricate photonic integrated circuits.

Intellectual Property

QuanNeCQT developed and is in the process of patenting multiple key hardware components of a quantum network, including the qROADM and qFC modules. The team has established intellectual property agreements with its partners and the university entities.

QuSTEAM

Launching an Equitable Solution to the Quantum Workforce Bottleneck

Lead PI: E. Johnston-Halperin
Johnston-Halperin.1@osu.edu

D.D. Awschalom
awsch@uchicago.edu

R.E. Ceballos
rceballo@uchicago.edu

A. Heckler
Heckler.6@osu.edu

A.K. Wilson
akwilson@msu.edu

Overview

QuSTEAM (Quantum Information Science, Technology, Engineering, Arts and Mathematics) is a team of researchers, undergraduate educators, and education researchers, with experts across industry and national laboratories. The team is developing and improving an undergraduate curriculum and designing an inclusive scalable network so that all colleges and universities can offer their students access to modular interdisciplinary curriculum in quantum information science and engineering (QISE). The team collaborates across more than 20 institutions spanning R1 research universities, national laboratories, 2-year colleges, and Minority Serving Institutions (MSIs) such as Historically Black Colleges and Universities (HCBUs). QuSTEAM's focus is designing, implementing, and scaling research-based educational strategies to build a convergent and inclusive curriculum for a diverse community of future scientists and engineers.

Description

The development of QuSTEAM will rely on research-based educational practices to provide a convergent and inclusive curriculum to a diverse community of future scientists and engineers. The severe human-resource shortage in all areas of quantum science and engineering is projected to significantly slow the societal impact of the second quantum revolution. To address this need and accelerate the U.S. National Science Foundation Quantum Leap, a comparable leap in education strategy is required. The QuSTEAM curriculum will have a modular format with in-person, online, and hybrid delivery modalities to meet the educational needs of diverse stakeholders, including future quantum professionals and members of the current industrial workforce, community colleges, MSIs, and other bachelors and doctoral degree-granting institutions. The team will draw on the extensive expertise of the core participants in both quantum research and science, technology, engineering, arts and mathematics (STEAM) education to create a new curriculum with multiple implementations at the module, class, minor, and certificate level to train a quantum smart workforce at the scale necessary to support economic development. QuSTEAM will incorporate professional development from two vantage points to successfully implement research-based educational strategies. From the perspective of onboarding subject matter experts to incorporate research-evidenced pedagogical design (e.g., backwards and inverted curriculum design, etc.), the team will convene workshops to support new QISE instructors within the team and is preparing to scale that network of engagement to professors from additional institutions that want to join the network as the program scales. From the vantage point of faculty who are not subject matter experts in QISE (e.g., particularly not at R1 institutions) but wish to help implement QuSTEAM curricula, there are professional development programs focused on introducing QISE content and concepts to faculty being developed in parallel.

Differentiators

QuSTEAM's paradigm shifts away from the hierarchal model of most undergraduate Science, Technology, Engineering, and Mathematics (STEM) programs in the U.S., where the most engaging, enjoyable content (i.e., content focused on field-leading innovations and societal impact) is traditionally delayed until the later years and students are first introduced to basic skill-building exercises, contributing to student attrition. Further, traditional pedagogy isolates STEM from broader arts and sciences engagement. In contrast, the QuSTEAM curriculum will seamlessly blend fundamental skill building with engaging, innovation-focused content from the outset, resulting in an inclusive and student-centered convergent educational experience in line with both modern pedagogy and the workforce needs of the rapid expansion of the community working in quantum information science and technology.

QuSTEAM will continue to directly engage the STEAM education research community to employ evidence-based practices in curriculum development and will prioritize maximizing opportunities for diversity, equity and inclusion through targeted curriculum, instructor professional development, and independent external evaluation. By drawing from expertise at multiple institutions, students will have access to world-leading experts in QuSTEAM relevant disciplines—far broader access than is possible within a single university or college. This access will manifest in convergent course material and instruction, for example enabling hybrid in-person and virtual on-line environments that blend experts and students from multiple institutions, providing a unique teaching and learning ecosystem.

Road Map

During the team's needs-finding and prototyping efforts, they identified the establishment of a common template for an undergraduate minor and associated certificate programs as the key near-term target for workforce development. The team is currently building out these degree and certification programs, including initial offerings of the critical classes and modules at the team's respective universities, while continuing with needs-finding and assessment to provide dynamic feedback on evolving workforce needs. QuSTEAM's introductory class was taught in Spring 2022 and the full slate of core classes for the team's minor is piloting at 15 institutions in 2022-2023. They will continue to develop and improve QuSTEAM curriculum beyond NSF funding through an expanding network facilitated by the nonprofit organization under the QuSTEAM name in October of 2022. This educational ecosystem is designed to be scalable to the national level and will provide a template for a novel approach to STEM education more generally.

Partnerships

The team consists of academic, national lab, and industrial partners. The backbone of QuSTEAM's more than 20 institutions academic team consists of 5 R1 institutional partners that have committed to teaching QuSTEAM classes and developing degree programs (Michigan State University, Ohio State University, University of Chicago, University of Illinois, and University of Michigan) and the IBM-HBCU Quantum Center. In addition, each of the R1 universities have identified one or more partners with whom they have

an existing transfer pipeline to support engagement with student populations beyond traditional STEM demographics for a total of over 70 faculty with a mixture of STEAM subject matter expertise and discipline-based STEM education research. This academic team is supported by a network of more than 20 collaborators including academic centers such as the NSF Quantum Leap teams, and a Department of Energy National Quantum Initiative center (Q-NEXT), as well as over 20 industrial partners with interest in quantum workforce development including: Applied Materials, General Electric Research, Honda, HRL, IBM, JPMorgan Chase, qBraid, Quantum Design, Quantum Economic Development-Consortium, Qubit by Qubit, Qutools, Stanford Research Institute, TOPTICA, and the Unitary Fund.

Intellectual Property

The intellectual property generated by QuSTEAM's program will be primarily in the form of copyrighted course materials and educational software in the form of simple simulators. The team plans to make all these materials developed under NSF support publicly available using a standard Creative Commons agreement with attribution shared among contributing participants.

PhoTeQC

Illuminating the Future of Quantum Technology

Ezekiel Johnston-Halperin
johnston-halperin.1@osu.edu

Mo Li
moli96@uw.edu

Edo Waks
edowaks@umd.edu

Zheshen Zhang
zszhe@umich.edu

Overview

Quantum photonics plays a pivotal role in future scalable quantum technologies for computing, communication, and sensing. Cutting-edge research conducted in labs need to be exported to large-scale manufacturing facilities to impact the whole quantum industry and society. The Photonic Technology Quantum (PhoTeQ) Consortium, founded by the four NSF Convergence Accelerator Track C teams, seeks to establish quantum photonic device manufacturing standards, in the format of a quantum photonic development kit (Q-PDK), that will be adopted by both the industry and academia. The Q-PDK and the knowledge base will facilitate the convergence of different quantum research fields to share the know-how and infrastructure and accelerate the lab-to-market of quantum technology.

Description

Photonic qubits and optically-addressed matter qubits (i.e., trapped ions, cold atoms, and defect centers) have many unique advantages such as compatibility with existing manufacturing infrastructure over electrically-addressed solid-state qubits for quantum computing, communication, and sensing. However, building scalable quantum systems with these quantum modalities universally requires scalable approaches and instrumentation to achieve optical control and integration on a large scale to reach extreme performance metrics in speed, fidelity, and efficiency. While such demands pose unprecedented challenges to current photonic technology, they also provide tremendous opportunities and spur pathbreaking innovations in photonic and optoelectronic materials, devices, and systems. Significant synergistic efforts in both academia and industry are necessary to make this vision a reality.

The Track C teams work on different critical quantum photonic technologies, but share the need for scalable and standardized manufacturing of photonic devices.

The PEAQUE team needs a large number of photonic modules to control neutral atoms and trapped ions to realize scalable quantum computers. The QuaNeCQT team requires stable and repeatable turn-key photonic devices to route and frequency convert single photons. The Quantum Sensors team desires scalable manufacturing of quantum light sources and sensors. The QuSTEAM team bridges these technical capabilities by focusing on education and workforce development for the emerging quantum economy.

Differentiators

Establishing a fabrication standard is critical to the development and proliferation of new technology by enabling large-scale, low-cost manufacturing. The success of semiconductor technology is the most prominent example and should be a guide for quantum technology. The various quantum photonic devices currently developed at individual labs use similar semiconductor processes that can be readily standardized. However, there has not been a collective effort in the research community to establish such a standard. Under the framework of the NSF Convergence Accelerator, the PhoTeQ Consortium leverages the ongoing collaborative efforts and established partnerships among academia, industry, and national agencies, to initiate the effort of establishing the manufacturing standard of quantum photonics devices.

Road Map

PhoTeQC will kick off the Consortium with a symposium on quantum photonics technology at a major Optica (formerly OSA) or Institute of Electrical and Electronics Engineers (IEEE) conference in 2023-2024. The first step will be to build a library, in industry-standard formats and tools (e.g., KLayout, Python, ANSYS/Lumerical), of devices, design, simulation, and fabrication processes that the teams are developing respectively. The library is compatible with those used by the semiconductor industry. In parallel, the team will identify the skills and capabilities needed for the emerging quantum workforce to engage with these design and fabrication processes. The initial version of the Q-PDK will be based on the technology capability of government facilities, such as Sandia National Laboratories (SNL) and National Institute of Standards and Technology's (NIST) nanofabrication facility, and later will be translated to commercial foundries. The major goal is to build an expandable, open-box framework such that the Q-PDK can be readily amended by all users (even students) to include the technologies provided by new fabrication foundries.

The PhoTekQ Consortium will ensure the sustainability of this effort through partnerships with public and private institutions so that the Q-PDK can be broadly adopted. The knowledge base will be disseminated to education and workforce training programs through curriculum and learning modules. The Q-PDK will evolve and adapt responsively to cutting-edge research and propel the advance of quantum photonic technology.

Partnerships

Each Track C team has already built its own extensive network of partners and collaborators, who will become the founding members of the Consortium and contribute to Q-PDK. Those partners include academic institutes, government agencies and laboratories (SNL, NIST, Lawrence Livermore, Argonne), and industry (Honeywell, IonQ, Atom Computing, IBM). As an open-approach organization, the PhoTeQ Consortium welcomes new members and partners from all sectors interested in utilizing and expanding the Q-PDK—from academia, industry, government, nonprofit, and others.

Intellectual Property

The intellectual property (IP) management of the Consortium will be governed by an overarching agreement. Generally, each entity participating in the Consortium maintains all claims to existing IPs, including proprietary data. The IPs developed as part of the integration activities will be jointly owned by the contributors and made available for licensing to the members of the Consortium. Each team member will retain IPs developed as part of their individual efforts.

TRACK D:
AI DRIVEN INNOVATION VIA DATA AND MODEL SHARING

High-quality datasets and environments, testing and training resources, and collaboration between academia and industry is required to develop technical solutions to address modern large-scale challenges. The U.S. National Science Foundation Convergence Accelerator's Track D: AI-Driven Innovation via Data and Model Sharing is funding solutions to address data and model-sharing challenges through tool and platform development to enable easy and efficient data matching and sharing, and privacy protection tools and processes to ensure secure access to sensitive data. NSF-funded projects are also developing technical solutions to enhance power grid reliability, reduce the risk of wildfires and biological threats, enhance animal health, and interact with vast amounts of data to improve hydrologic scenarios and polymer materials research.

AI-Driven Innovation via Data and Model Sharing funded Phase 2 teams include:

AI-Grid—Coordinated networked microgrids provide significantly enhanced power grid reliability and allow for more green energy solutions to go online. Led by Stony Brook University, AI-Grid is an artificial intelligence-enabled solution for managing networked microgrids. Using a programmable platform that integrates deep learning, reachability analysis, formal control, and high-assurance software architectures, AI-Grid is being deployed at one of three highly influential networked microgrids systems, where it will demonstrate its capabilities to modernize and decarbonize America's power sector.

BurnPro3D—BurnPro3D enables safe and effective prescribed burns at the scale required to proactively reduce the risk of devastating megafires. The platform, led by University of California, San Diego and powered by WIFIRE Commons, transforms the work of burn bosses and land managers through access to AI, high-resolution data, 3D fire modeling, and visualization capabilities for collaboration and optimization.

42

Computing the Biome—The world needs intelligent systems for detecting and predicting biological threats. Led by Vanderbilt University, Computing the Biome is creating a data and AI platform for monitoring and predicting biothreats in a major U.S. city, and to drive economic sustainability by empowering businesses and advanced science missions to deliver valuable consumer apps and breakthroughs.

CRIPT—Led by Massachusetts Institute of Technology, CRIPT (Community Resource for Innovation in Polymer Technology), an AI-enabled cloud application and database, allows polymer scientists to easily find and interact with complex data. Delivered by a team of experts in materials, information systems, and computer science, CRIPT accelerates material innovation tenfold, reducing research and development costs by more than $1 billion.

HydroGEN—Led by Arizona University, HydroGEN is a web-based machine learning (ML) platform, generating custom hydrologic scenarios on demand. The solution combines physics-based simulations with ML and observations to provide customizable scenarios from the bedrock through the treetops. Without any prior modeling experience, users can manipulate state-of-the-art tools to explore scenarios that matter to them.

Precision Epidemiology (pEPIC)—Sustainable livestock production requires proactive and refined best management practices that enhance animal health at the farm. Led by University of California, Davis, the Precision Epidemiology Consortium converges data, AI models, and expertise across the livestock production and health space, providing an online user-friendly platform, the Disease BioPortal, for prediction and effective management of animal health problems.

Integrating AI-Driven Innovation via Data and Model Sharing

CORE Institute—The AI-Driven Innovation via Data and Model Sharing Phase 2 teams are collaborating on "track integration" to create the Convergence Research (CORE) Institute. The CORE Institute provides graduate students and early and mid-career researchers and professionals with a foundational experience to position them for impact on the most challenging societal issues of our time. The program gives participants the skill sets and networks to identify use-inspired problems and build convergent teams to deliver impactful solutions.

TRACK OUTCOMES:

- AI-GRID successfully demonstrated AI-based microgrid functions to multiple agencies and industry partners, including the U.S. Navy, Long Island Power Authority, ComEd (Commonwealth Edison Company), and Ørsted.

- BurnPro3D extended its demonstration network to Sequoia and Kings Canyon National Parks, in partnership with the U.S. Geological Survey, to produce spatially continuous, high-resolution fuel maps as well as to the California Department of Forestry and Fire Protection sites to show the use of BurnPro3D for prescribed fire training, planning, and execution.

- Computing the Biome developed the state-of-the-art AI models to detect disease transmitting species, using only digital sensors, which reduce the cost of delivering biosecurity. These models have been validated on biological weather states, which are now integrated into public health operators and monitored for dangerous species 24/7 in the greater Houston, Texas area.

- CRIPT, publicly launched in November 2022, followed the launch with an updated version in August 2023. CRIPT now has more than 200 users and the project team is working toward establishing a nonprofit to continue to support and expand CRIPT.

- HydroGEN released a publicly accessible national application this fall that can be accessed through the project's website: hydro-generation.org.

AI-Grid

Enabled, Provably Resilient Networked Microgrids

AI-Grid

Lead PI: Peng Zhang
p.zhang@stonybrook.edu

Scott Smolka
sas@cs.stonybrook.edu

Scott Stoller
stoller@cs.stonybrook.edu

Xin Wang
x.wang@stonybrook.edu

Yifan Zhou
yifan.zhou.1@stonybrook.edu

Overview

Coordinated networked microgrids (NMs) promise to significantly enhance power grid reliability. Three main challenges prevent their wide adoption: 1) Lack of understanding of NM dynamics; 2) Big data but limited/unscalable analytics; 3) Cyber-infrastructure bottlenecks. This project aims to develop AI-Grid: artificial intelligence-enabled, provably resilient NMs. Key innovations are a programmable platform integrating reliable modeling under uncertainty, reachability analysis, formal control, high-assurance software architectures, and cybersecurity technologies to enable scalable, autonomic, and ultra-resilient microgrids and NMs.

Description

Microgrids are a promising new paradigm for electricity resilience. In August 2017, for example, multiple microgrids kept critical community services running in Houston despite utility grid outages caused by Hurricane Harvey. Coordinated NMs, which allow microgrids to coordinate to support various smart city functions, are expected to provide increased electricity resilience during extreme events. As anticipated by the U.S. Department of Energy, research & development of NMs will lead to the next wave of smart-grid research, which will help achieve the vision of a highly resilient grid. NMs are also expected to empower the nation's digital economic engine–the swiftly growing data centers.

Three main challenges have prevented NMs from serving as dependable resilient power resources and thus prohibited their wide adoption: 1) Lack of understanding of NM dynamics under frequent changes in status, ubiquitous uncertainties, fast ramping, low inertia, and non-synchronism; 2) Big data but limited and unscalable analytics, as current technologies are unable to handle the volume of dynamic data needed for real-time decision making; and 3) Bottleneck in cyber-infrastructure due to delays,

congestion, failures, cyberattacks, and the ever-increasing pace of functional/structural changes which can catastrophically plague microgrid cyber-networks.

To address these challenges, this project aims to develop AI-Grid: AI-enabled, provably resilient NMs. The key innovation is a programmable platform that integrates reliable modeling and prediction of system states under uncertainty, reachability analysis, formal control, high-assurance software architectures, and cybersecurity technologies to enable scalable, self-protecting, autonomic, and ultra-resilient microgrids and NMs capable of coordinating ultra-scale distributed energy systems and cultivating America's smart communities and cities.

Differentiators

AI-Grid is a hardware-independent, software-defined platform that will enable previously unseen low capital expenditure/operating expenditure and improved social welfare for communities. It optimizes the use of real-time modeling and analysis to provide low power and energy costs with guaranteed high reliability, resiliency, and cybersecurity. It achieves AI-enabled microgrid operations, learning-based microgrid modeling, and a neural Simplex architecture for runtime safety and security assurance.

Road Map

A functional AI-Grid prototype platform will be fully tested and verified by November 2023. Demonstration of AI-Grid will be completed on Commonwealth Edison's (ComEd) Networked Microgrids in Chicago by March 2024. AI-Grid will be further developed into a resilient power distribution management platform which will be demonstrated for the Navy. Finally, an executable AI-Grid test platform, data, and training materials will be made accessible to U.S. communities by September 2024.

Partnerships

Strong, cross-cutting partnerships are pivotal to AI-Grid's successes. The AI-Grid team has established 29 partnerships with America's leaders of all relevant sectors. The team's end-user partner includes ComEd, which operates networked microgrids in Chicago City. AI-Grid will be tested and demonstrated in ComEd's Grid Integration and Technology Lab. The team is developing a programmable AI-grid platform with Stony Brook's Center of Excellence in Wireless and Information Technology and industry partners Hitachi and RLC Engineering. Major power utilities, including ComEd, ISO New England, Long Island Power Authority, PSEG Long Island, National Grid, and Eversource are providing or will provide data, guidance on grid integration and risk management, and assistance in the evaluation. These partners are providing equipment, data, dynamic models, and technical support. Connecticut Center for Advanced Technology has coordinated engagement between the academic and industrial partners. Stony Brook University's Advanced Energy Center are collaborating on research, evaluation, and dissemination of AI-Grid.

Intellectual Property

The intellectual property (IP) used in the AI-Grid platform is being developed by the Principal Investigator's research groups. The AI-Grid platform will be publicly released to promote broader adoption and impact. IP agreements covering shared data, models, etc., will be negotiated with each relevant partner.

BurnPro3D

Fighting Wildfires Proactively with WIFIRE Commons

Lead PI: Ilkay Altintas   Yolanda Gil
             ialtintas@ucsd.edu

             Kevin Hiers   Rod Linn

Overview

A century of suppressing wildfires has created a dangerous accumulation of flammable vegetation on landscapes, contributing to megafires that risk human life and property, and permanently destroy ecosystems. Small controllable fires can dramatically reduce the risk of large fires that are uncontrollable. BurnPro3D (wifire.ucsd.edu/burnpro3D) is a decision support platform to help the fire management community understand risks and tradeoffs quickly and accurately to plan and implement prescribed burns.

Description

In 2020, wildfires swept across 10 million acres in the western U.S., killing dozens, destroying 10,000 structures, and causing $15 billion in property damage. Tens of thousands of firefighters risked their lives to fight the fires. The 2019-2020 fire season in Australia was a warning that the problem can worsen worldwide. Almost 50 million acres burned, driving some species to extinction, and emitting 300 million tons of CO_2.

Over the last decade, the WIFIRE Commons team developed the first digital infrastructure to accelerate fire science and management through data, computing, and artificial intelligence. The team's initial efforts transformed the way fire response is being managed in California during the first six hours of a fire. However, even the most sophisticated approaches to fighting fires are reactive and cannot always control fire under extreme weather conditions. There is an urgent need to turn to proactive approaches to reduce the risk of severe fires by removing dangerous accumulations of vegetation.

The BurnPro3D platform is powered by the next-generation WIFIRE Data and Model Commons. The platform provides diverse users with a common ground for understanding risks and tradeoffs related to prescribed burns and wildfire management through detailed models of vegetation and fire behavior.

BurnPro3D can be used in fire mitigation by land managers and burn bosses to prioritize land for treatment and conduct prescribed burns. It can also be used in fire response to evaluate unplanned fires for opportunities to work with incident commanders to manage wildfires to benefit ecosystems, instead of focusing solely on suppression. BurnPro3D provides unique capabilities for active collaboration among these users, providing 3D, high-resolution models to increase the proactive use of fire to end devastating megafires. In both fire mitigation and fire response, BurnPro3D can support users in communicating risks and tradeoffs to regulators and the public.

Differentiators

Currently, wildfire-related data, models and interfaces exist in silos. WIFIRE Commons is a community-facing data system to bring these resources together. As an example, the team and their partners generated the first 3D fuel datasets at the continental scale at 1m resolution to ingest into next-generation fire models and connect to the BurnPro3D platform. The Commons enables the AI innovations necessary for users to optimize prescribed burns and improve wildfire management using fire model predictions made accurate by 3D weather and vegetation data at a 30X higher resolution than previously available.

To achieve this vision, the team is developing specific AI innovations to: (i) Use knowledge management techniques to fuse data coming from diverse sources and prepare it for fire modeling; (ii) Conduct physics-based machine learning within next-generation fire models to use deep learning to understand complex processes that drive fire behavior; (iii) Apply constraint optimization methods to address complex tradeoffs in the decision process for the placement and timing of prescribed burns; (iv) Employ explainable AI to increase the interpretability of data and models by diverse users all along the decision-making chain.

Road Map

The BurnPro3D platform supports users as they create five-year fire management plans, prepare burn plans, and implement prescribed burns. The team will continue to fine-tune the user experience for creating fire management plans, planning and implementing burns, and completing post-burn monitoring with state and federal partners. They will also work closely with test users in their demonstration network to move from proof of concept to operational use for the platform, showing that their users can collaborate more effectively via BurnPro3D. The team is focused on efforts to disseminate their minimum viable product for broad use among federal users in the fire management community and solidify a model for long-term sustainability. In parallel, they are committed to the long-term sustainability of the WIFIRE Commons framework that BurnPro3D is built on, creating a space for the scientific user community to collaborate on AI-enabled fire science. The team will also continue to engage with potential future users who would benefit from platforms developed to solve related challenges, e.g., making decisions about how to manage power lines to prevent fires or when it is safe to send mutual aid during a fire.

Partnerships

As exemplified by the team's 50+ collaborators and partner institutions, their multi-disciplinary team is supported by a consortium of influential advisors and users from 12 academic, 10 for-profit, 16 government, and eight nonprofit entities, in addition to other U.S. National Science Foundation Convergence Accelerator teams. Through these partnerships, they are building a culture of creating public/private partnerships as a vehicle to extend reach and use, while ensuring integration into existing systems for fire response and mitigation. Initial partners contributed expertise, data, models, model products, prototype testing, evaluation, and feedback. These core partners will adopt WIFIRE Commons for their operations and serve as the beta users of the BurnPro3D platform. They will be joined by an expanded list of partners focused on transitioning their research to practical use, including U.S. Forest Service Stations, U.S. Geological Survey, California Governor's Office of Emergency Services, Orange County Fire Authority, Los Alamos National Lab, National Oceanic and Atmospheric Administration, and National Oceanic and Atmospheric Administration. The team's convergence research effort focuses on accelerating solutions by transferring technology to agencies in ways that complement existing focus and strategic direction.

Intellectual Property

The WIFIRE Commons team is committed to open-source development and embraces the Findable, Accessible, Interoperable, and Reusable (FAIR) principles. The data and models in the Commons will be made available for use through open license for researchers. They will create restrictive data and software distribution and use agreements when necessary. All other data and models will be publicly available. Commercial applications built on top of the Commons by their external partners and others will be encouraged.

Computing the Biome

Sensing and Predicting Biothreats with AI

Lead PI: Janos Sztipanovits
janos.sztipanovits@vanderbilt.edu

Ethan Jackson
ejackson@microsoft.com

Overview

Individuals, industries, societies, and governments want to stay healthy. They need cost-effective systems to detect biological threats and predict future disease outbreaks as early as possible. COVID-19 acutely and painfully demonstrated the impacts of the unpredicted. The goals of this project, Computing the Biome, are twofold: (1) demonstrate an extensible data and Artificial intelligence platform that continuously monitors and predicts biothreats in a major U.S. city, and (2) create a framework for economic sustainability and global scalability of these results, by empowering businesses and advanced science missions to consume predictions and produce valuable consumer apps and breakthroughs.

Description

Predicting biological threats is hard. Earth's biome is home to hundreds of millions to possibly a billion species ranging from nanometer-sized viruses to kilometer-sized forests. These species are interconnected, co-evolving, and moving at breathtaking scales and speeds. As a result, biological threats such as emerging diseases, invasive species, and agricultural pathogens can appear unexpectedly and quickly harm societies and ecosystems. They already cause hundreds of billions of dollars per year in economic damages.

Predicting these will require: (1) continuous data streams not yet available today, (2) detailed models harnessing expertise from across the science domains, and (3) modern AI platforms that use data and models to compute the biome in real-time–just as weather forecasts are continuously computed using real-time data streams and models.

Fortunately, revolutions in sensing technology and AI, coupled with cross-sector demand are about to transform how to compute the biome and predict threats. First, this team will produce and interconnect novel data streams ranging from kilometer-scale hyper-local weather, to autonomously identified disease transmitting insects (millimeters in size), to genomically recognized known and novel viruses (nanometers in size)–demonstrating that cross-cutting continuous data streams for biothreat detection and prediction can be rapidly unlocked.

Next, the team will combine their expertise in ecology, epidemiology, and virology to design new predictive models and anomaly detectors. The team will develop the first of these high-impact AIs focused on predicting mosquito-borne diseases, which are difficult to control and impact over 600 million people per year. More broadly, the resulting data platform will empower development of new foundational methods for use by the AI community–based on real-world data and grounded in the societal challenges of the age.

Finally, economic sustainability will depend on a vibrant ecosystem where businesses and global missions can consume state-of-the-art models and produce applications and insights that people want to use. Even before COVID-19, the U.S. spent over $1 billion per year on biothreat mitigation. The team aims to deliver solutions that benefit these critical efforts.

Differentiators

The main premise is that only a modern sensor network–that continuously monitors species at geographic scales across environments–will be capable of predicting complex biothreats early enough to manage risks. This perspective is based on the successes of existing sensor networks and AI models to monitor and predict other complex phenomena (e.g., weather systems, smart power grids, and transportation systems).

Today, outbreaks of human disease are usually detected through clinical case data, news reports, and other digital data. The World Health Organization's Global Outbreak Alert and Response Network system is a global aggregator of many of these data sources. It has successfully detected outbreaks early, but generally not early enough to stop their spread.

On the other hand, efforts like the U.S. Agency for International Development's PREDICT program preemptively sampled the environment to look for

future novel threats, even sampling coronaviruses in bats in China prior to COVID-19. However, these programs rely on manual sampling. The team believes new platforms and AI could empower and help scale these important efforts.

Results

The team's first user is Harris County, Texas–home to the city of Houston and 4.7 million people. Below is a summary of key results over the first two years.

(1) Real-time biome data for public health operations: Harris County Public Health now receives first-of-its-kind real-time data about the abundance of mosquito species via autonomous sensing in the environment. At time of writing, millions of biotic and abiotic data points have been remotely sensed from field environments.

(2) Multi-modal AI to accelerate threat detection: An array of AI capabilities can now detect biothreats in Harris County. Mosquito (and other insect) species are detected in the environment using AI models developed by the team for public health missions. State-of-the-art genomics-based AI is integrated into operations, enabling same-day broadest-spectrum detection of (novel) disease vectors and (novel) pathogens.

(3) A fully adaptive biothreat detection system: All capabilities are upgradable over-the-air, allowing new biothreat signatures to be deployed quickly and recovery of specific biotargets or bio-anomalies for fast molecular analysis. Modern cloud data, and edge platforms are utilized end-to-end.

The team's goal is economically sustainable and scalable biothreat detection. Public health organizations are encouraged to contact the authors to discuss partnerships, access, and sustainability approaches.

Partnerships

1. Microsoft: sensor nodes, species recognizers, models, and industry leadership.

2. Tomorrow.io: hyperlocal local climactic models for habitat suitability including newly launched satellite-based weather radars.

3. Harris County Public Health: equitable deployment and management of systems over the 1,800 mi2 of Harris County, Texas.

4. Vanderbilt University: open-source data platforms and application design studios for the wider community, and academic leadership.

5. Johns Hopkins University: AI-ready disease control policies and coordination with global health missions.

6. University of Pittsburgh: genomic data analytics for microbial threat detection and liaison with biotech stakeholders.

7. University of Washington: AI-enabled epidemiological models and forecasts built on top of the above capabilities.

Intellectual Property

Open platforms will be utilized, and arrangements have been made for data and code releases under open data and code licenses.

CRIPT

Bringing the Age of Information to Polymers

{ CRIPT }

Community Resource for Innovation in Polymer Technology

Lead PI: Bradley Olsen
bdolsen@mit.edu

K. Aou

D. Audus

R. Barzilay

T. Jaakkola

S. Jegelka

K. Jensen

K. Kroenlein

J. de Pablo

Overview

Polymer materials, ranging from clothing and personal protective equipment to construction materials and food packaging, are fundamental to providing human basic needs for food, shelter, health, and transportation. Developing new polymers for next-generation products takes decades, and faster movement is necessary to remain competitive. To accelerate this process, the team developed Community Resource for Innovation in Polymer Technology (CRIPT), a polymer data ecosystem consisting of a web-based application and a database that allows polymer scientists to easily find, share and communicate complex data.

Description

The diversity of polymers and their properties has enabled them to fill critical roles in nearly every sector of the modern economy. However, this diversity also yields an incredibly large chemical design space, making it extremely challenging to navigate. To make the development process tractable, scientists often search locally, starting from known solutions and exploring new chemical designs around proven polymers. Being able to quickly review existing material designs and identify those having optimal properties is critical to accelerating polymer development.

Currently, searching among existing polymers is a daunting task because polymer data exists as small, disparate sets, making the navigation a complex process combining the harmonization of different data formats and the reconciliation of metadata, both of which currently require expert intervention. CRIPT offers a cloud database based on a new polymer-specific data model that simultaneously provides interoperability across different domains of polymer science and engineering, while retaining critical

metadata that allows domain experts to correlate information across many independent records. A series of chemically inspired AI innovations, including a chemistry-based query language, a graph-based schema preserving temporal structure in data, algorithms for automatic data validation, AI-human cooperative tools for data ingestion, and the integration of machines into the data ecosystem are also provided to add Findable, Accessible, Interoperable, Reusable (FAIR) principles, trust in data, and ease of use to the system.

The team anticipates extensive adoption of CRIPT will have a significant economic impact by leading to a more than $1 billion reduction in Research & Development costs for new material innovation and a societal impact by accelerating the speed of discovery twofold of the next generation of medical therapies, sustainable packaging, lightweight transportation materials, recycling technologies, and advanced textiles directly improving the quality of life for all Americans.

Differentiators

Current digital data solutions for polymers are fragmented and presented without adequate context to make data findable, interoperable, or reusable. Polymer data is provided as disparate, specialized sets each containing, at best, hundreds of polymer samples. In most cases, metadata associated with the reported properties, such as how physical or chemical measurements were carried out, as well as how each material sample was made, are not explicitly provided, limiting the data's utility.

CRIPT resolves these issues by structuring data so that connections can be easily drawn between polymers, processes, and properties. This data structure documents and indexes the heretofore lost history associated with the making of a material.

This feature alone provides a key advantage over existing polymer data solutions, wherein scientists must rely on rare domain expertise and multiple data sources to obtain the same information. As materials history provides a rich context for how a material is made and characterized, this allows CRIPT to assimilate data across sources with highly different standards, reconciling data and providing universal access.

By implementing new advances in AI, CRIPT's ecosystem enables an intuitive workflow: a new chemical structure query language provides for intuitive data search, natural language processing is used to translate users written descriptions into the standard data format, and validation tools help users to trust the data that they are encountering within the ecosystem. Coupling these features with visualization, analysis, and data set construction tools enables teams to share, collaborate, and communicate like never before to accelerate their innovation.

Road Map

Q4, 2021-Q1 2022: During the partner-centered design phase, the CRIPT team refined its data model, developed ingestion tools, visualization tools and continued to develop more features for the platform. The team had their first CRIPT launch on April 28th, 2022, and opened to the CRIPT early-adopter partners.

Q2-Q3, 2022: During the community adoption phase, the CRIPT team worked closely with the polymer community to test the platform, input datasets, get feedback about the platform and ideas for new features, and developed security infrastructure for housing open datasets.

Milestone: On November 10, 2022, the team released CRIPT as a public tool with ingestion and visualization features for the community.

Q4, 2022-Q1, 2023: During the industrial expansion phase, the team refactored the platform and scaled its performance. In addition, the CRIPT team organized a successful CRIPT symposium and presented CRIPT at the Expo, American Chemical Society Fall meeting in San Francisco. Furthermore, the team released version 2 of CRIPT. Currently the team is developing data privacy infrastructure.

Milestone: Release version 2 of CRIPT.

Q2-Q3, 2023: During the incorporation phase, the team is in the process of spinning off CRIPT as a nonprofit corporation and continuing development of CRIPT.

Milestone: Spin CRIPT into an independent nonprofit that continues to maintain and improve the ecosystem.

Partnerships

The CRIPT team's multidisciplinary program brings together experts across academia (Massachusetts Institute of Technology and University of Chicago: polymer domain experts & computer scientists in AI/ML), industry (Citrine Informatics: database specialists; Dow: industrial polymer experts), and government (National Institute of Standards and Technology: expert in informatics and standards). The team's partnership with six academia research laboratories, four multi-institute research centers, three government labs, five materials manufacturers, and three industrial polymer consumers spans the full spectrum of stakeholders. The team is directly collaborating with four other teams within Track D, both leveraging their tools for searching data sets and models, federated learning, data privacy, and 3-dimensional modeling developed in the U.S. National Science Foundation Convergence Accelerator program within the team's own ecosystem. Conversely, the team's tools for validation, schemas for organizing and integrating small data, search tools, and data extraction algorithms will make valuable contributions to their efforts.

Intellectual Property

CRIPT's AI innovations will be freely distributed. The data models and conceptual designs will be openly licensed; the associated code will be distributed open source under the MIT license. The code to operate the CRIPT app will be proprietary to CRIPT. Data will be FAIR compliant.

HydroGEN

A Machine Learning Platform for Hydrologic Scenario Generation

Lead PI: Laura Condon
lecondon@arizona.edu

Reed Maxwell
reedmaxwell@princeton.edu

Peter Melchior
melchior@astro.princeton.edu

Nirav Merchant
nirav@arizona.edu

Overview

HydroGEN is a web-based machine learning (ML) platform to explore watershed conditions and generate custom hydrologic scenarios on demand. The team combines powerful physics-based simulations with ML and observations to provide customizable scenarios from the bedrock through the treetops. Without any prior modeling experience, water managers and planners can get detailed information on the status and seasonal outlooks of watersheds in their area.

Description

Water is the driving force behind extreme events like floods, droughts, and wildfires. These events have cost the United States billions of dollars every year, and this figure is projected to increase. The record-setting wildfires and the mega drought on the Colorado River are merely the latest illustrations of these events. Historical data are no longer a reliable guide for the risks to be faced in the future. This uncertainty poses a huge challenge for decision makers.

The scientific community has developed models that can simulate complex changing systems. However, they are too complicated and computationally expensive for non-modelers to develop and use. As a result, the tools used for decision making lag behind the science and are often severely limited in their ability to predict evolving systems.

HydroGEN places sophisticated models in the hands of planners and decision makers. The team trains ML emulators on advanced, physically-based simulations integrating real-world observations. Their interface lets users build customizable scenarios without any prior ML or modeling experience. The HydroGEN platform goes beyond streamflow and is designed to provide spatially distributed simulations of complete watersheds.

The platform also includes a comprehensive database of hydrologic observations that span many parts of the hydrologic system. The team pulls together data from multiple organizations into one place and provides users with tools to seamlessly view current watershed conditions in a wholistic way.
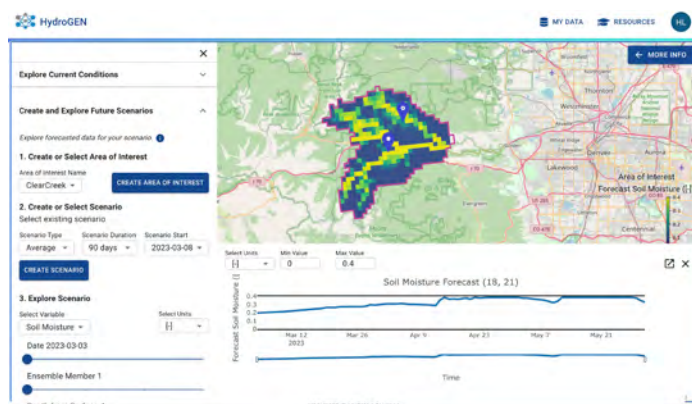
Figure 1: Example view of the HydroGEN application. This shows a seasonal soil moisture forecast for a small watershed in Colorado.

Differentiators

Data-driven models are not well equipped to predict out-of-sample behavior (e.g., predicting drought conditions that are beyond what is in the observed record). What sets this team apart is their ability to develop predictions that can cover (1) parts of the system that are hard to observe, such as groundwater, (2) conditions that fall outside what have been observed in the past.

HydroGEN builds upon the first and only physics-based high-resolution groundwater surface water model in the U.S. This gives the team a unique ability to train ML models using state of the science tools with a proven ability to capture watershed changes in both the surface and subsurface for events that have not yet happened.

Another major barrier to entry for advanced simulations are compute and data requirements. HydroGEN's ML models cut the computational demand of simulations a thousand-fold. The platform is scalable and can be deployed in commercial cloud settings, allowing users to bring their own compute allocations. Thus, the team can rapidly grow their user base with minimal hardware requirements.

Road Map

This project is currently in the third year of Phase 2. The team has completed multiple rounds of user testing and usability testing on the application. They are completing their first public release for the HydroGEN platform this fall. The first release will include free content covering current watershed conditions. Users will need to register for the application but once they have done so they can freely explore and plot all the free data and download datasets. The first release is primarily focused on current watershed conditions. By December, HydroGEN will be adding baseline national forecasts to the platform for their second release.

The team has already built the workflows for user specific watershed modeling. In the spring and summer of 2024, they will be building out the ability to have users pay for this content and will be working with early adopters to test this capability.

Partnerships

HydroGEN is working closely with CyVerse; a U.S. National Science Foundation cyberinfrastructure project specializing in data and workflow management with more than 100,000 users from thousands of institutions.

They partnered with the Bureau of Reclamation (Reclamation), which is the nation's largest wholesale water supplier providing water to more than 31 million people and 10 million acres of farmland. Reclamation staff have participated in concept development and user testing at every step of the project.

The team has also assembled an external advisory to help guide their pilot studies and expanded user engagement. The board includes federal agencies, regional and state-level water managers across five states, environmental consultants, national water programs and environmental groups.

Intellectual Property

HydroGEN's sustainability plan follows a Software as Service model. They will maintain a free version of the platform that will host national datasets and forecasts for general users. Paid users will have access to customizable watershed specific forecasts that they can generate on demand. All the models will be published and open source, but HydroGEN maintains exclusive commercial rights for their training datasets.

PRECISION EPIDEMIOLOGY

Data-Driven Disease Prevention and Control in Animal Health

Lead PI: Beatriz Martinez Lopez
beamartinezlopez@ucdavis.edu

Maria Jose Clavijo
mclavijo@iastate.edu

Xin Liu
xinliu@ucdavis.edu

Kun Zhang
Kunz1@cmu.edu

Overview

Sustainable livestock production systems are needed to feed a growing world while protecting the planet. Livestock farming systems, in particular pork production, play a significant role in addressing this global challenge. However, sustainability of the livestock industry hinges on the maintenance of elevated animal health and wellbeing, and high production efficiency. Therefore, there is a need for proactive and refined best management practices that enhance animal health at the farm level. The team's precision epidemiology consortium converges data, artificial intelligence models, and expertise across the livestock production and health space, providing an online user-friendly platform called Disease BioPortal (bioportal.ucdavis.edu), for prediction and effective management of animal health problems.
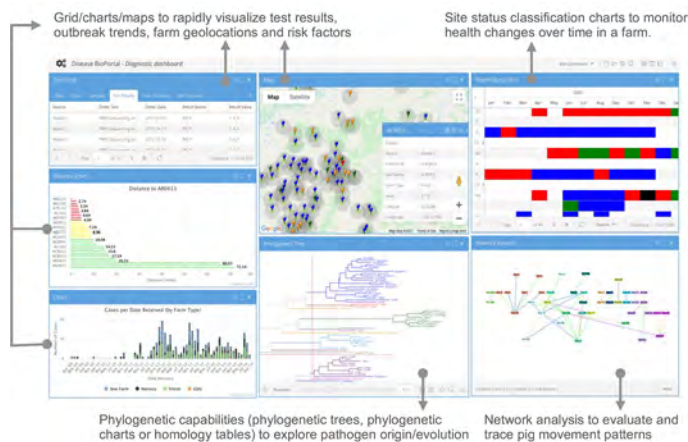
Description

The U.S. livestock industry has an enormous socio-economic impact, producing $195 billion in sales annually and generating over 5.5 million jobs. This project focuses on the swine industry, which is currently facing important global challenges with both endemic and emerging issues (e.g., swine influenza, antimicrobial resistance, African swine fever pandemic). However, the team's models and outcomes have been designed to be adapted to other diseases and species by minor modifications in the data structure.

In swine production, disease outbreaks represent a significant economic loss for the industry, reducing productivity, compromising animal welfare, and leading to an overdependence on antimicrobial drugs. Furthermore, the introduction of foreign animal diseases, such as African swine fever, could have cost $50 billion in losses and would worsen the current protein gap. Therefore, early detection and mitigation of animal health issues become crucial not only to maximize production efficiency and food safety and security but also to mitigate catastrophic economic consequences.

Phase 1 interviews of end-users revealed three main barriers to improve animal health: 1) lack of data availability, integration, sharing, and use 2) poor data efficiency, data governance and privacy, and 3) absence of explainable prediction models and accessible user-friendly visualization tools. The Disease BioPortal platform integrates multilevel animal health data with advanced prediction models, providing end-users (including farmers, veterinarians, pharmaceutical companies, researchers, and policy makers) an easy and secure access to data and models through a simple user interface to support animal health decisions.

Differentiators

Grid/charts/maps to rapidly visualize test results, outbreak trends, farm geolocations and risk factors

Site status classification charts to monitor health changes over time in a farm.

Phylogenetic capabilities (phylogenetic trees, phylogenetic charts or homology tables) to explore pathogen origin/evolution

Network analysis to evaluate and trace pig movement patterns

Current practices in the swine industry are usually reactive as most of the testing/interventions take place after having an outbreak or observing clinical symptoms in animals. Ideally, the team will have a predictive early warning system that enables prevention, earlier detection, and faster control of problems both at animal and farm level. Their pEPIC approach and Disease BioPortal platform offers four unique value propositions: (1) a user-centered design informed by interviews with more than 40 organizations from pig companies to veterinary clinics and diagnostic labs, (2) data standardization, integration, secure sharing and

communication capabilities, (3) innovative AI-based prediction models, cutting edge visualization tools, and domain-specific applications of data and models, and (4) a convergent team and academic-industry partnerships that brings together leading organizations, data providers, end-users and experts in computer and data science, visualization and computer-human interaction, causal discovery, software engineering, bioinformatics, epidemiology and animal health.

Road Map

Year 1

• Continue with data collection, standardization, integration, and curation to generate AI-ready datasets and facilitate data usage/sharing.

• Develop AI models (including explainable machine learning models, causal discovery and reasoning and topic models) and integrate data and models into user-friendly dashboards within the Disease BioPortal to facilitate their use/visualization by stakeholders.

• Expand their working groups with selected industry partners and end-users to incorporate new data sources, increase user cases, receive feedback, and enhance user experience during the beta testing of Disease BioPortal.

• Beta-test the mobile App, a key differentiator requested by end-users for "on-the-go" usage.

Year 2

• Publish AI models on GitHub.

• Release of the new version of Disease BioPortal (new data, AI, and visualization capabilities available for all end-users).

• Develop and implement new services as well as training and documentation.

Partnerships

The team has assembled a convergent research-industry team that will be able to gather all crucial data, develop the necessary methods and test them in real-farm applications. Through existing close collaborations and Phase 1 expansions, the team consists of the top veterinarian schools in the U.S., the largest swine veterinary diagnostic laboratory (VDL at

Iowa State University conducts 50% of all diagnostics in the U.S.), the largest animal genetics company (Pig Improvement Company), the largest veterinary clinic in the U.S. (Pipestone), and several of the top 10 largest swine producers (Seaboard, Pipestone, Tosh farms, Hanor) and the National Pork Board. The team has also extended their partnership with other companies such as GlobalVetLINK, the U.S. leader in digital animal records and data aggregation; pharmaceutical companies such as Merck & Co. (MSD), which is the world's seventh largest pharmaceutical company by market capitalization and revenue; and Amazon Web Services research team to improve their data architecture. These partners all are key data providers and end-users.

Intellectual Property

The Disease BioPortal code is already protected in the form of copyright, and the team plans to seek other types of intellectual property protection and licensing in the future such as trademarks or patent applications for AI algorithms, processes, visualizations, and the mobile app. Their tiered pricing model is based on the type of customer/end-user segment, the volume of data and the tools needed.

Additional Information

For additional questions or information, please contact bioportal@ucdavis.edu.

CORE Institute

Catalyzing an Impact Network for Convergence Research

coreinstitute@ucsd.edu

Overview

The Convergence Research (CORE) Institute is designed to catalyze an impact network of students, researchers, and practitioners who will collaborate across disciplinary and sectoral boundaries to tackle use-inspired research problems and develop scientifically innovative solutions. The Institute brings together individuals committed to engaging in projects driven by specific and compelling societal problems that require deep integration across disciplines and sectors.

Description

The Convergence Research Institute was created as a joint effort from a cohort of Principal Investigator's (PI's) and Co-PI's from the Convergence Accelerator working on AI Driven Innovation through Data and Model Sharing (Track D). The Institute was created with the goal to equip individuals with the necessary skills and networks to tackle national and global scale challenges through multidisciplinary and multisector collaboration.

Key to achieving the Institute's goal is its pioneering CORE Fellows program: a training program developed specifically for students and early to mid-career professionals interested in applying their skills and using convergence research to solve societal problems. The curriculum provides Fellows with a foundational experience to identify use-inspired research problems and build convergence solutions that seamlessly integrate into existing societal systems.

Each year the CORE Institute selects a thematic focus related to a societal grand challenge. In 2023, the theme for the inaugural cohort of CORE Fellows was "Tackling Climate-Induced Challenges with AI".

The CORE curriculum includes distinct segments for: (i) foundations of convergence research taught; (ii) case studies on artificial intelligence strategies for climate-induced challenges; and (iii) garage sessions for teams to engage in problem definition and new solution ideation. Supported by Institute mentors, a select group of fellows participates in an in-person incubator at University of California, San Diego. During the incubator, fellows work together to draft research proposals for and/or to prototype their AI solutions.

In 2023, the Institute trained 95 fellows including assistant and associate professors, graduate students, and professionals from private companies, local governments and nongovernmental organizations. In the coming years, the CORE Fellows will continue to focus on issues related to sustainability challenges and advanced computing solutions.

Differentiators

A key distinctive feature of the CORE Institute is its unique location. Based at the Cyberinfrastructure and Convergence Research and Education (CICORE) Division at the San Diego Supercomputer Center, the CORE Institute benefits from a network of professionals with artificial intelligence and advanced-computing access and expertise. Artificial intelligence applications expand the possibilities of use-inspired, science-driven partnerships by facilitating the rapid integration of new models and data among an increasingly broad user base. This provides Fellows with enhanced opportunities for collaboration with experts from diverse disciplines and sectors.

Another key characteristic of the Institute is its focus on well-defined use-inspired research problems to produce tangible, real-world outcomes in line with the essence of convergence research principles. To accomplish this goal, the Institute places a strong emphasis on fostering user engagement and maintaining an ongoing feedback loop as integral components of all the projects it supports.

Road Map

In 2024, the CORE Fellows will leverage data and AI to build solutions for more sustainable cities & regions. In preparation for their projects, the Institute will host a series of workshops with stakeholders to define use-inspired research problems at the local level during the fall of 2023.

During the spring of 2024, Fellows will form convergence research teams to work on the use-inspired research problems identified through the workshop series. The practitioners who participate in the workshops will work with the Fellows as they create convergence research AI-powered solutions for sustainable cities and regions.

Both stakeholders and fellows will participate in the trainings organized by the Institute throughout the winter and spring. During the summer, Fellows will present prototypes of their solutions to the Institute's team and network, as well as to potential users.

Partnerships

Since its creation in September 2022, the CORE Institute has been guided by an advisory council of U.S. National Science Foundation Convergence Accelerator Track D PIs. It has also built partnerships with the Proactive Wildfire and Environmental Sustainability Solutions Center and the Bioregional Center for Sustainability Science, Planning and Design. Through these partnerships, the Institute has been able to reach a diverse pool of research fellows, training instructors and speakers, and subject-matter experts. Moreover, the Institute's partners have contributed and will continue to contribute to the definition of the annual thematic focus of the Fellows Program, as well as to the identification of stakeholders to inform discussions around use-inspired research problems, curriculum updates, and overall development of a rich and diverse convergence research network.

TRACK E: NETWORKED BLUE ECONOMY

Ocean-related industries and resources, known as the blue economy, play a central role in addressing challenges related to climate, sustainability, food, energy, pollution, and the economy. The U.S. National Science Foundation recognizes that the changes to our earth are occurring at an accelerated pace, requiring convergence across experts, organizations, and sectors to address societal, environmental, and economic challenges related to oceans. NSF Convergence Accelerator's Track E: Networked Blue Economy focuses on interconnecting the blue economy and accelerating convergence across ocean sectors—creating a smart, integrated, connected and open ecosystem for ocean innovation, exploration, and sustainable use. Collectively, funded research teams are building strong multi-organization partnerships involving researchers, users, and other stakeholders to develop solutions to pressing problems such as plastic waste; illegal, unreported, and unregulated fishing; coastal erosion; and the need for better monitoring of changing conditions. The teams will also produce tools, methods, and educational resources to improve human engagement with the world's oceans as both an environment and a resource.

Networked Blue Economy funded Phase 2 teams include:

Backyard Buoys—Led by University of Washington, Backyard Buoys partners with Indigenous and other coastal communities to collect and use ocean data to support maritime activities, food security, and coastal hazard protection. Innovations include a sustainable process for community-led stewardship of affordable ocean buoys and a web-based application that renders data easy to understand and bridges to Indigenous Knowledge.

BlueGAP—Led by University of South Florida, BlueGAP is broadening the coalition of people aware of and fighting to reduce nitrogen pollution. BlueGAP raises awareness of nitrogen pollution through personalized stories, trusted local data, and place-based community events. Co-designed by scientists, engineers, and community organizers, BlueGAP equips communities, particularly those experiencing continuing injustice from nitrogen pollution, through expert consultation and access to resources to act and drive change in their watershed.

Digital Reefs—Coral reefs support livelihoods for one billion people globally-but are under increasing threat from human activities. Led by Woods Hole Oceanographic Institution, Digital Reefs delivers interactive 4-D visualizations of reef environments into the hands of local communities, empowering stakeholders to ensure a sustainable future for all-coral reefs.

Nereid Biomaterials—Led by University of California, Santa Barbara, Nereid Biomaterials is enabling a healthier ocean through safe and rapid degradation of ocean plastics. By merging marine microbiology, synthetic biology, material science, and robotics, the team is developing "ocean degradable" polymers with embedded additives to accelerate and control

degradation. The project's initial focus is the ocean instrument industry, a rapidly-growing, and paradoxically plastic waste generating sector.

Ocean Vision AI—Led by Monterey Bay Aquarium Research Institute, Ocean Vision AI accelerates the processing of underwater visual data with a globally integrated network of services, tools, and a diverse community of users. Composed of data scientists, oceanographers, game developers, and human-computer interaction experts, Ocean Vision AI streamlines access and analysis of visual data to enable effective marine stewardship.

ReCoast—Led by Tulane University, ReCoast's vision is to create coastal community recycling programs to keep glass out of landfills and instead use it for glass sand products that support coastal restoration and preservation. Through extensive regional economic, social, cultural, and environmental research, ReCoast is ensuring ecological safety and mitigation of land loss.

TRACK OUTCOMES:

- Several Backyard Buoys were deployed in coastal waters off Alaska and Washington by local teams of Indigenous community leaders, oceanographers, and observing system staff. The team is documenting successes and lessons learned to help future communities develop robust wave buoy stewardship plans, and the prototype smartphone app has gained wide appreciation as it delivers near real-time data to users.

- BlueGAP has created a suite of services and resources that includes (but not limited to) consulting, educational products, and eco documentaries. Among them is production of impactful multimedia, such as documentaries and a creative art exhibit, focused on the complex problem of nitrogen pollution that connects people with others' lived experiences in and across watersheds.

- Digital Reefs received an honorable mention in Fast Company's World Changing Ideas-Nature award in 2023.

- Nereid Biomaterials has filed a provisional patent for their living material technologies to enhance biodegradation of plastic in the ocean.

- Ocean Vision AI has expanded upon three solutions, including the release of version 1 of the FathomNet and a beta version of the Ocean Vision AI Portal, both core AI enabled annotation solutions. Additionally, FathomVerse, an AI enabled interactive game, launched a beta test version, which captured more than 430,000 annotations from over 1,000 players within two months of the minimum viable product or MVP.

Backyard Buoys

Equipping Underserved Communities with Ocean Intelligence Platforms

Lead PI: Jan Newton
janewton@uw.edu

Tim Janssen
tim@sofarocean.com

Melissa Iwamoto
mmiwamoto@hawaii.edu

Sheyna Wisdom
wisdom@aoos.org

Overview

The aim of Backyard Buoys is for Indigenous and other coastal communities to collect and use ocean data to support their blue economy: maritime activities, food security, and coastal hazard protection. These communities have been substantially underserved and climate change is making predictability even harder. To serve the desire for autonomy, the team's innovations include a sustainable process for community-led stewardship of affordable ocean buoys and mobile and web-based applications (apps) that render data easy to understand and bridge to Indigenous knowledge.

Description

The Backyard Buoys team brings together regional ocean observing networks of the U.S. Integrated Ocean Observing System (IOOS), underserved Indigenous communities, and a sensor company working collectively to democratize local wave measurements and provide a solution to the existing hurdle of observing technologies that are too expensive and cumbersome to purchase and sustain. Through co-design of an implementation and stewardship plan, as well as apps tailored to transmit data in low-bandwidth scenarios, the team is revolutionizing the status quo. By using lower-cost tools and deepening the human and data connections, collectively their system is effective at addressing needs within the hyper-local scale–sorely lacking in the design of existing ocean observing systems–while assuring it is within a globally-connected network.

Differentiators

This project is not about putting buoys in the water, but identifying the barriers and challenges that communities will run into as they attempt to get buoys in the water. As a group of explorers, Backyard Buoys continues to advance the convergent achievements of the Phase 1 effort, fostering the original partnerships while adding new partners focused on education

and project management. They are sharing training and activities on various aspects, including: Sofar wave buoy operations, mooring design, data analysis, Indigenous knowledge integration, wave and climate modeling, engagement, and education. The Indigenous communities engaged during Phase 1 are the ultimate stewards of the wave buoys within their own waters throughout the project and beyond. To date, they have identified their optimal locations for deployments and are conducting deployment and recovery tasks. The communities are doing this themselves, rather than sending a researcher to each community, and have autonomy over data sharing. This aspect is a switch from the typical ocean research model, where the communities are simply told what is going to happen in their community, without much consideration for their needs or broader goals.

Road Map

The Backyard Buoys team makes progress through Working Groups that have been established to provide a shared forum for technical support and to identify expansion opportunities. Working Groups include Buoy Operations, Data Tools, Educational Development, and Co-Design. One of the primary tools is the development of Community Research and Implementation Plans (CRISPs) that are used by community stewards to execute the Backyard Buoy project. CRISPs are developed with a user-friendly web-based tool designed to encourage community involvement. Low-bandwidth data tools such as Text-a-Buoy and a mobile app have been co-designed to provide the necessary real-time wave data. They are implementing wave buoys in all three regions, along with the data dissemination applications. An education and translation layer focuses on engaging the communities more fully by developing educational materials that will be used in the region. To grow community participation in the project, each region will provide opportunities aimed at inspiring a younger generation to participate in ocean observation.

Partnerships

The team has a geographically, academically, institutionally, and culturally diverse group of partners collaborating on Backyard Buoys. Their partnership is between 1) three U.S. IOOS Regional Associations; 2) Indigenous partners in each region; 3) a proven ocean wave buoy developer; 4) educational partners; and 5) project management.

Pacific Northwest: Northwest Association of Networked Ocean Observing Systems (NANOOS), Quileute Tribe, Quinault Indian Nation, Western Washington University

Alaska: Alaska Ocean Observing System, Alaska Eskimo Whaling Commission, University of Alaska Fairbanks, Alaska Department of Natural Resources, Alaska Native Science and Engineering Program

Pacific Islands: Pacific Islands Ocean Observing System, Marshall Islands Conservation Society, National Park of American Samoa, Hawaii Sea Grant, Conservation International Hawaii

Buoys: Sofar Ocean Technologies

Project Management: Weston Solutions

Intellectual Property

The Intellectual Property (IP) will be freely shared within and beyond the partners. IP primarily consists of data delivery systems and web intake surveys. The ocean observing buoy systems being deployed are already mature and commercially available products that are wholly owned and patented by Sofar.

Additional Information

Based on the outcomes from the CRISPs and Working Groups, an Ocean Best Practices document will be developed that will guide other regions and groups in lessons learned and practices that lead to success.

An additional benefit of getting wave buoys in the water at sites which are in historically under-measured regions and have a diverse range of environmental conditions is the generation of data from highly-localized coastal areas available for large scale scientific research to improve climatologies and predictions, especially important in light of climate change. This is critical for effective advanced planning to ensure a safe blue economy for the communities.

Photo Caption: Quileute Tribe deploying wave buoy off La Push, WA.

BlueGAP

Bridging Communities Upstream and Downstream

Lead PI: Maya Trotz
matrotz@usf.edu

Maya Burke
mburke@tbep.org

David Cwiertny
dcwiertny@uiowa.edu

Tiara Moore
ceo@bims.org

Rebecca Zarger
rzarger@usf.edu

Overview

A strong Blue Economy requires healthy watersheds. The Blue-Green Action Platform (BlueGAP) combines story telling with trusted water quality data to catalyze community action against nitrogen pollution in our waterways. As a hybrid organization (nonprofit and for-profit), BlueGAP provides consulting services, education materials, and grassroots environmental documentaries to spur actions the team believes will facilitate a reduction in nitrogen pollution. BlueGAP is co-produced with local champions in each watershed whose stories, networks, and actions guide development.

Integrating a virtual information system with place-based activities, BlueGAP engages and empowers people to create a more equitable and sustainable Blue Economy.

Description

Nitrogen pollution costs the United States over $200 billion annually. Globally, reducing nitrogen pollution is now a United Nations goal. Whether it's from wastewater, stormwater and agricultural runoff, vehicle air emissions and other human activities, nitrogen pollution degrades water quality, threatens our public health, and impacts the economy. Often, frontline communities are the most affected.

BlueGAP is dedicated to reducing the harmful effects of nitrogen pollution by providing stories, trusted data, resources, and consultation services for those most impacted by nitrogen's effects.

BlueGAP activities leverage a dynamic website that helps users translate stories and data into action, on the ground activities (e.g., workshops, community festivals, etc.) with BlueGAP partners and champions through place-based Academies, and documentary filmmaking to reach broader audiences on the issue of nutrient pollution.

BlueGAP serves as a call to action. They guide people to solutions by pairing stories of lived experiences of water pollution within a watershed with visualizations of water quality data and connecting this information to targeted actions that can drive change from the community level within a watershed.

At the core of BlueGAP are "Champion" members, people fighting to combat nitrogen pollution and environmental injustice in their communities.BlueGAP provides a venue where Champion members can share their first-hand experiences and serve as inspiration to users. In return, BlueGAP helps to amplify their stories, message, and impact.

The BlueGAP Information System is a virtual space that will engage a wide range of users on the sources and impacts of nitrogen pollution. Users may interact with accessible educational content, experience relatable real-life Champion member stories, and explore a personal relationship with nitrogen pollution within their own watershed. It will also share evidence-based best practices and provide decision support tools that prompt users to become involved in mitigating nitrogen pollution.

Differentiators

BlueGAP directly engages diverse communities in shaping their Blue Economy, which is distinct from traditional top-down management strategies. They use a human-centered convergence framework to build coalitions to solve problems with communities, keeping frontline communities at the forefront. All BlueGAP products prioritize accessibility and inclusion,amplifying new voices, and broadening participation in the Blue Economy. Their team provides expertise in developing authentic relationships with communities, serving as a resource to entities (e.g., governments, corporations, or philanthropic organizations) looking to forge meaningful connections with communities impacted by deteriorating water quality.

The BlueGAP Information System provides added value by consolidating trusted nitrogen data all in one place. Currently, data on nitrogen loads in water are maintained by numerous different groups across the nation. For the general public, such data is challenging to find and access. BlueGAP is capitalizing on the opportunity to centralize nitrogen data so that it is easier for the general public to find, access, and understand.

Road Map

To date, the team has constructed a prototype of the BlueGAP Information System, integrating stories from their first six Champion members and trusted data sources from across three model watersheds used in product development. They are currently conducting focus groups with prospective beachhead markets (e.g., community groups, advocates, residents of frontline communities) to refine and improve aspects of the Information System and other BlueGAP products.

Other ongoing activities involve the collection of additional interviews with local nitrogen champions. To date the team has completed 62 of the proposed 75 interviews that capture storytelling, local expertise, experiences, and values with nitrogen pollution.

In early 2024, the team is targeting a soft launch of the BlueGAP Information System for their first place-based Academy, led by BlueGAP partner, Tampa Bay Estuary Program. The target market for BlueGAP's services will be segmented into nonprofit and for-profit categories with cross-over markets.

Partnerships

BlueGAP is co-developed by a diverse group of academic (University of South Florida, University of Iowa, Stetson Law School), nongovernmental (Black in Marine Science), and quasi-governmental (Tampa Bay Estuary Program) organizations, and community and private sector organizations. This open partnership brings in BlueGAP Champions as partners, initially from six community organizations in Iowa, Florida, and the U.S. Virgin Islands, to co-design and build capacity across and between watersheds.

BlueGAP is also building a broad network of governmental and organizational agencies to participate in a series of round-table discussions on the value and sustainability of BlueGAP.

Intellectual Property

A cornerstone strategy of BlueGAP is the use of open science principles and methods. BlueGAP is a fully open platform and materials will be copyrighted and stories will be assigned Digital Object Identifiers.

Converging on the Blue Economy

The team's vision is to stimulate the Blue Economy by accelerating convergence on best practices for nitrogen management. BlueGAP empowers local communities, particularly frontline communities who have encountered many overlapping barriers to participating in the Blue Economy, by integrating information, contacts, and legal and policy decision-making tools and placing these resources directly in the hands of people who need them most urgently. By extending the Blue Economy beyond the ocean to include watersheds, BlueGAP provides multiple pathways for frontline communities to engage in reshaping the Blue-Green Economy.

Digital Reefs

Digital Reefs at Your Fingertips

Lead PI: Anne Cohen
acohen@whoi.edu

Michael Fox

Nathan Mollica

Simon Thorrold

Weifeng Zhang

Overview

Coral reef ecosystems are in decline. Science-based tools that can transform the development and execution of sustainable strategies exist, but are not accessible to decision-makers. Consequently, critical decisions affecting the health of coral reefs are made every day, often without the appropriate data. Digital Reefs leverages digital twin technology and gaming engine platforms to create immersive, interactive, 4-dimensional, visual replicas of coral reef ecosystems, delivering accessible, understandable, and actionable data to users around the world. With Digital Reefs as a go-to decision-support tool, decision-makers will minimize risk, optimize strategy, and be prepared for the future.

Description

Coral reefs support the livelihoods of 1 billion people globally, and hundreds of thousands of jobs in the United States alone. But today, coral reefs face multiple threats, from global climate change to local stressors, fueling an urgent, world-wide push to ensure their survival. Digital Reefs addresses this need by developing the first digital twin, a virtual replica, of a coral reef ecosystem. Users will visualize 4-dimensional reef environments, access state-of-the-art data and models, and conduct 'what-if' experiments scenarios to optimize proposed management strategies and infrastructure changes before they are implemented in the real world.

The initial prototype is designed for decision-makers in government agencies, management, conservation and restoration practitioners, ecotourism developers and research scientists. The core architecture is intentionally designed to port to mobile platforms for eventual expansion to "on-the-water" users such as fishermen and tour operators coral reef islands.

Digital Reefs facilitates development of a Networked Blue Economy by connecting users with actionable data that is fundamental to the development of sustainable practices. Building on a successful Phase 2 outcome, the team envisions a globally interconnected Digital Reefs Network as the go-to tool for effective management of coral reefs in the 21st century.

Differentiators

Digital Reefs is the first of its kind: a digital twin of the coral reef environment built around meter-scale bathymetric and hydrodynamic models developed specifically for this purpose. Then, leveraging recent advances in scientific knowledge, gaming engine platforms, computational power and cloud technologies, these sophisticated models are combined with in situ observations, satellite mapping, and photogrammetry to create the immersive, interactive, 4-D replicas of the coral reef.

Digital Reefs differentiates from existing platforms in critical ways: i) by providing data at the scale at which management decisions are made, ii) by enabling users to access, interact with and immerse in data presented as visualizations rather than spreadsheets or graphs, iii) by providing actionable toolkits with which users can conduct particle tracking simulations, access future projections of reef temperature and flow, and conduct what-if scenarios. Parallel efforts to construct ocean digital twins include the European Union-funded Iliad Digital Twin of the Ocean, focused on European seas and Environmental Systems Research Institute's Digital Twin of the Caribbean Island of Grenada. Digital Reefs is communicating with both efforts to explore potential partnerships.

Road Map

The team's functional, interactive Palmyra Atoll Digital Reefs prototype, delivered by the end of Phase 2, will include data layers and toolkits that facilitate climaterisk assessment, ecosystem service optimization, and particle dispersal monitoring. In Phase 1 of the U.S.

National Science Foundation Convergence Accelerator, the team conducted user interviews and created a low fidelity prototype, and have iteratively evolved their current prototype to align with user feedback. Their next round of user feedback took place in September 2023, testing new online interactivity, with more user engagement through the rest of Phase 2.

In Q1 of 2024, the Digital Reefs prototype will incorporate the 'what-if' scenario functionality that helps differentiate Digital Reefs from other data products available today. Additionally, in Q1 of 2024, they will host an all-hands workshop to collect a final round of feedback and begin trials and training for the Digital Reefs prototype with the goal of finalizing the prototype by the end of the quarter. After the interactive, accessible prototype is finalized, scalability testing will be conducted through July 2024, and will likely include user stress testing of the Digital Reefs prototype in a production environment. The planned testing will allow the team to more effectively estimate the time and cost required to create and maintain a new Digital Reef and will inform their pricing model moving forward.

Partnerships

Digital Reefs is a unique team of ocean scientists, software engineers, conservation organizations and stakeholders. Woods Hole Oceanographic Institution (WHOI) is leading the project, providing the vision, designing the interface and toolkits, conducting user research, marketing the product, and developing the high-resolution hydrodynamic models that are the cornerstone of Digital Reefs. Siemens Technology is an industrial pioneer of Digital Twin applications. They lead the front and back-end software development for the prototype. The Nature Conservancy is a global leader in coral reef conservation. TNC oversees fieldwork and provides user-input, resources, and data. Scripps Institute of Oceanography, and Stanford University bring world-leading expertise in coral reef ecology, coral physiology, coral reef fisheries, climate, and oceanography. These partners are providing high resolution 3-D imagery and generating field data to support toolkit development. All Phase 1 partners input on the Digital Reefs name and logo, and Phase 2 partners contribute to prototype development.

Intellectual Property

An intellectual property (IP) Agreement was executed by all project participants for Phase 2. Any background IP owned at the start of the project remains the participant's IP after the project ends. For example, the high-resolution reef models that are a foundational piece of Digital Reefs remain WHOI IP. Any new IP developed during Phase 2 is jointly owned by the developing parties. The WHOI Office of Technology and Transfer along with legal counsel are involved with developing IP and licensing agreements for beyond Phase 2.

Additional Information

Digital Reefs is drawing world-wide attention and has been showcased in multiple venues and media types, including Fast Company's 2023 World Changing Ideas Awards, Monocle Companion's "Fifty essays for a brighter future", 27th Conference of the Parties (COP27), and the Massachusetts Institute of Technology Media Lab's Enabling the Metaverse event.

Nereid Biomaterials

Biodegradable Plastics for Tomorrow's Ocean

Lead PI: Alyson Santoro
asantoro@ucsb.edu

Anne Meyer
anne.meyer@rochester.edu

Melissa Omand
momand@uri.edu

Allison Pieja
allison@mangomaterials.com

Overview

Nereid Biomaterials develops ocean-degradable plastics, including products with embedded bacteria and enzymes that accelerate biodegradation. Plastic accumulation in the ocean is an urgent problem, and ocean-centered strategies are needed to address it. Unfortunately, common compostable materials are proving to degrade extremely slowly, if at all, in the marine environment. The team's initial focus is on single-use, expendable ocean instruments used by the scientific, merchant marine, and defense sectors, with follow-on expansion into the fishing and aquaculture industries. These instruments are left to accumulate as waste long after their useful life and fishing gear is consistently lost at sea. Instrument manufacturers are eager for purpose-built, innovative solutions that meet the material needs of the Blue Economy, while protecting the health of the oceans.

Description

The weight of plastic waste in the ocean may soon be greater than the weight of fish. Simultaneously, people are increasingly reliant on plastic materials for expendable ocean instruments to predict the weather, guide maritime shipping, and model climate. The trend toward using large numbers of small, low-cost sensors extends beyond the scientific community; privately-operated sensing networks enable data-driven decisions for global shipping and resource extraction, supporting a maritime data analytics market expected to reach $2.1 billion by 2028.

Eighty percent of the plastic in the Great Pacific Garbage Patch derives from offshore fishing and 'ghost fishing' by derelict gear greatly harms ocean life. This issue led the team to add fishing traps and aquaculture equipment to their targets.

Nereid Biomaterials' ocean-degradable materials are based on the biopolymer polyhydroxybutyrate (PHB), sustainably produced from waste methane gas. As

PHB is a compound naturally made by bacteria, many marine bacteria have evolved to fully degrade PHB to carbon dioxide and water, without the creation of microplastics or other harmful byproducts. The team has shown that PHB biodegrades 40x faster in ocean conditions than the biopolymer PLA (polylactic acid), which is biodegradable only under specific composting conditions. Enabled by their deep understanding of marine microbial metabolism, the team combines additives with the base PHB formulation to further accelerate degradation by over 30%. By incorporating naturally-occurring microbes or enzymes into innovative "living materials," they can tune and trigger degradation. This allows for development of a range of products that customize the rates of degradation to the applications.

By first focusing on a specialized application such as ocean instrumentation, where plastics represent a small fraction of the cost of the finished good, Nereid Biomaterials will be able to scale up production of both PHB formulations and living materials. This enables contributions to reef restoration and brings costs down for sectors with incentives for ocean-degradability but tighter cost constraints.

Differentiators

Nereid Biomaterials is a team of material scientists, microbiologists, and oceanographers working across industry, academia, and government with decades of experience in sea-going oceanography—a field where research and instrument development are closely intertwined. Their implementation of living microbial additives for degradation of waste plastics is the first of its kind—in either marine or terrestrial settings. In contrast to products that embed only enzymes for plastic degradation, they focus on naturally-occurring marine microbes and additives that enhance ocean-degradability in cold, deep environments that do not intersect land-based, industrial composting methods. The team aims to enable targeted degradation rates is also unique, a reflection of the broad range of

instrument lifespans required by end-users. Finally, their use of Mango Materials' polymer—made by microbes and derived from waste methane—is truly sustainable since it does not compete with food sources.

Road Map

Manufacturers need data on material properties, degradation rates, and environmental toxicity to effectively integrate new materials. Quantification of degradation rates for a range of formulations in laboratory and field conditions is ongoing, as is development of 3D-printed microbial "stickers" that can degrade PHB at tunable rates and are transferable. Material property evaluation of prototypes will begin in 2023 and the team is in talks with the U.S. Environmental Protection Agency to enable toxicity testing. The result of these endeavors will be products that degrade by 80% carbon mass on three timescales: weeks, months, and years, and they will work with their industry partners to incorporate their materials into a range of expendable ocean instruments. Finally, the team is in the initial stages of exploring the feasibility of their materials for fishing traps, nets, and buoys.

Partnerships

Nereid Biomaterials has over 15 partners spanning government, industry, military, nonprofit, communications, and education. Their customer discovery revealed a nearly unanimous enthusiasm and demand for ocean-degradable materials across these sectors and interest in their data to drive regulations. The team continues to strengthen their relationship with the Navy and their industry partnerships include some of the country's largest producers of expendable ocean instruments.

Intellectual Property

Nereid Biomaterials' project combines formulated PHB (Mango Materials trade secret) with additives proven to accelerate marine degradation and living microbes or enzymes. Their intellectual property derives from their custom formulations and their methods to embed living materials into 'accelerant' products such as stickers, inserts, or packets for addition to PHB products by the end-user to enhance degradability. They submitted their first provisional patent related to the living materials in 2023 and have a signed non-disclosure agreement between core members.

Additional Information

The team's collaboration with the Center for Science and Engineering Partnerships produced a robust internship program focused on recruitment of students from populations historically underrepresented in Science, Technology, Engineering, and Mathematics (STEM). Of their recent cohort selected from University of California, Santa Barbara, 100% were underrepresented, 43% underrepresented minorities, 29% low-income, 14% first generation, and 71% female-identifying. The internship has expanded to include a course curriculum and year-long series of placements that span multiple institutions, culminating in a poster and networking session. The team's leadership is 100% female-identifying or LGBTQ.

Ocean Vision AI

Accelerating Ocean Discovery

Lead PI: Kakani Katija
kakani@mbari.org

Katy Croff Bell
katy@oceandiscoveryleague.org

Angus Forbes
agforbes@purdue.edu

Henry Ruhl
hruhl@mbari.org

Ben Woodward
benjamin.woodward@cvisionai.com

Overview

Ocean Vision AI accelerates the processing of underwater visual data with a globally integrated network of services and tools to serve a diverse set of users–from scientists to environmental managers to ocean enthusiasts. Composed of data engineers, oceanographers, game developers, and human-computer interaction experts, Ocean Vision AI streamlines access and analysis of ocean visual data to enable effective marine stewardship.

Description

Ocean Vision AI is building a global-scale community of ocean visual data collectors, annotators, and users. Ocean Vision AI is undergirded by a suite of innovative technology that allows individuals and organizations to rapidly translate their imagery into actionable data. Their service leverages FathomNet, their large-scale collection of annotated image datasets, while working to develop intuitive human-AI experiences and data portals to accelerate exploration. Ocean Vision AI has taken concrete steps toward developing these collaborative workspaces that enhance access to ocean expertise, machine learning know-how, and visual data throughout the depth and breadth of the ocean.

Phase 1 of the Convergence Accelerator supported the beta launch of FathomNet, their open-source, distributed image database designed to ingest and serve annotated images to users around the world. The data in FathomNet are being used to inform the design of the Ocean Vision AI Portal, their interface for ocean professionals to select concepts of interest, acquire relevant training data from FathomNet, and tune machine learning models. To inspire a diverse new generation of ocean explorers, the team has begun development on a video game FathomVerse that will educate players while generating new annotations.

Ocean Vision AI's ultimate goal is to democratize access to ocean imagery and the infrastructure needed to analyze it. Their cost structure will reflect this aspiration, charging users on a per-project basis driven by the quantity of data uploaded and institutional need. The contributions of large, well-capitalized private and public institutions will support access for historically excluded communities. Providing data and tools to all will yield a more connected community of practice, better AI systems, support a growing Blue Economy, and encourage a more sustainable ocean.

Differentiators

Ocean Vision AI is unique in the Blue Economy space: no other organization is working on a system for distributing annotated ocean visual data and providing analytic services. The closest analogs are for terrestrial ecology: Wildlife Insights–a commercial product for processing camera trap data–and iNaturalist and eBird, two community driven, freely available data aggregation and processing services. In addition to software and data architecture, these systems lean on existing networks of enthusiasts who provide contributions in the form of knowledge and imagery. Enthusiast knowledge networks do not exist at the same scale in the ocean domain.

To address this gap, Ocean Vision AI's scope goes beyond data aggregation and processing pipelines. They are working to build and educate an enthusiast network specializing in ocean life through the release of Ocean Vision AI's game FathomVerse. Through this platform, they will seamlessly integrate the data analysis pipeline and global set of users, marrying state-of-the-art technology and community power to build an unprecedented resource for the ocean.

Road Map

Ocean Vision AI has identified three core deliverables for Phase 2 of the Convergence Accelerator: expansion of FathomNet, launch of the Portal, and release of the video game. Currently FathomNet v1.0 has been

released, and a beta release of FathomVerse and the Portal has also been achieved. Both the Portal and FathomVerse are undergoing extensive user testing, generating feedback from hundreds of participants. They started development on v1.0 of FathomVerse in September 2023, with an anticipated release in February 2024. Findings from the first two versions of the game will inform the final design to be released in Fall 2024 as a standalone, multiplatform game for high school aged and older players. The Portal will continue to release features in beta every three months until finally launching v1.0 in Summer 2024. By Spring 2024, they will have codified the export of machine learning enabled ecological survey data from FathomNet and the Portal to ecological metadata repositories, like the Global Biodiversity Information Facility, used to inform large-scale policy and management decisions.

Partnerships

Ocean Vision AI brings together public, private, and academic organizations. The Monterey Bay Aquarium Research Institute (MBARI), a nonprofit with decades of ocean engineering and data management experience, provides infrastructure and leadership. The Central & Northern California Ocean Observing System, a federally accredited source for integrated ocean data, distributes data to stakeholders. CVisionAI, an industry leader providing machine learning and data science expertise in the ocean space, will develop software architecture that underlies Ocean Vision AI. The Ocean Discovery League, a nonprofit that provides low-cost deep sea observational capacity to historically excluded communities, will lead development of the Portal. The Internet of Elephants, a conservation-focused video game company, has guided the team's development process and collaborates with &ranj (a game design studio in the Netherlands) on FathomVerse. Their partners at Purdue University will produce novel and engaging data visualization experiences. Education experts at the Monterey Bay Aquarium will continue to assist with game testing and K-20 curriculum development around Ocean Vision AI. The National Oceanographic and Atmospheric Administration is providing data access and computing resources. The National Geographic Society has provided data access and will publicize Ocean Vision AI's activities across their channels.

Intellectual Property

Ocean Vision AI is an MBARI-led project and will follow the intellectual property (IP) policies of the organization. IP developed as part of Ocean Vision AI's activities will be licensed to their for-profit partners, and all non-embargoed data will be made open-source through their data partners as described in their Data Use Policy.

ReCoast

Glass Recycling to Restore the Coast

Lead PI: Julie Albert
jalbert6@tulane.edu

Kat Fogg
kfogg@tulane.edu

Ehab Meselhe
emeselhe@tulane.edu

Katie Russell
krussel1@tulane.edu

Franziska Trautmann
franziska@glasshalffull.co

Sunshine Van Bael
svanbael@tulane.edu

Overview

The ReCoast Team's vision is to create coastal community recycling programs to keep glass out of landfills and instead convert it into glass sand products that support coastal restoration, preservation, and resiliency. Through extensive regional economic, social, cultural, and environmental research, the team is ensuring ecological safety and mitigation of land loss.

Description

In 2020, Glass Half Full (GHF) was founded in response to the lack of glass recycling in New Orleans, Louisiana's largest municipality, and that state's massive rate of land loss, on the order of a football field every

Glass sand and gravel produced by GHF

hour. GHF's ambitious mission to crush glass into sand for use in coastal restoration catalyzed the formation of the ReCoast Team a year later. Today, ReCoast consists of over twenty scientists and engineers conducting the research needed to ensure that recycled glass sand is safe to use in coastal environments and to identify sustainable pathways for other coastal communities to replicate the "recycling-for-restoration" model that is taking off in southeast Louisiana. The ReCoast Team's research is providing the foundation for long-term growth of a "blue economy network" centered on glass recycling and community engagement to restore and protect coastal environments, including marshes, sandy beaches, and urban shorelines, and to promote smart and sustainable use of our ocean-related natural resources in the future.
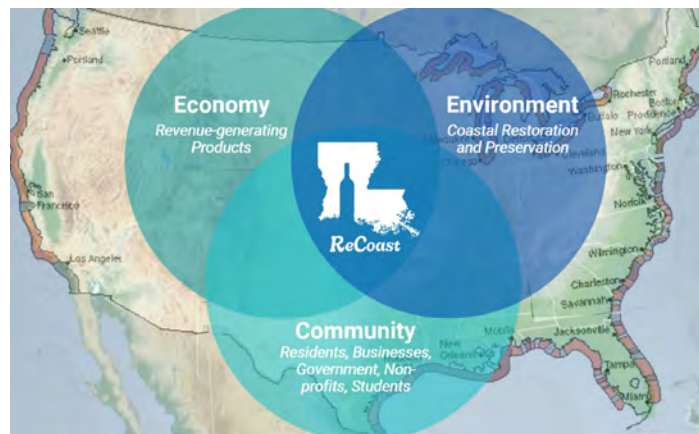
ReCoast's vision for a Networked Blue Economy

Differentiators

ReCoast engages stakeholder groups to advance a collective understanding of the dynamic interconnections between technological innovation, economics, society, politics, history, and the environment to enable sustainable, region-specific recycling-for-restoration models. The ReCoast Team's convergent research approach brings together science, engineering, and business disciplines capable of engaging a broad range of stakeholder interests. Leveraging each team member's disciplinary expertise alongside their personal and professional networks has enabled ReCoast to facilitate rapid deployment of recycled glass sand in marsh (2022) and beach dune (2023) environments (lab to field in under nine months). These accomplishments are a testament to the effectiveness of ReCoast's approach to creating recycling-for-restoration solutions and differentiates it from other organizations in the recycling and restoration spaces.

Road Map

The ReCoast Committment:

Q3, 2022-Q3, 2024: Extend scientific lessons learned from Louisiana's coastal marshes to beach dunes.

Q4, 2022-Q3, 2024: Continue broadening participation efforts, which include engagement of residents and community partners in demonstration project planning and implementation, providing opportunities for citizen science, and K-12 outreach.

Q4, 2023-Q2, 2024: Assess translation-readiness of value-added products and pursue provisional patents or sunset accordingly.

Q3, 2023-Q2, 2024: Combine technoeconomic, life cycle, and multi-criteria decision analyses conducted Q1–Q3 2023 based on the GHF operation to make the economic and environmental case for recycling-for-restoration in other coastal regions.

Q3, 2023-Q3, 2024: Create and implement a business plan for ReCoast's continued operation as a nonprofit entity.
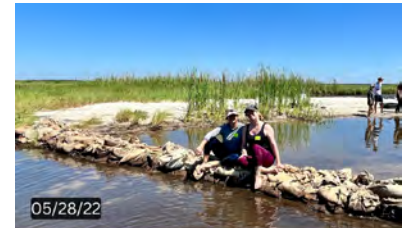
Q4, 2023; Q2-Q3, 2024: Carry out restoration projects in the Central Wetlands (bald cypress swamp) and Terrebonne/Lafourche Parish (intermediate-to-brackish marsh).

Partnerships

The ReCoast Team visited the Pointe Au Chien Indian Tribe shortly after Hurricane Ida in 2021. Helping the Tribe recover allowed the team to see firsthand the impact of land erosion on the daily lives of a frontline community, leading to their first demonstration project. Working with Tribe leaders, the team has since identified areas where recycled glass sand could be optimally utilized to protect and preserve culturally important locations (Terrebonne/Lafourche Parish restoration projects). Other key partners in planning, implementing, and monitoring the effectiveness of recycled glass sand-based restoration projects include the U.S. Fish and Wildlife Service, the Coalition to Restore Coastal Louisiana, Common Ground Relief, Wetland Resources, and the Meraux Foundation.

A new collaboration with University of South Alabama researchers at Dauphin Island Sea Lab has enabled rapid lab-to-field research in beach dune environments. The findings from these experiments are providing the scientific data ReCoast needs to build partnerships with various municipalities and organizations along the Gulf and Atlantic coasts who want to use recycled glass sand safely and effectively for beach renourishment. Other potential collaborators identified for expanding glass recycling for restoration outside of the Greater New Orleans area include Disney and the Surfrider Foundation.

Big Branch Marsh National Wildlife Refuge, marsh restoration

Additionally, the Lower 9th Ward Center for Sustainable Engagement and Development, Home by Hand, and Glassroots have been key partners for broadening participation and education through college service-learning classes.

Intellectual Property

An Intellectual Property Management Plan was developed in consultation with Tulane's Office of Intellectual Property Management and continues to serve as ReCoast's central reference in its ongoing development of a business plan and its approach to the timely disclosure and dissemination of results to the public while ensuring protection of intellectual property.

TRACK F: TRUST & AUTHENTICITY IN COMMUNICATION SYSTEMS

Modern life is increasingly dependent on access to communications systems that offer trustworthy and accurate information. Economic growth and opportunity depend on dynamic innovation and transaction networks that connect American families, communities, and businesses to an expanding range of goods and services that improve the quality of life.

The U.S. National Science Foundation Convergence Accelerator's Track F: Trust & Authenticity in Communication Systems teams are focused on education, training, and support to help information consumers and providers become better equipped to function in today's environment.

Trust & Authenticity in Communication Systems funded Phase 2 teams include:

ARTT—Led by Hacks/Hackers, ARTT (Analysis and Response Toolkit for Trust) supports health communicators, educators, and other responders who work to keep local, online communities more informed. The main tool, the ARTT Guide, is a web-based software assistant that provides a framework of possible response strategies for everyday conversations around tricky topics. Possible response strategies include listening, empathizing, and encouraging healthy inquiry. The project brings together insights from research fields such as computer science, social science, media literacy, conflict resolution, and psychology, in addition to practitioners from communities focusing on health-related communications.

Chime—Led by University of Wisconsin–Madison, Chime (formerly known as Course Correct) is developing a digital dashboard which amplifies transparently verified evidence. The project team plans to extend the existing computational work to verified

information deficits, using multimodal signal detection of linguistic and visual features surrounding issues coupled with network analytic methods to pinpoint key information deficits across audience segments; further develop A/B-tested informing strategies using ad promotion infrastructure and randomized message delivery to optimize efficiency; and evaluate the effectiveness of evidence-based interventions using various scalable techniques by conducting a series of randomized control trials within affected groups.

Co-Designing for Trust—Led by University of Washington, Co-Designing for Trust is a community-led collaboration that is designing socio-technical infrastructure to support libraries, schools, and other community organizations to develop, implement, and share effective and locally contextualized digital literacy resources. The project recognizes that digital literacy approaches need to be updated to account for the complex and unique everyday realities of how different types of communities interact with information. This requires approaches that not only build critical thinking skills, but also support individuals to reflect on and regulate how emotions and socio-culture context mediate their information behaviors. The project infrastructure supports communities to collaboratively develop these new literacy approaches so that they are consistent with local needs and interests ensuring that they are widely adopted and impactful. The infrastructure further supports the growth of a broader community of practice for sharing and scaling effective literacy approaches, with an emphasis on including and empowering practitioners from historically underserved communities.

Co·Insights—Led by Meedan, Co·Insights is a convergence of computational social science and ethnographic inquiry. The project's overarching goal is to empower people to understand and evaluate the information they see online. The solution does this by building tools, such as misinformation tiplines, that people can choose to consult if they want to learn more about a piece of content. All of the tools are opt-in, and are being built in close collaboration with Asian-American and Pacific Islander (AAPI) communities, who are dramatically underserved by current information interventions due to the variety of languages involved, use of alternative platforms, and limited understanding of the diverse social issues affecting the many ethnic groups within the broad umbrella of AAPI.

DART—Online deception disproportionately targets seniors to disastrous effects. Led by SUNY at Buffalo, the DART (Deception Awareness and Resilience Training) project helps older adults better recognize various forms of online deception and understand how to avoid or mitigate harm. The project creates and releases a simple and fun mobile game for older adults to familiarize them with common online deceptions. The game ensures that older adults keep up their guard against scams. DART's web-based training system also provides older adults with structured, self-paced learning about online deceptions. These tools accommodate older adult users' unique needs, preferences, and pace for an engaging and informative learning experience.

Expert Voices Together—Led by George Washington University, Expert Voices Together is developing a system to provide real-time support to experts, including scientists, who are facing campaigns of intimidation or harassment online. Drawing on best practices from trauma-informed care, the project will allow beneficiaries to work with a highly trained personal coordinator to customize a flexible plan that can be updated as their needs change over time.

Lead PI: Connie Moon Sehat   Franziska Roesner   Amy X. Zhang
artt@hackshackers.com

Overview

Communicators in public conversations, both professionals and ordinary citizens, try to provide their communities with reliable information, but this work is hard. These individuals need help when topics are complicated, discussions are contentious, and rumors spread online. The (ARTT) Analysis and Response Toolkit for Trust project's software tool and curriculum will support communicators with easy access to reliable information, tips for effective, trust-building conversation, and encouragement.

Description

"What do I say and how do I say it?" Every day, people in on- and offline communities wrestle with this challenge while engaging in conversations.

The problem is online information is often difficult to navigate and discuss. In addition to its abundance, issues such as access, education, and bot attacks present challenges to citizens trying to discern accurate information for their daily lives.

Whether amateur volunteers or local professionals such as health communicators, people seek assistance—not just in understanding the information out there, but more fundamentally on how to best engage with others in ways that promote productive conversations. While these individuals may know their community well, they may be less aware of the latest research on how to best assess and respond to the latest rumors while leaving room for respectful disagreement. They need options and guidance, which do not impose any particular beliefs, for conversational responses that are effective and trust-building.

ARTT's software tool, currently called ARTT Guide, will address these needs in an accessible format available through both desktop and mobile devices. In addition, a curriculum will help provide training about further research-backed methods. The main topical focus of ARTT's efforts has been vaccines and public health.

Differentiators

The ARTT project presents a new, unique framework of possible responses for everyday conversation. These responses come from recent research in fields including psychology, conflict resolution, and media literacy. While there are tips on how to best correct inaccurate information based on that growing research, it will also share with users guidance on other response possibilities, including: co-verify, de-escalate, empathize, encourage healthy inquiry, listen, share. ARTT users are empowered to craft their own responses and make decisions about how they want to engage with others.

Features will include: the ability to create and evaluate messages in the public interest based on tips and examples of effective communication methods from the ARTT research library; and the ability to save messages and consult a library of effective messages from others. A second version of the tool will incorporate optional artificial intelligence (AI) suggestions for crafting messages based on the guidelines from the research library. Through static templates or AI-powered suggestions, ARTT will offer multiple possibilities for conversation that communicators can consider. Ultimately, at each step of the way, users will determine what they want to say or to message.

Road Map

ARTT's main deliverable is the ARTT Guide, a software tool at the heart of the project. The project also has two additional supporting deliverables:

- A second version of a curated research catalog, which informs the communication model that the team has distilled from research.

- A curriculum that explains the communication model.

Key milestones are built around the Guide and the testers (communications professionals) who will use it:

- A first version of the tool, based on feedback from testers in 2023 and user interviews in 2024, will launch as a free public beta later in 2024.

- A second, paid version of the tool that incorporates AI features for communications professionals is intended to be ready by December 2024.

The project is aiming to launch in this way to provide free online versions of the tool that limit use of ARTT's AI tools, to ensure the tools follow still-emerging ethical AI guidelines.

The project's software will undergo a second round of cybersecurity testing in summer 2024.

Partnerships

This project is led by members from Hacks/Hackers, a nonprofit organization focused on journalism and technology, and from the Paul G. Allen School of Computer Science & Engineering at University of Washington. In Phase 2, the team has been joined by members of the National Public Health Information Coalition, the Social Science Research Council, Children's Hospital of Philadelphia, Georgia Tech Research Institute, and other organizations to help to continue the refinement of ARTT.

Intellectual Property

ARTT aims to make its resources available under various open-source licenses when possible. For example, content on the project website has been released under a CC-BY 4.0 license.

Chime
Precision Guidance Against Misinformation

Lead PI: Michael W. Wagner Porismita Borah Munmun de Choudhury

Srijan Kumar

Overview

The trust individuals have for verifiably accurate information is in crisis. Information professionals and citizens alike are overwhelmed by the volume of unverified information, which may be misleading, flowing through social media platforms and, as a consequence, are not always sure which claims to rely on. Chime, formerly called Course Correct, helps information professionals meet the needs of the public and consumers for high-quality information, rebuilding trust in civic institutions by amplifying information that is transparently and verifiably accurate onto social media platforms.

Description

Chime–amplifying high-quality information–is a flexible and dynamic digital dashboard that helps information professionals to (1) identify both low- and high-quality information that is being shared online about a variety of topics on social media platforms like X, formerly called Twitter, and Facebook; (2) amplify verified, high-quality information about those same topics onto social media platforms, focusing on individuals who are more likely to have been exposed to unverified information; and (3) scientifically examine the effectiveness of amplification of high-quality information in real time.

Chime uses cutting-edge techniques to help information professionals identify networks of people on social media who are sharing low-quality, unverified information and high-quality, verified information about a variety of issues. Once information professionals independently evaluate the size and reach of these networks and produce evidence that is transparent and verifiably accurate, they work with Chime staff to develop and rapidly test messages that will amplify the flow of high-quality information in social media networks.

Phase 1 testing revealed that Chime accurately identifies low-quality/unverified information networks on social media. In Phase 2, Chime will test the effectiveness of amplifying accurate information, giving information professionals valuable feedback about the performance of their efforts to improve information quality.

Differentiators

Many efforts to share verifiable information, increase public trust in information, and the like focus on fact-checking individuals' comments. Research shows that while these fact checks are occasionally effective, people tend to view these efforts as biased, diminishing public trust in the authenticity of information seeking to correct misinformation. Other efforts seek to build media literacy in the citizenry, but research consistently demonstrates that these efforts do not scale up from individuals to the public at large. Concerns expressed about content moderation as restricting free expression limit its effectiveness.

Instead, the Chime team conducted a set of theoretically-grounded empirical experiments that demonstrated the value of observational corrections (i.e., seeing others' misleading content being juxtaposed with other information) in reducing individual acceptance of low-quality claims. The project also showed that sharing these messages via sponsored content performed just as well as non-sponsored messages. This means that Chime's method will scale up effectively as the team leverages social media platforms' sponsored content infrastructure to amplify the flow of verifiably accurate information online.

The project's interdisciplinary team of mass communication researchers, health communication researchers, computer scientists, engineers, political scientists, information professionals, brand professionals, and social media platform professionals

is uniquely suited to help more accurate information reach citizens across the political spectrum who are surrounded by low information quality networks.

Road Map

Summer 2023: Completed a scalable detection system for unverified information flow that provides information professionals impact scores for unverified information being shared on social media.

Fall 2023: Developed Minimum Viable Product and began testing with partner end users.

Summer 2024: Conduct randomized control trials with partners to demonstrate Chime's market value and the scalability of observational correction as a strategy to amplify targeted exposure to high-quality information.

Fall 2024: Connect Chime with information professionals and end users outside Chime's partner base and meet with capital investors.

Partnerships

In addition to their team of interdisciplinary researchers, Chime partners with media literacy and brand professionals to help accurately and effectively amplify verified information.

Intellectual Property

Chime is in the process of trademarking the logos and website, pursuing patents and copyright protection for their network detection system and their amplification system for targeting verified information to audiences who are encountering low-quality content online.

Observational Correction Works
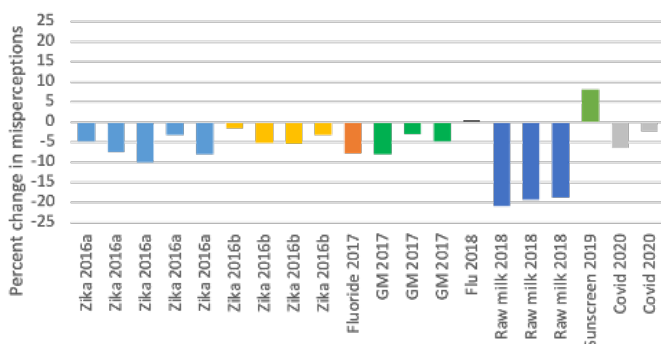
As seen in the figure, Chime's Strategy of observational correction reduces mispereceptions across multiple types of issues.

Unverifed Information Network Maps are Helpful to Information Professionals

Chime identifies creators (the 117 red dots), sharers (the 237 yellow dots), and the people exposed to unverified information (the 46,769 green dots) so information professionals can specifically amplify the stories via sponsored content mechanisms on social media platforms. Journalists, health professionals and brand managers Chime interviewed told them that Impact Score figures like this one, for those making unverified claims that COVID-19 vaccines cause infertility, are extremely useful.

Co-Designing for Trust

Building Trust Through Community

CO–DESIGNING for TRUST
Building Trust Through Community

Lead PI: Jason Young
codesigningfortrust@gmail.com

Ahmer Arif

Katie Davis

Shaun Glaze

Jevin West

Overview

The goal for Co-Designing for Trust is to leverage community-based and participatory approaches to design locally-contextualized digital literacy resources for historically underserved communities, including Black, Indigenous, and rural communities. To increase the impact of the project's work, the team will also develop a broader set of infrastructure that supports community stakeholders to continue to produce new, locally-tailored resources.

Description

There are many community organizers—librarians, teachers, and other professionals (i.e. many digital literacy interventionists)—who are working to support their communities to use digital resources in safer and more effective ways. Because the work of creating locally contextualized literacy interventions is hard and not well understood, a participatory approach is critically needed to create resources that are more robust and likely to have impact.

With the participatory approach at the core of the project, Co-Designing for Trust will achieve: (1) the co-design of digital literacy resources that serve as good starting points for community organizers and interventionists; (2) the development and documentation of methods that help community organizers and professionals tailor educational resources to their own local contexts; (3) the development of best practices to support community organizers and other professionals in sharing their resources with other communities; (4) the implementation of an online system to support scaled collaboration; and (5) the nationwide dissemination of project resources to scale out this community-oriented infrastructure.

Co-Designing for Trust will have an impact along myriad dimensions. The project will create multiple standalone resources for supporting digital literacy across Black, Indigenous, and rural communities. This will impact, at a minimum, over 200 people across 60 co-design sessions at over a dozen different sites of practice. The project will also contribute social, information, and technical infrastructure for sustaining and scaling digital literacy interventions. Finally, the project's intellectual work will create a broader understanding of the types of skills required to build trust within communities, producing insights into how critical thinking, emotion, and sociocultural dynamics converge to shape trust and mistrust within communications systems.

Differentiators

Efforts to update digital literacy curricula are often designed with classroom strengths and weaknesses in mind, which do not perfectly translate to community settings. They also typically emphasize critical thinking over the sociocultural and emotional processes that shape how critical thinking translates into action. This project aims to equip people with not only skills to assess the facticity of information, but also skills to reflect on and regulate their sociocultural and emotional attachments to information. It is doing this by co-designing digital literacy with diverse community stakeholders that typically fall outside of formal education, building them into the structure of the research team through significant subawards and leadership positions.

The true strength of the project lies in its ability to broadly scale these participatory approaches, beyond Phase 2 partner communities, to design digital literacy interventions tailored to their own needs. Efforts to update digital literacy curricula frequently struggle with scalability and sustainability because they fail to account for how teachers, librarians, and others discover, adapt, and use educational materials in practice. The end result is often static materials that don't inspire reuse. This project is developing a

community-oriented infrastructure to help these different practitioners have sustained interactions and develop shared resources and practices.

Road Map

Co-Designing for Trust has split this project into two major workstreams—one focused on co-designing and evaluating standalone resources for supporting digital literacy across underserved communities, and the other focused on scaling insights from that work in convergent and sustainable ways.

The co-design workstream's deliverables include: rural library materials for engaging community members on the topic of digital literacy (May 2023); a set of rural high school curricula (May 2023); materials to support two different sets of library programs related to digital literacy (May 2024); materials to support the implementation of a Media Mentorship Night event at rural high schools (May 2024); a digital literacy toolkit to support urban community colleges in incorporating digital literacy into their curricula (Sept. 2024); a game for engaging Black communities in discussions of digital literacy (Sept. 2024); and digital literacy resources tailored to Native communities (Sept. 2024).

The second workstream's deliverables include initial (Aug. 2023) and final (Aug. 2024) drafts of a Community Playbook; evaluation activities to support digital literacy interventionists in assessing the impact of their interventions (Sept. 2024); a style guide and template to support the sharing of resources (June 2024); and a web-based platform that supports collaborative work on educational materials (Sept. 2024). The project will also hold three Convergence Workshops (May 2024, July 2024, and Sept. 2024) and will produce publications and conference presentations throughout the project timeline

Partnerships

Partners involved in participatory design include community-based organizations, public libraries and cultural centers, high school teachers and librarians, community college faculty and staff, and national organizations that support education.

Intellectual Property

This project does not currently possess Intellectual Property (IP). Ownership of IP shall follow inventorship in accordance with United States patent law or authorship in accordance with United States copyright law, as applicable. Unless agreed otherwise, the project partners shall be joint owners of project IP that is developed jointly by the partners. The IP plan will be monitored and updated as necessary.

Co-Insights

Fostering Community Collaboration to Combat Misinformation

Co·Insights

Lead PI: Scott A. Hale
co-insights@meedan.com

Kathleen Hall Jamieson

Shiri Dori-Hacohen

Jonathan Corpus Ong

Kiran Garimella

Natasha Shrikant

Overview

Co·Insights is a convergence of computational social science and ethnographic inquiry with a unique platform that enables community and academic organizations to work together to respond effectively and contextualize information for Asian-American and Pacific Islander (AAPI) communities. These communities are dramatically underserved by current efforts due to the variety of languages involved, the use of alternative platforms, and the limited understanding of the diverse social issues affecting the many ethnic groups within the broad umbrella of AAPI.

Description

Information integrity is a global challenge, but successful mitigations must come from the communities affected and not be imposed by external entities. The project's overarching goal is to enhance free speech and empower people to understand and evaluate the information they see online. The Co-Insights team does this by building opt-in tools such as "chatbot tiplines" that people can choose to consult if they want to learn more about a given piece of content. These easy-to-use, mobile-friendly chatbots can help community members discover relevant context explainers, fact-checks, media literacy resources, and other materials. By building taxonomies and using machine learning (ML) to map claims to them, the project can move to a proactive model where explainer articles are available before new claims spread widely. The insights from these data can enable community leaders to create better materials tailored to the needs of each community and ultimately promote a healthy and inclusive public sphere online in which everyone can participate

Differentiators

While some of Co-Insights' approach encompasses social listening (e.g. CrowdTangle, Meltwater), their approach is significantly differentiated by (a) platform coverage, (b) diversity of languages, and (c) preemptive taxonomies.

Platforms: Co-Insights offers chatbot tiplines to directly connect community organizations with their audiences on Telegram, LINE, Viber, WhatsApp, and other messaging platforms popular among AAPI communities.

Languages: Efforts in non-English languages are often far behind those in English, and many machine learning (ML) algorithms are trained only on English-language data. The Co-Insights consortium is creating ML models specifically to support languages from Asia. As an example, the team trained a model for matching similar claims in Tagalog and English during Phase 1.

Preemptive Taxonomies: Co-Insights' expertise in taxonomy development, community-knowledge, and ethnography contribute to a novel approach that enables rapid identification and response to new claims. Overall, the project seeks to move the status quo away from opaque content moderation towards more transparent approaches akin to email spam detection or local antivirus software.

Road Map

- **Chatbot tiplines** on major messaging platforms were created for and promoted by the project's four community organizations within the first month of the project. The community organizations immediately used these tiplines to discover new trends and more widely disseminate their content.

- Ecosystem mappings by Co-Insights ethnographers informed the development of **data pipelines** to

crawl social media platforms. These were integrated into the web interface in March 2024 with sources and keywords being updated monthly.

- **Classifiers** to map content to taxonomies will be added in June 2024. Thereafter it will be possible for users to create their own taxonomies and train their own classifiers through the web interface.

- **Shared feeds** to pool data and collaborate with academics were first available in March 2024. Each component has specific impact metrics to be tracked such as the percentage of tipline conversations ending with positive feedback and human-in-the-loop evaluations of the taxonomy classifications.

Partnerships

The project is led by Meedan, a technology nonprofit that builds open-source software used by over 75 community and fact-checking organizations across the world. In this project, the team is centering the voices and needs of AAPI community organizations—work led by ethnographers at University of Massachusetts (UMass) and strengthened by four AAPI community-organizations joining the consortium for Phase 2: Viet Fact Check (Vietnamese), Piyaoba (Chinese), Tayo (Filipino), and DesiFacts (Hindi, Bengali, Tamil). Annenberg Public Policy Center is leading the creation of taxonomies around infectious disease, maternal health, and similar topics. These taxonomies highlight where gaps in high-quality content exist. University of Colorado Boulder will use discourse analysis and communication design to help community organizations strengthen their content. **Rutgers University** is pioneering community-led, data donation while UMass (Media Cloud) is building data pipelines for news, blogs, and YouTube. The **University of Connecticut** is developing ML for mapping content into taxonomies.

Intellectual Property

Data access is controlled by each community organization using Co-Insights, and these organizations have agreed to share data with the consortium and each other throughout the project. The project will evaluate wider data sharing opportunities as part of Co-Insights' sustainability work. The core platform and

software are being developed open-source as all of Meedan's software is. Specific integrations funded by the grant (data pipelines for news, data donation, etc.) are owned by their developers, and all consortium partners are given a license to the code.

Sustainability

Co-Insights' interviews with academics found large demand for labeled and diverse datasets going beyond English. The team is exploring pathways to sustainability such as asking academics to include data access fees in their grants.

Lead PI: Siwei Lyu   Natalie Bazarova   Dominic DiFranzo

Darren Linvill   Anita Nikolich

Overview

The 54 million older adults (age 60 and up) in the U.S. are particularly vulnerable and disproportionately targeted by online deception. DART (Deception Awareness and Resilience Training) is designed to improve the awareness and resilience of older adult users to online deception, such as spear-phishing and catfishing scams, personal information hunting schemes, and impersonation in grandparent or tech help scams.
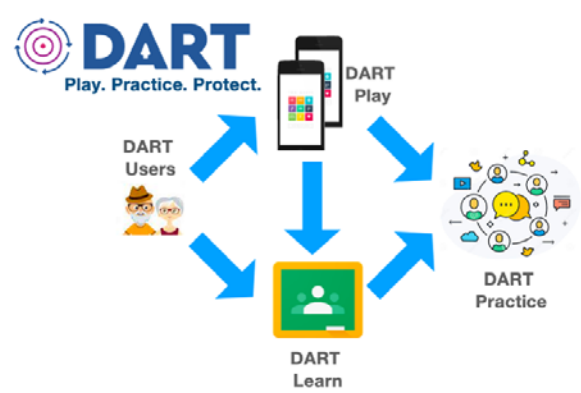

Figure 1. Overview of DART Components

Description

According to a recent FBI report, in 2021, those aged 60 and older comprised the majority of victims of various forms of online deceptions (more than 92,000 victims, accounting for 22% of all victims) with the highest total financial losses (around $1.7 billion). This trend is growing at an alarming rate, with total financial losses jumping 74% from 2020. Through DART, the team expects to achieve three general learning objectives for older adult users: (1) understand the motivation and impact of the specific type of online deception; (2) recognize its telltale signs; and (3) develop appropriate responses. DART comprises three interconnected components—**DART Learn, DART Practice, and DART Play**. Together, they provide flexible and multiple pathways for older adults to learn how to protect them against online frauds and scams.

DART Learn is the backbone learning platform that presents a structured environment with feedback, adaptive guidance, and customization. DART Learn will afford simple user interfaces to facilitate experiential learning while reducing the cognitive load of older adult users. DART Learn is web-based and can be accessed from older adult users' smartphones, tablets, and personal computers. The curriculum followed by DART Learn will be designed by a team of domain experts in education, gerontology, communication, cybersecurity, and media studies, with the topics and contents periodically updated to adapt to new deception schemes or technologies.

DART Practice simulates a situation of helping others avoid falling victim to online deceptions. This has the advantage to avoid users' psychological discomfort of becoming the victim of online deception themselves. An example scenario may entail the user persuading a friend to see through a potential catfishing scheme while exposing a fake Facebook account profile image created using AI algorithms. The users can use DART Practice to exercise what they learned in DART Learn.

DART Play is a suite of lightweight, engaging, fun games designed to meet the accessibility needs and game type preferences of older adults. The games provide an entertaining, effortless, and intuitive introduction to online deception themes and serve as an on-ramp to DART Learn and DART Practice. Online deception-related themes help people cultivate basic awareness of the concepts and language of online deception. A unique feature of DART Play is the incorporation of the proven game design features of "reward mechanisms" and built-in "gameplay bonuses" that encourage players to stay engaged with the content.

Differentiators

While there are existing online media literacy training programs (e.g., MediaWise for Seniors) and gamified approaches for social media (e.g., Harmony Square, Bad News, Spot the Troll, BBC iReporter, The War on Pineapple, and Cranky Uncle), DART is an unprecedented system that combines the following features: (1) comprehensive coverage of a wide range of online deception schemes; (2) real-world-relevant content updated as online deception schemes evolve; (3) development by professional game developers, including user experience (UX) experts, to ensure that DART is designed with input from older adults and for older adults specifically; and (4) realistic simulation of social media environments and state-of-the-art media synthesis to emulate real-world online deception scenarios.

Road Map

DART deliverables are developed using a software development lifecycle (SDLC) process. Currently, the project has completed the first version of the DART Play mobile game (available on Apple App Store and Google Play Store as DeepCover). The mobile game has obtained more than 2,000 downloads since December 2023. The DART Learn platform is being developed and will be launched to the public (public name is DART Academy) with modules on DeepFakes, Romance Scam, and Identity Theft, among others. For the next 12 months, DART's priority is to make DART Collective sustainable. The DART team will continue to develop both DART Learn, DART Collective and DART Practice in the next 12 months.

Partnerships

DART will be developed by an interdisciplinary team with both depth of research expertise and a breadth of experience in multidisciplinary collaborations and community outreach. The emphasis on the deliverable of tangible software systems necessitates the inclusion of a team of professional software/game developers, creatives with expertise in UI/UX design and art/sound, and promotional materials production.

DART will also collaborate with local and national older adult serving organizations, including Amherst Center for Senior Services (west New York) and Clemson Downs (South Carolina), to help "spread the word" about DART. Furthermore, the team's local partners Clemson Downs, Amherst Center for Senior Services, and the Buffalo and Erie County Public Library will also serve as local user community liaisons for the team to recruit older adult users for focused group interviews and usability feedback, and to host community outreach workshops to demonstrate DART through facilitated sessions.

Intellectual Property

Software created with DART funding that is intended to be released under an open-source software (OSS) license is encouraged by the team but not required to be released under an attribution style license, with a preference for BSD, MIT licenses, and Apache, using GitHub.

Additional Information

The team is establishing a nonprofit business entity, DART Collective, that will develop a sustainable business model for maintaining and further developing the tools created under the NSF Convergence Accelerator award period by identifying and validating potential markets for DART Learn as well as opportunities for future philanthropic support. DART Collective will also facilitate the transition from NSF Convergence Analysis Project funded development to sustainability by simplifying processes for developing new content and tools, and developing processes for ensuring existing content is kept current and periodically refreshed.

Expert Voices Together
Taking Back The Internet

Lead PI: Rebekah Tromble   David Broniatowski   Susan McGregor

Kathleen Searles   Denetra Walker

Overview

Expert Voices Together (EVT) is a comprehensive support system that addresses the harms experts experience due to online and hybrid forms of harassment. Grounded in trauma-informed and consent-based research and drawing on expertise from a range of academic disciplines and sectors, EVT's mission is to support experts in moments of crisis, while helping the institutions and sectors in which they are embedded build long-term resilience.

Description

Online and hybrid online/offline harassment campaigns reduce trust in communication systems by undermining confidence in expert sources of knowledge and by driving experts—especially members of marginalized communities—out of the public sphere. Although a majority of Internet users report being aware of online harassment, and nearly half have directly experienced it, options for support remain few. EVT brings together a diverse coalition of academic researchers, psychologists, technologists, civil society and institutional representatives dedicated to addressing the impacts of online abuse on expert communities.

In its initial stage of development, EVT began by focusing on journalists as the expert audience for their system of care. Based on findings from interviews with scholars, advocates, clinicians, and journalists who have experienced harassment, the EVT team is developing a trauma-informed, rapid response means of connecting experts to the support they need.

As the project team concluded their research with journalists, they expanded to consider the needs of other expert groups, focusing in particular on the needs of scientists and scientific researchers.

Drawing on their evidence-based findings, experts turning to EVT will find a rapid-intake system and a dedicated case manager. EVT's case managers will walk experts through a menu of support options, ranging from help with digital security to ideas for how to effectively communicate with managers and other institutional representatives. Case managers will also help experts identify and build a broader community of care, including friends and family members, as well as other experts who have experienced harassment.

By centering the individual's unique experience and leveraging an array of evidenced-based tools and approaches, EVT is designed to reach experts who face a variety of circumstances and needs. Widespread adoption of the EVT system in the industries in which experts are embedded will have broad societal impacts, not only reducing online harms for individual experts, but increasing trust in communication systems and building organizational capacity for prevention.

Differentiators

Efforts to understand and address misinformation, inauthentic behavior, and other forms of potentially harmful information in online communication systems have largely focused on identifying, downranking, and removing content; locating and minimizing the reach of purveyors; and/or correcting the misperceptions that result from exposure to inaccurate information. EVT stands in stark contrast to these approaches, instead focusing on the need to protect and preserve the rights of experts who seek to share their perspectives across the marketplace of ideas. Experts—those best equipped to offer evidence-based information to the public— deserve to receive the tools and support necessary to continue their vital work and to exercise their right to free expression.

Roadmap

The project team is working together to generate a number of deliverables—both technical and non-technical—that, together, comprise the EVT system of care.

Technical deliverables include a web-based rapid-intake system and a case management system.

Non-technical deliverables include educational materials for the general public, and more specialized "best practices" materials and resources for experts and their institutional representatives. The EVT team will also develop a series of training materials and step-by-step protocols for case managers and for members of the expert's community of care.

All deliverables will be carefully user-tested.

Partnerships

The EVT team brings together a wide range of expertise from academia, media, and the nonprofit sector. Team members have backgrounds in decision-making; digital communication; data ethics; systems engineering; experimental and clinical psychology; human-computer interaction; information communication technology; case management; journalism and mass communication; and post-traumatic stress disorder, resilience, trauma, and trauma-informed design. Academic team members join from George Washington University, Louisiana State University, University of Georgia, and Columbia University. The team also includes consultants from the nonprofit organizations Right To Be, the Poynter Institute, and PEN America, as well as clinical psychologists with experience in trauma-informed care for members of expert communities.

TRACK G: SECURELY OPERATING THROUGH 5G INFRASTRUCTURE

Telecommunication networks have evolved significantly over the years, offering faster speeds and enhanced capabilities; however, each advancement brings its own set of challenges and risks. The fifth generation (5G) wireless technology is poised to transform the digital landscape and serve as a catalyst for innovation, new markets, and economic growth, according to the Cybersecurity and Infrastructure Security Agency. As the 5G wireless network enables the movement of massive amounts of data through the connection of sensors and other Internet of Things devices, it poses challenges in secure operations for the U.S. military, federal government, and infrastructure operators.

Partnering with the Department of Defense Office of the Under Secretary of Defense for Research and Engineering, or DOD OUSD (R&E), the U.S. National Science Foundation Convergence Accelerator's Track G: Securely Operating Through 5G Infrastructure's goal is to seek enhancements to end devices and/or augmentations to 5G infrastructure to enable operators to have the capability to operate through public 5G networks, while meeting security and resilience requirements.

The Securely Operating Through 5G Infrastructure funded Phase 1 projects include:

5G Firmware Symbiote—Led by Red Balloon Security, 5G Firmware Symbiote is an automated technique to modify 5G firmware binaries to harden them with defense-in-depth security. The solution protects people whose lives may depend on maintaining security of their communication by making it prohibitively expensive for adversaries to exploit protected devices through low-level vulnerabilities, and especially to do so covertly.

ASTRALinQ—Led by Florida International University, ASTRALinQ connects military and government wireless devices covertly through public 5G networks. Using a combination of radio hardware flexibility, artificial intelligence device fingerprinting, post-quantum cryptography, and data hiding, ASTRALinQ provides 5G users with end-to-end data integrity, confidentiality, and resiliency.

AVOID—Led by University of California, San Diego, AVOID (Automated Verification of Internet Data-paths) secures commercial 5G communications against the hidden and pervasive threats posed by communications infrastructure. Combining graph analytics, neural networks, and more intelligent routers, AVOID helps end-users win future conflicts by ensuring that critical 5G communications remain invisible to even the most sophisticated adversaries.

GHOST—Led by University of Colorado, Boulder, GHOST (5G Hidden Operations through Securing Traffic) is a software application which prevents 5G network operators from identifying and tracking a user, or from observing the activities of an organization. GHOST is transparent to the end-user, operating in the background without affecting the everyday use of the end user device.

INDIGO—Led by AT&T corporation, INDIGO (Intelligent Networks Designed and Integrated for Global Operations), a comprehensive system of systems approach to ensuring military and civilian missions are accomplished by providing secure, resilient, rapidly adaptable communications. Using extant and ad hoc infrastructure, INDIGO provides support in allied, hostile, or contested areas. In addition to developing solutions for securely operating through 5G infrastructures, INDIGO will aid in the development of new infrastructures and partnerships for future wireless solutions aligning with emerging open standards.

Pack5G—Led by BlackBerry Corporation, Pack5G is a game-changing solution for 5G cybersecurity network customers. Capturing the customer's cybersecurity requirements, Pack5G provides real-time notifications when the requirements are violated. Using a machine learning translator, Pack5G translates cooperation agreement text into new, user-specific cybersecurity checks to keep 5G infrastructure secure.

Peregrinator—Led by Novowi, Peregrinator is a lightweight 5G base station software solution for ground forces that provides dependable, secure communications to commodity 5G end devices when indigenous 5G infrastructure is unavailable or denied. It enhances and accelerates achievement of situational awareness through advanced RF data analysis and integration with Team Awareness Kit.

pico—Led by SRI International, the pico software solution secures 5G-based team communication by enabling government and commercial organizations to control the visibility of application data and to hide communication endpoints. pico protects communication even on ordinary mobile devices on

untrusted 5G, other wireless and wired networks, and cloud infrastructure.

SCORE—Led by Peraton Labs, SCORE (Secure Censor-resistant Overlay Resilient Networks) is software covertly deployed on mobile devices that use apps available in the country of interest. SCORE hides messages in plain text or images using advanced steganography to protect the lives of U.S. and foreign nationals in hostile countries, who are taking risks working with the U.S. military and government.

SE-RAN—Led by SRI International, SE-RAN (Security-Enhanced Radio Access Network) defends against the most sophisticated adversaries. Through a comprehensive O-RAN compliant 5G-Native Application Protection Platform, mission-critical 5G operators can quickly monitor and perform policy enforcement across mobile devices, base stations, and the cloud control plane to keep operations secure.

SWAYAMBHU—Led by IBM, SWAYAMBHU provides end-users secure and resilient communications over indigenous 5G networks. Using policy-based zero-trust automation combined with continuous monitoring for situational awareness and zero-touch reaction to security threats, SWAYAMBHU ensures mission critical communications are secure. SWAYAMBHU software provides high-throughput, low-latency connectivity for massive IoT, critical communications, and eMBB use cases.

SONIC—Led by University of Utah, SONIC (Securely Operate through 5G with Intelligence & Control) provides operational superiority through intelligent orchestration by providing visibility and control across the system-of-systems that make up the national defense 5G communication environment. SONIC turns a collection of standalone and inflexible black box systems into a flexibly orchestrated communication system that is cognizant of federal or military operational requirements.

WindTexter—Led by George Mason University, WindTexter, a secure messaging app, provides private and resilient communication with maximum universality and interoperability for federal government and nongovernmental organization personnel operating overseas. The app hides user input messages in mundane contents and can establish a covert and end-to-end secure channel on top of SMS/MMS channels of mobile networks.

ZENIX—Led by University of Michigan, ZENIX, a software platform, provides zero-trust continuous monitoring, security analytics, and access control of 5G networks against increasingly sophisticated advanced

persistent threats and lateral movements. By using this solution, next-generation network operators will be empowered to effectively manage mission-aware risks by leveraging fast data analytics at the edge and enforcing end-to-end zero trust access.

Zeta Security—Led by Texas A&M University Engineering Experiment Station, Zeta Security enables 5G users and operators to rapidly and securely deploy, configure, and manage 5G network slices. Zeta Security supports time-sensitive, zero-trust security for joint operations through flexible and programmable capabilities that are compatible with 5G industry standards.

ZTX—Led by University of Kansas, ZTX (Zero Trust X) software enables end-users to discover malicious network activities in near-real-time and provides communication mechanisms to avoid adversarial control over network traffic. Indigenous 5G networks are often untrusted and challenging to use by military operators and squads to share situational awareness securely.

5G Firmware Symbiote

Defend from Within

Lead PI: Ang Cui
research@redballoonsecurity.com

Stephen Kuhn
stephen.kuhn@phaedrusllc.com

Aleksey Nogin
aleksey@redballoonsecurity.com

Overview

The 5G Firmware Symbiote team is developing an automated firmware hardening solution that modifies firmware binaries of 5G devices to add defense-in-depth security, thereby protecting people whose lives may depend on maintaining the security of their communication. 5G Firmware Symbiote will make it prohibitively expensive for adversaries to exploit protected 5G devices through low-level vulnerabilities, especially doing so in a covert manner.

Description

Today's 5G cybersecurity investments overwhelmingly focus on specifying and implementing the intended functionality to protect the security of the network. The low-level security of the software deep inside the individual devices is often overlooked and underappreciated. Yet, consider the consequences of a multitude of 5G devices with potentially vulnerable firmware being used in the field. What would happen when adversaries discover new vulnerabilities, compromise these devices, perhaps pivoting from one vulnerable device to another, and then passively sit inside, staying covert, and waiting for an opportunity to strike? Based on the research demonstrated by team lead Red Balloon Security, Inc (RBS) as well as others, these concerns are not merely theoretical.

Over the past 10+ years, RBS has pioneered and successfully deployed a suite of novel, host-based embedded firmware defense technologies that the team collectively calls Symbiote. Symbiote protections are injected by rewriting the to-be-protected firmware at the binary level, which does not require access to source code. Through a combination of binary attack surface reduction and hardening, and injected run-time monitoring and continuous integrity attestation, Symbiote protections can prevent and detect large classes of cyber-attacks, including ones exploiting zero-day vulnerabilities.

The 5G Firmware Symbiote vision is to bring these protections to the 5G ecosystem. Informed by the U.S. National Science Foundation Convergence Accelerator's Track G Phase 1 work, the team will mature and demonstrate this effort in Track G Phase 2, and they will position themselves to further expand this effort through follow-on technology transition and commercialization activities. The end-result will be a toolkit capable of analyzing and applying 5G Firmware Symbiote to 5G device firmware.

Differentiators

The team's approach would add further defense-in-depth security to the 5G ecosystem. It is complementary, rather than competitive, with most other 5G security efforts. To give a concrete example, out of 15 other Track G Phase 1 teams, 5G Firmware Symbiote's approach competes with none, but is significantly synergistic with the approach of at least eight–more than half. Teams that are developing novel application-layer communication protocols that are intended to run as an application on mobile devices, or as additional protocol implementation on routers, would benefit from the team hardening the underlying software stack for those devices and potentially implementing further run-time monitoring focused on their specific use case. Others that are developing new hardware solutions would benefit from the team's hardening of the firmware for their devices. Others that are developing new network monitoring and situational awareness approaches and tools would benefit from the team's continuous run-time monitoring and integrity attestation being able to provide unprecedented levels of visibility deep into the state of the software stack inside individual devices.

Road Map

In each of the two years of Phase 2, the 5G Firmware Symbiote project will demonstrate and deliver an increasingly capable 5G Firmware Symbiote solution. Each year the team will deliver a recorded demonstration, along with the corresponding source code, and a report documenting the results of testing and evaluating the demonstrated implementation.

The first-year deliverables will focus on demonstrating a successful integration of the 5G Firmware Symbiote

technology onto the Open RAN (O-RAN) based Benetel Radio Unit. The second-year deliverable will have a dual focus. First, it will focus on demonstrating a successful integration of the 5G Firmware Symbiote technology onto a second 5G device, such as the Centralized Unit/Distributed Unit server that along with the Benetel RU is a part of the TLC Indigo Standalone 5G network solution, or a 5G access point. The team will select the specific second year target device by the end of the first year and will document the selection in their first year-end report. Second, it will focus on demonstrating the integration of receipt of Symbiote telemetry by an appropriate network management software.

Partnerships

Prime awardee RBS, the inventor of Symbiote, will bring the expertise in embedded security, firmware binary analysis and hardening, FPGA security, formal methods, and commercialization of Government-funded research. With input from the rest of the team, RBS will integrate the Symbiote protections onto 5G devices.

Subawardee Phaedrus LLC will continue on the team from Phase 1, bringing hands-on expertise in communication security, and offensive and defensive software development experience across the intelligence, cyber, and military communities. They will provide the military network operational use perspective and perform an independent "Red Team" security evaluation of the technology.

New to the team: consultant TLC Solutions will provide expertise in 5G tailored network deployments to the Department of Defense and other Government customers, and consultant Benetel will bring experience as a 5G O-RAN-based radio unit manufacturer. They will support the integration effort with their expertise, test the resulting implementation, and support technology transition.

Intellectual Property

The 5G Firmware Symbiote is based on RBS's commercial Symbiote product that has been deployed on several million devices since 2015. To inject it into firmware, RBS uses the OFRAK framework, which is also a commercial product. RBS licenses both commercially and intends to continue incorporating improvements into these products, including those funded by NSF.

ASTRALinQ
Connect Covertly

Lead PI: Elias Alwan
ealwan@fiu.edu

Luke Beckwith
luke.beckwith@pqsecurity.com

Eric Burger
eric.burger@vt.edu

Dimitris Pados
dpados@fau.edu

John Volakis
jvolakis@fiu.edu

Overview

U.S. Department of Defense (DOD) plans to leverage 5G technology for various use cases. Public 5G networks can provide an alternative, not necessarily trusted, communication pathway for operations in contested, degraded, and otherwise spectral-limited environments. Private customized open 5G networks also have their security risks. The project team is developing and prototyping ASTRALinQ (Autonomous, Secure, and Tunable Radio Adapter for Quantum-Safe and Covert Operation of DOD Devices Through 5G Networks), a universal radio adapter to provide quantum-safe and covert communications services over untrusted 5G networks.

Description

ASTRALinQ operates at the IQ signal sample level and implements secure antenna remoting (spectrum transfer) over 5G. ASTRALinQ is, therefore, waveform agnostic and compatible with virtually all DOD terrestrial and satellite communication protocols, standards, and devices operating in frequency bands ranging from the ultra-high frequency (UHF) to the Ka-band. DOD personnel, aircraft, satellites, mobile phones, vehicles, sensors, drones, and other Internet of Things (IoT) devices will be able to securely operate through the ASTRALinQ adapter over friendly or adversarial untrusted 5G network infrastructure, autonomously switch between communications pathways (either terrestrial or space-based), and seamlessly connect with devices on trusted U.S. military networks.

ASTRALinQ is a first-of-its-kind device to provide a "secure bridge" through 5G for DOD devices across extremely large bandwidths. ASTRALinQ leverages zero-trust principles by: 1) authenticating DOD devices connected to ASTRALinQ (source and destination) via Artificial Intelligence-assisted radio frequency (RF) fingerprinting; 2) real-time post-quantum encrypting the digitized, compressed IQ samples of the wireless DOD signal without decoding/accessing data; 3) disguising the ASTRALinQ packet traffic by data embedding and matching traffic patterns of popular 5G applications; and 4) providing side channel security against attacks that use physical characteristics of ASTRALinQ (such as power level). The team is planning to develop a low-size, weight, power, and cost (SWaP-C) device that is ultra-portable (fits in a backpack), wideband (tunable from UHF up to the Ka-band), and in its initial release, covers a large subset of waveforms and protocols used by DOD devices. ASTRALinQ will be an RF-System-on-Chip programmable adapter with integrated FPGA accelerators for physical-layer operations, steganography, quantum-safe cryptography, and data hiding to interoperate with existing and future-proofed 5G RANs.

Differentiators

Military devices and tactical radios cannot connect over 5G networks without significant software and hardware modification. Concurrently, commercially available 5G devices are not implemented with military standard certifications and cannot achieve secure and reliable communications. A competitive solution is the Samsung tactical radio, which can access tactical networks but requires installing a third-party gateway. ASTRALinQ is the only device that does not require a third-party gateway to operate through 5G. Therefore, it does not access the DOD waveform and does not have to change the military protocol. ASTRALinQ is easy to pair with legacy radios, either wirelessly or using a wire, without any software or hardware modification at the DOD device or the carrier network.

Road Map

Over two years, the team set up milestones and deliverables to bring ASTRALinQ to a Technology Readiness Level (TRL) 6 or higher. In Year 1, they will furnish a minimum viable product (MVP) capable of demonstrating the basic functionalities of ASTRALinQ. In the nine-month milestone, the team will deliver

an initial radio adapter prototype that includes an extremely wideband aperture operating from UHF up to Ka-band that will be paired with British Aerospace Systems's (BAE's) MATRICs® RF-FPGA transceiver technology to test ASTRALinQ security features (AI authentication, quantum-safe encryption, and data hiding). The team will collaborate with the Air Force Research Laboratory (AFRL) in Rome, NY to test this prototype in their 5G testbed at Stockbridge, NY. By the end of Year 1, they will also fabricate and test the multi-band front ends in a controlled lab environment.

In Year 2, the antenna, front ends, and Radio Frequency System On Chip (RFSoC) board will be integrated into a single low SWAP-C package. Then, the overall RFSoC-based board will be integrated with physical-layer operations for IQ acquisition and compression and security features for authentication, quantum-safe cryptography, and data hiding. The team will collaborate with L3Harris to test this board with live DOD devices (e.g., Link 16 tactical radios) at the AFRL 5G testbed in Stockbridge, NY, and the Hill AFB in Utah. By the end of Phase 2, they plan to bring ASTRALinQ to a TRL 6.

Partnerships

ASTRALinQ brings together three universities; Florida International University (FIU), Florida Atlantic University (FAU), Virginia Tech (VT), U.S. National Science Foundation/DOD-funded start-ups (PQSecure Technologies LLC, Luminous Cyber Corp.), leading defense contractors L3Harris and BAE Systems, and government scientists from the Army Research Laboratory and the Air Force Research Laboratory. Their industry partner in Phases 1 and 2, PQSecure, is developing hardware accelerators for the new NIST-selected post-quantum cryptography schemes for ASTRALinQ. The team is also collaborating with Dr. Neil Vallestero, associate branch chief at the RF Electronic Warfare Branch in the U.S. Army, who is helping them connect to appropriate transition partners within DOD. For Phase 2, they have expanded their industry partners to include Luminous Cyber, which will play the role of the red team and test ASTRALinQ against adversary tactics and techniques. The team has also established a collaboration with L3Harris and AFRL in Rome, NY, to test and evaluate ASTRALinQ with tactical radios in relevant 5G/DOD environments. The team has already initiated discussions with BAE Systems and Motorola to create a market-ready device post Phase 2.

Intellectual Property

During Phase 2, the FIU Office of Technology Management and Commercialization (OTMC), with the tech tech transfer and intellectual property (IP) offices of the team members, will harvest, evaluate, and manage the IP disclosures developed from the project, provide feedback to the team, and determine the best course of action for IP protection. The offices will work together to protect and commercialize any IP developed during the project. Concerning sub-awardees and third-party collaborators, the team will work with FIU's Office of Research and Economic Development to enter into sub-awards and collaboration agreements with these parties to appropriately protect any jointly developed IP.

The FIU OTMC will create a dual licensing model allowing key partners to use data and/or software designed for noncommercial purposes for no cost or minimal cost while offering a commercial license pathway for some software components to monetize the developed technology. The team notes that during Phase 1, a joint IP entitled "ASTRALinQ" (including FIU, FAU, VT, and PQSecure) presenting the end-to-end design has been disclosed to the FIU OTMC and is under review.

AVOID

Securing 5G Against Hidden Threats

Lead PI: Alex Marder
amarder@caida.org

KC Claffy
kc@caida.org

Kyle Jamieson
kylej@princeton.edu

Erik Kline
kline@isi.edu

Ricky Mok
cskpmok@caida.org

Overview

Leveraging robust, high bandwidth, and ubiquitous commercial 4G and 5G networks is critical to winning future conflicts. However, operating through these wireless networks cedes control of the communication paths to the black box of Internet routing, and risks exposing communications to network infrastructure controlled by sophisticated adversaries. The AVOID (Automated Verification of Internet Data-paths) project seeks to give Department of Defense (DOD) control of its communication paths, ensuring that communications never fall under adversary control.

Description

Military communications across unknown network infrastructure potentially expose communications to an adversary, who can potentially disrupt traffic or extract intelligence even from encrypted data. The team predicts the next great capability leap for operating through 5G networks will be sophisticated analytics that provide situational awareness of threats within the communications infrastructure and dynamically route communications along benign paths. The AVOID team brings nearly a century of combined research experience in revealing and identifying unknown network infrastructure, which the team applies to develop a new capability for DOD: restructuring communication paths to avoid adversary-controlled infrastructure, thus keeping DOD communications unobservable by the adversary.

The two parts of AVOID tackle the two highest risk attack vectors for 5G communications. The first attack vector the team targets is adversarial control of base stations in commercial 4G and 5G networks around the world, allowing observation of all traffic passing through those base stations. AVOID's first component connects DOD 5G devices to benign base stations.

The second attack vector targeted is the ability of adversaries to analyze any DOD communications that traverse communications infrastructure they control. AVOID's second component embeds situational awareness into a routing system, providing a mechanism for DOD's communications to avoid adversary-controlled communication infrastructure. The outcome will be an end-to-end adversary avoidance routing system that does not require modification to existing applications or routers in DOD networks, nor cooperation by any third-party network. The team's approach complements the broader landscape of zero-trust architectures and secure 5G implementations, and ongoing obfuscation technique development.

Differentiators

To the best of the AVOID team's knowledge, a technique to detect adversary-controlled base stations does not currently exist. Their project will create that capability and include a method of connecting to benign base stations. Their research team brings unique expertise in conducting cross-layer measurements and analytics across both 5G and the Internet. This expertise enables the team to gain insights that inform the design and implementation of tools and systems, which will ultimately enable the DOD to securely operate through 5G communication infrastructure.

Road Map

Year 1 will focus on creating capabilities and collecting measurement data to develop prototypes of the two AVOID modules, which the team aims to release in Q2, 2024. The scope will include identifying safe 5G base stations, deploying their Internet analytics, and implementing their core routing system.

In Year 2, the team's efforts will shift toward integrating the two models into a complete system, and then evaluating and deploying AVOID. They will leverage national 5G laboratory resources to evaluate the accuracy of their base station classifier in a controlled environment (Q3, 2024). MQ Prime will begin testing the team's prototypes on 5G networks (Q4, 2024). They will

examine the effectiveness of AVOID routing in Defense Research and Engineering Network (DREN) and work with cadets at the U.S. Air Force Academy to set up a prototype of AVOID on the campus (Q3, 2024).

Partnerships

In Phase 1 AVOID cultivated a team that includes two industry partners: ExpressVPN and MQ Prime; and four academic partners: University of California San Diego (UCSD), Princeton University, University of Southern California's Information Sciences Institute, and Buffalo State (SUNY) University. Their academic partners include experts on the leading edge of wireless signal analysis, and the author of the most advanced LTE control channel decoder available. Their team also includes Defense Advanced Research Projects Agency-funded researchers with previous projects on overlay and circumvention routing approaches. Their industry partners will integrate the team's fingerprinting capability with a base station selection capability, as well as help and test and evaluate their approach in realistic networks. The team also has industry partners who have knowledge of DOD networks and will connect the team with operational DOD commands that will help them quickly transition the project to DOD use.

Intellectual Property

The team is leveraging open-source software in their development efforts, including systems developed by team members. UCSD has filed a provisional patent for technology developed in Phase 1. Team members have agreed to an intellectual property management plan to cover IP developed jointly by participants. The team is positioning the technology for integration by as many partners as possible.

GHOST

Hiding in Plain Sight

Lead PI: Keith Gremban
Keith.Gremban@colorado.edu

Sal D'Itri
sal.ditri@federatedwireless.com

Eric Keller
Eric.Keller@colorado.edu

Tamara Lehman
Tamara.Lehman@colorado.edu

Alexandra Siegel
Alexandra.Siegel@colorado.edu

Overview

When stationed abroad, U.S. military, diplomatic, and non-governmental personnel use 5G networks that may be operated by untrusted and potentially hostile actors. GHOST (5G Hidden Operations through Securing Traffic) enables secure operations over these networks, hiding sensitive movement and communications from adversaries.

Description

GHOST aims to secure user devices, protect identities, prevent the tracking of group or individual activities, and enables injection of "false flag" activities into the 5G network to mislead adversaries.

Specifically, GHOST is a software application that can swap device IDs and usage patterns periodically to prevent individuals from being identified and tracked; make single devices appear to act like multiple devices to hide the size and activity of operations; and create false network activity to lure adversaries to locations or frustrate their surveillance efforts. Importantly, GHOST is hidden inside a Trusted Execution Environment (TEE) so that the software will not be compromised in the event a device is lost or captured.

GHOST will enable organizations ranging from the U.S. military to private entities to securely operate over
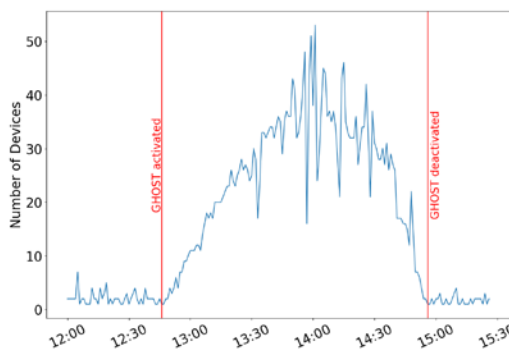

Figure 1: In Phase 1, GHOST demonstrated that one device can appear to be many to a network operator.
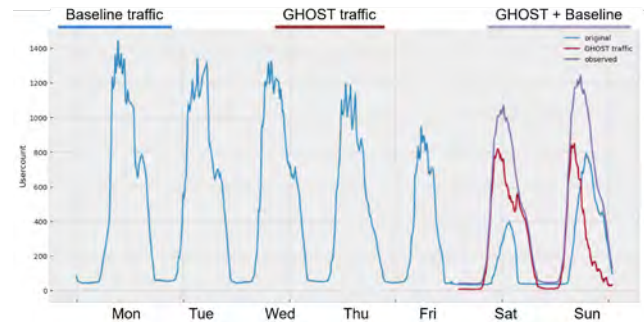

Figure 2: In Phase 1, GHOST demonstrated that one device can appear to be many to a network operator.

indigenous 5G networks, even when facing hostile network operators.

Interviews with active duty and retired military personnel, communications security experts, state department and NGO employees highlighted the urgent demand for a software like GHOST that can protect and secure personnel operating on untrusted 5G networks. As a former Department of Defense (DOD) civilian who worked in Afghanistan explained,

"When I arrived, my contacts gave me a helmet, body armor, and an Afghan cell phone. I needed the cell phone to maintain contact with my colleagues, make appointments, call for transportation, and other normal activities."

GHOST can play a vital role in overcoming these common vulnerabilities.

Differentiators

GHOST addresses threats that cannot be countered by traditional cyber security solutions. It is specifically designed to 1) protect devices from being associated with individuals and used to track and target them; 2) frustrate analysis of device usage patterns, including visits to specific websites; 3) mask aggregate statistics such as the number of active device connections, which may reveal troop movements or other large group

activities; 4) obscure sudden changes in usage patterns that might uncover an impending operation; 5) prevent lost devices from compromising security.

The GHOST team brings 30 years of experience with the DOD, military intelligence experience, cellular communications expertise, expertise in using digital trace data to model human behavior, and experience designing efficient secure hardware architectures. This enables the team to develop novel approaches to combat these multidimensional real-world threats.

Road Map

Q1/Q2, 2024	• ID and Persona swapping (time/location controls) • Collect baseline campus data and inject traffic • Database of IDs and Personas and base policy engine • Trusted execution environment (TEE) • Plan adversarial analysis • Secure mobile processor and virtual sim development
Q3/Q4, 2024	• ID and Persona swapping (proximity-based controls; voice/text/data) • Multiple device activity generation and test bed evaluation • INL collection engine & field test • Run GHOST software in TEE • Begin red teaming field tests
2025	• Test bed evaluation: bump swapping/platoon impersonation/false flag operations and continue red teaming field tests • Virtual sim migration and hardware extensions to enable GHOST software for secure mobile processing and identity swapping

Partnerships

The interdisciplinary GHOST team at University of Colorado Boulder spans aerospace engineering; electrical, computer, and energy engineering; computer science; applied mathematics; and political science, facilitating the development of innovative, convergent solutions. Moreover, their partner Federated Wireless integrates, deploys, and operates 5G networks for military, governmental and commercial entities.

In Phase 1, the GHOST team has demonstrated 1)

the capability to swap subscriber IDs and device IDs on representative devices; 2) that one device can be made to look like multiple different devices to the network operator (see Figure 1); 3) that network activity patterns can reveal organizational behavior, and can be accurately modeled mathematically; 4) that regular network activity patterns can be hidden by injecting GHOST traffic into the network (see Figure 2), and 5) that GHOST traffic generation software can be located in a TEE and execute properly.

In Phase 2, the team will bring the individual development efforts from Phase 1 from the lab into an integrated production quality platform. They will develop 1) functionality for identity swapping and persona swapping based on time, geographic location, and device-proximity; 2) functionality for activity shaping, making it appear as though events or mass movement are occurring at different places or times; 3) a command and control server for assigning identities and operational plans to individual devices; 4) monitoring capabilities to assess GHOST efficacy; and 5) will deploy GHOST software in a trusted execution environment.

Deliverables	Team Members
Identity Swapping	(Lehman, Keller, Federated Wireless)
Persona Swapping	(Gremban, Siegel, Curry)
Activity Shaping	(Gremban, Siegel, Curry)
Command and Control	(Gremban, Lehman, Keller, Federated)
Monitoring	All team members
Trusted Execution	(Lehman, Keller, Federated Wireless)

Intellectual Property

If new intellectual property is developed in Phase 2, the team will file invention disclosures. They will pursue publication of non-confidential research as well as commercial and governmental opportunities for the GHOST team. The team has developed plans to protect confidential information, address membership changes, and resolve disputes.

INDIGO

5G Communications through Innovation and Collaboration

Lead PI: Tracy Van Brakle
vanbrakle@att.com address

K.K. Ramakrishnan
kk@cs.ucr.edu

Sundeep Rangan
srangan@hyu.edu

Ivan Seskar
seskar@soe.rutgers.edu

Gil Zussman
Gil.zussman@columbia.edu

Overview

INDIGO (Intelligent 5G Networks Designed and Integrated for Globalized Operations Securing) addresses a goal common to the Department of Defense (DOD) and Public Safety (PS): Secure, Adaptive, Resilient Connectedness for Warfighters and First Responders in a Crisis.

Description

The guiding principle of INDIGO is to bring to bear Human-Centered Artificial Intelligence (HCAI) to address the complex 5G-Operate-Through problem for military (DOD) and civilian (PS) situations. HCAI is the process of designing AI systems, tools, and agents that can enhance human decision-making to configure and manage complex networks. To this end, INDIGO uses a hierarchical AI Planner that incorporates and augments human expertise to help accelerate human decision-making. Situational awareness is provided by the Service Management Orchestration (SMO) from the Open Radio Access Network (O-RAN) ALLIANCE to enable intelligent automation using open-source and multi-vendor applications that may be rapidly onboarded and integrated.

Differentiators

INDIGO pairs the AI Planner with O-RAN SMO componentry, i.e., RAN Intelligent Controller (RIC) and rApps, to optimize 5G networks and enable faster decision-making in a crisis by providing policy-based guidance using data analytics and AI/ML training/inference. Optimization is "non-real-time (non-RT)," defined as an automation loop longer than one second. rApps are modular applications that use the functionality exposed by the non-RT RIC/SMO Framework over the R1 interface to perform multi-operator and multi-vendor optimization and assurance. HCAI-enabled optimization techniques are more useful in some operating environments than in others. For example, in G.1 (5G Non-Cooperative) environments,

there are relatively few data collection options and no provisioning services exposed, i.e., minimal situational awareness and no "knobs" to turn. Consequently, HCAI-enablement is either impossible or quite limited, as there is insufficient knowledge to take corrective action even if there were knobs to effect it, and it is generally not possible to optimize. Conversely, in G.2 (5G Cooperative) environments there are numerous data collection and provisioning services, i.e., a wealth of intelligence and many actions that may be taken, not only to correct but also to optimize. The significance of INDIGO's innovative approach with respect to a Multi-Operator Service Management and Orchestration framework is its ability to accept topology information from multiple operators' 5G Non-Cooperative networks with overlapping coverage and then design and integrate a 5G Cooperative Network-of-Networks that is HCAI-enabled and can support resource pooling (RAN sharing), slicing, and Quality of Experience optimized beyond the limits of typical roaming agreements.

Road Map

Phase 2 major milestones include:

Months 1-3: Design

Months 4-6: Initial Development

Months 7-9: Initial Integration; TRL-5 demo

Months 10-12: Enhance component development

Months 13-15: System Integration; MOU

Months 16-18: Operationalize; TRL-6 demo

Months 19-21: TRL-6 second iteration

Months 22-24: TRL7 stretch goal

Partnerships

Current industry partner Phase 1 responsibilities and their expected contributions (tasks) during Phase 2 are AT&T (CTO/Labs): Principal Investigator; Global Tier 1 operator and wireless service provider; O-RAN founding member; chair of Alliance for Telecommunications Industry Solutions (ATIS); Chair of Open RAN Policy Coalition Executive Committee, 5G/NextG thought leaders; Wireless-Wireline network design and operations; university collaborations; Ericsson: Industry – 5G/NextG Information and Communications Technology provider; 3GPP Cellular Networks, 5G security, interoperable open ecosystems for data driven outcomes, Innovation and orchestration enablement; Fujitsu: Industry – 5G/NextG Information and Communications Technology provider O-RAN Information Model / Data Model team lead; Multi-operator Service Management Orchestration framework, TM Forum open APIs; highstreet technologies USA Corp: Industry – Technology Research Company; O-RAN Software Community PTLs, Software-defined networking and network functions virtualization applications; RAN Intelligent Controller open source and proprietary applications and SI; Linux Foundation, Open Networking Foundation subject matter experts.

Intellectual Property

INDIGO's intellectual property (IP) management plan is intended (a) to promote rapid dissemination of information and inventions for the public good; and (b) to promote patent filing and licensing when the public good is best served by controlling the activities of those commercializing inventions and/or by providing economic rewards necessary to encourage commercial partners to make the investment required to move an early-stage technology to the market. AT&T, as the prime recipient of the Award, will oversee IP Management Plan implementation. It is the intent of all parties to encourage sharing of data and other information related to the Award Work through publication, presentation, or other scientific communications consistent with academic or commercial standards. Parties jointly owning Project IP are jointly responsible for compliance with the Bayh-Dole Act, including reporting, patent filing, and licensing activities related to the Project IP. In the event of a dispute, there are clearly defined resolution procedures intended to preserve the rights of all. Thus far, no relevant patents have been filed during the INDIGO Phase 1 period of performance.

Additional Information

INDIGO will be capable of onboarding and demonstrating Zero Trust (ZT) capabilities, e.g., centralized Authentication, Authorization, Accounting for users/devices/systems, Interactive Application Security Testing for continuous, real-time vulnerability management, traffic encryption, anonymization and obfuscation, threat detection and attack mitigation. Some of these ZT capabilities are commercialized or are in the process of being commercialized, and others are being developed by other Track G teams.

Pack5G

Secure Together

Lead PI: Andrew Walenstein
awalenstein@blackberry.com

Bryan Cunningham
b.cunningham@uci.edu

Ian G. Harris
harris@ics.uci.edu

Overview

Pack5G leverages recent breakthroughs in "generative Artificial Intelligence" to create novel, customer-specific cybersecurity risk monitors within 5G network infrastructure. The indicators they generate can be shared with customers, including U.S. Department of Defense (DOD), operating through 5G infrastructure (private or commercial) so that they can apply Zero Trust (ZT) access solutions to react to 5G risks in real-time.

Description

5G customers are typically not notified immediately when the network operator encounters conditions (attack, bad update, etc.) that expose them to security risks. When cybersecurity risk indicators (CRIs) are shared in real-time, it tends to be limited and hard to update. Interviews revealed key concerns limiting sharing: lack of trust, the CRI must be specific and actionable, and costs must be controlled. As such, it is necessary to build trust with allied parties to share network security information in real time.

Pack5G aims to unlock game-changing CRI sharing in 5G through innovations in both technology and design of incentives. The key is leveraging the tremendous translation capabilities of large language models—like the popular GPT—in precisely the right way. Convergence research is required on three interlocking concerns.

Translator: Known limitations of GPT-like AI must be addressed to automatically create trustworthy cybersecurity monitors for 5G networks. The team created a demonstration prototype that creates security monitors from requirements stated in plain English. For example, it can automatically translate statements like "no calls through equipment with known vulnerabilities" into working code that checks the versions of the network software involved in all calls of the customer. In Phase 2 the team will eliminate so-called "hallucinations" and will "guide" the AI to utilize correct security logic, and to generate explanations that can be used to verify the correctness of the programs.

The team will initially focus the AI on creating monitors for 5G core, including management and orchestration and virtualization of network functions, and for Open Radio Access Networks (O-RAN).

Optimizer: If a network operator is to offer custom monitors to tens or even hundreds of customers, the operator must be able to understand and manage cost. In Phase 2 the team will create the Pack5G Optimizer that will be used to "guide" the Pack5G Translator, and which works to maximize existing cybersecurity information (including from legacy components in non-standalone 5G installations) while maximizing the accuracy of the monitors.

Incentive Framework: The team will develop a legal framework to allow all stakeholder parties to leverage the Pack5G solution to reach understanding, agreement, and trust. A corporate lawyer will be able to ask Pack5G to explain how the new cybersecurity monitors meet a given set of privacy laws. A regulator will be able to receive early feedback on the feasibility and costs for requiring carriers to share certain cybersecurity risk indicators with the nation's critical infrastructure and DOD.

When successful, Pack5G improves the security of DOD operating through cooperating carriers or their own private 5G, but also improves the entire Nation's resilience to cyber-attack from foreign and local adversaries.

Differentiators

The team does not focus on hardening the networks or their protocols: despite such work, 5G networks will still be attacked and customers will need CRIs that the team focuses on. But Pack5G will also bring added value to nearly all 5G cybersecurity advancements (including cohort results) by using them to improve CRI sharing. Pack5G also differs from prior work by delivering new abilities to corporate and regulatory leaders for incentivizing and accelerating CRI sharing, including by offering machine-enforceable model legislation, procurement contract templates, and similar. Technical innovations alone will not solve the key problems.

Road Map

Software: At the end of year 1 of Phase 2 the team will deliver an initial version of the Pack5G Translator and Pack5G Optimizer; at the end of year 2 they will deliver a solution combining the Translator and Optimizer and offering interfaces for multiple user groups to specify, build, and verify new monitors, and to build trust through understanding the solutions from their individual perspectives.

Data Sets: Benchmark datasets will be delivered in two increments at the ends of year 1 and 2 of Phase 2. One is a set of captured 5G network behaviors under synthetic attack and benign workloads, and the other is a benchmark of English security statements representing key customer concerns, and their correct translations to monitors. These will be used to define evaluations, including in commercially available equipment with testing partners.

Incentive Framework: The core framework will be delivered in year 1 and the incentive designs (including draft laws) will be delivered in two increments at the ends of years 1 and 2.

Partnerships

The two partners are University of California, Irvine (UCI) and BlackBerry. Phase 1 work has been overwhelmingly collaborative, particularly in developing new product concepts, developing the legal framework and incentivization approach, and developing partnerships for integration, testing, and commercialization for Phase 2. UCI has led the charge of developing the early translation prototype using GPT3.5, and of developing the team's approach to ensuring correctness of the results. BlackBerry has led the charge of developing the low-fidelity prototypes, developing the team's approach to ensuring efficiency of the 5G network monitors, and developing the experimental 5G security testbed.

In Phase 2 UCI will continue to lead the work on automated construction of 5G network monitors and BlackBerry will continue to lead the work on monitor efficiency and building effective solutions meeting customer needs, but the two groups will continue to work very closely.

Intellectual Property

The team is not utilizing background intellectual property (IP) from either partner; the first patentable foreground IP is expected to be developed in May for verifying correctness of the monitors created by Pack5G Translator. The team's IP arrangement permits IP access to all partners for this research.

Peregrinator

Securing 5G on the Move

Lead PI: Guevara Noubir
gnoubir@novowi.com

Sashank Narain

Colin Funai

Triet Vo-Huu

Omprakash Gnawali

Overview

Peregrinator is a lightweight 5G base station software solution for ground forces to simplify deployment of resilient and secure mobile communications networks when indigenous 5G is unavailable or denied. It enhances and accelerates achievement of situational awareness (SA) through built-in Android Tactical Assault Kit (ATAK) support and is compatible with all existing 5G end devices.

Description

Human-portable tactical radios are the standard communications solution for ground forces today, but these radios are often heavy, power hungry, expensive, or slow. Networks of these radios can have long setup times, and supporting surveillance over them requires sophisticated equipment which is in limited supply.

Those properties make human-portable tactical radios a suboptimal communications solution for many missions. When U.S. forces partner with or equip local national forces, use of expensive tactical equipment with sensitive software may not even be possible. Other examples include Army squads on routine patrols and island-hopping Marines, where increased mobility and SA are far more beneficial than stealth capabilities. Indigenous 5G is an attractive choice in these cases, because 5G offers high data rates and support for commercial-off-the-shelf (COTS) communications and surveillance devices which are lightweight, inexpensive, and widely available.

Despite these benefits, commercial 5G is highly vulnerable. Peregrinator's past research has identified sophisticated attacks at the 5G wireless edge which can deny service, track users, and have other adverse effects. These attacks can be commoditized, allowing adversaries with limited resources to execute them at low cost. Additionally, stable commercial 5G coverage is not guaranteed where ground forces operate.

Peregrinator is a 5G base station software solution for ground forces that:

- Improves dependability of 5G compared to indigenous offerings so that mission plans can depend on 5G communications

- Accelerates the achievement of SA compared to tactical radios

- Enhances SA with information about RF spectrum usage presented through ATAK

- Is compatible with COTS 5G end devices
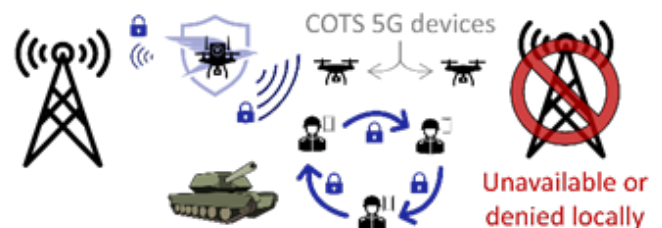
- Is deployable to lightweight COTS devices

Figure 1. Peregrinator provides dependable communications when indigenous 5G is unavailable or denied.

Differentiators

Existing 5G base stations are not designed for defense use cases. They are susceptible to wireless vulnerabilities, and many platforms are either not extensible or not stable. In a survey of 5G researchers regarding existing 5G base station platforms, 88% of respondents were not satisfied with extensibility and 94% of respondents were not satisfied with stability. These platforms also lack 3GPP compliant resilience features which are not prioritized by civilian carrier networks due to lack of need.

Peregrinator's 5G base station software platform is extensible through standardized software interfaces defined in the Open Radio Access Network (O-RAN)

specification. Peregrinator is stable and hardened through inclusion of wireless security and privacy vulnerability mitigations and implementation in Rust, a language with National Security Agency recommended safety guarantees. Peregrinator provides 3GPP compliant spatial and spectral interference avoidance features through use of sidelinks, integrated access and backhaul (IAB), and intelligent spectrum selection. Avoidance features are driven by a radio frequency (RF) spectrum SA capability that also provides information directly to warfighters through ATAK, a mobile SA application with over 250k defense users.

Road Map

5G SA Integration (9 months):

- 5G base station software platform will be stable and support O-RAN interfaces

- RF SA capability will be customized to support 5G defense use cases and integrate with the base station through O-RAN

- ATAK RF SA plugin will be complete and integrates with RF SA capability through a well-documented API

Internet Access Integration (12 months):

- 5G base station software platform will have multi-input multi-output (MIMO) support

- 5G base station will be Citizens Broadband Radio Service (CBRS) certified

- Begin pilot deployment with real users

Peregrinator alpha release (18 months):

- Wireless security and privacy enhancements

- Spatial and spectral avoidance capabilities

Peregrinator beta release (24 months):

- Basic distributed base station capability

- Added code hardening and quality assurance

Partnerships

Novowi is a small business that offers expertise in secure wireless communications, including a portfolio of existing IP which will be customized to create Peregrinator. Novowi's team is comprised of qualified, full-time engineers in RF systems software development, systems integration, and user engagement.

Raytheon BBN is a contractor with expertise in the defense domain, including Department of Defense transition of Defense Advanced Research Projects Agency technologies. They provide strategic access to resources within broader Raytheon and its stakeholders. Raytheon BBN team members include experts in ATAK development and tactical network deployment systems.

University of Houston will use Peregrinator components to help the nonprofit organization Compudopt provide Internet access to under-served communities.

Northeastern University and University of Massachusetts Lowell will perform studies to help improve the security of Peregrinator.

Intellectual Property

Novowi will develop a 5G base station software solution with enhanced security, privacy, and resilience, driven by Novowi's existing RF spectrum SA capability. Raytheon BBN will develop an ATAK plugin to display RF spectrum SA information to users.

All intellectual property (IP) will be licensed under Government Purpose Rights with organizations retaining IP for commercial licensing. University partners' work will be open sourced or published.

pico

Confidential Team Collaborations Made Easy

Lead PI: Linda Briesemeister
linda.briesemeister@sri.com

Karim Eldefrawy
karim.eldefrawy@confidencial.io

Overview

The pico software solution secures 5G-based team communication by enabling teams to control the visibility of application data and to hide communication endpoints. pico protects communication even on ordinary mobile devices on untrusted 5G, other wireless and wired networks, and cloud infrastructure. pico capabilities are delivered by two products, pico Selective Share and Conceal, which teams can deploy independently or together.

Description

pico Selective Share cryptographically enforces fine-grained access control policies on application data. A software developer uses the pico Selective Share Software Development Kit (SDK) to enhance an application by enabling application users or system administrators to control which users or groups can view which information. In military or other highly regulated enterprise environments, security administrators can ensure that only end-users with the need-to-know can access certain application data (e.g., the data field containing the GPS coordinates for a crate of ammunition, or a document describing plans for a corporate merger). In less restrictive environments, end-users can specify individual users, roles, or other groups that can access application data.

pico Conceal provides a self-organizing, secure, and resilient overlay that prevents any observers (including malicious cellular operators) from detecting that two users are communicating with each other. pico Conceal mixes and routes network traffic and provides ephemeral message storage to prevent a network observer from gaining information that links a message sender to its receiver. pico Conceal is an application proxy service that network administrators deploy onto end user devices, other nodes within an organization's network, and nodes that the organization controls in externally hosted cloud systems.

Differentiators

pico Selective Share enables finely grained protection of objects inside unstructured content, such as a paragraph or figure in a document or a row or column in a spreadsheet. No other product on the market provides this fine granularity of selective protection. pico technology preserves the native document's format so that applications can open the document whether or not they are pico-enabled.

pico Selective Share performs all encryption and decryption on the client device and does not write any cleartext data to storage, ensuring strong end-to-end data confidentiality. Because pico Selective Share uses only National Institute of Standards and Technology (NIST)-approved cryptographic schemes, it can be deployed in defense and other regulated enterprise domains. The team also provide a seamless upgrade path to post-quantum encryption once it is finalized by NIST.

While pico Conceal algorithms are related to anonymity services like Tor, pico Conceal does not rely on volunteers who allow their computers to be used as relays. Instead, pico Conceal customers control their own deployments of overlay servers in the cloud. The pico Conceal architecture provides resilience under the threat of partial failure and avoids single points of failure.

Road Map

During the first quarter of Year 1, the team will create a system architecture specification and develop an integration scenario. The outcome of these activities will feed into the implementation and testing tasks for the remainder of Year 1. An internal red-team member will evaluate designs and implementations from an adversarial perspective. In Year 2, the team will iteratively apply lessons learned during Phase 1 evaluations in updated deliverables and follow the same pattern of milestones. Each year will end with use-case demonstrations for both products.

Throughout this project, the team will apply the use-centric design process to inform ongoing development and demonstration scenarios with insights from stakeholders, future customers, and transition partners.

Partnerships

SRI International (SRI) is joined by partners Confidencial, Stephenson Stellar Corporation, and Red Balloon Security for this Phase 2 project.

SRI will lead the architecture and use-centric design efforts of the pico software technologies. Confidencial will lead the product design because they will adopt the pico technologies into their product portfolio during the sustainability phase after the NSF grant concludes. SRI and SRI-spinout company Confidencial collaborated in the Phase 1 use-centric design process to better understand the needs of future pico customers and shape the pico product focus.

In Phase 2, Stephenson Stellar and Red Balloon Security will join the pico team. Stephenson Stellar operates a 5G testbed laboratory and will guide the integration of the pico technologies into the 5G ecosystem and lead the project's 5G functional testing and performance optimization efforts. Red Balloon Security will perform an adversarial assessment of the pico systems and software to provide additional assurance in pico's data-protection capabilities.

Intellectual Property

pico's underlying technology foundations were developed under two Defense Advanced Research Projects Agency programs, Brandeis and Resilient Anonymous Communication for Everyone (RACE). The Government has rights to all the Intellectual Property (IP) developed under these two programs (in the research prototype form). Confidencial, has developed a new production- and enterprise-grade version of the software from the Brandeis program. If this technology is required for commercial deployments, Confidencial is committed to engage in good faith with any commercial customers and/or the Government in a licensing deal for any background IP and software owned and/or exclusively licensed to Confidencial. SRI and all its team members will grant the Government "Government purpose rights" for all IP (patents and software) developed under funding resulting from this proposal

and for any work described in the tasks to be carried out in this project.

Confidence in Sustainability

pico team member Confidencial has committed to extending its product line to include the new pico products. Confidencial currently offers an enterprise-oriented product based on technology underlying pico Selective Share. Confidencial's product is deployed in over 14 enterprises in regulated sectors including defense, cyber-security, financial, and pharmaceuticals.

SCORE

Hiding Secret Data in Plain Sight

Lead PI: Christine Zhang
qinqing.zhang@peratonlabs.com

Gabriel Kaptchuk
kaptchuk@bu.edu

Ufuk Topcu
utopcu@utexas.edu

Michael Wu
mhwu@arizona.edu

Overview

SCORE (Secure Censor-resistant Overlay Resilient Networks) is software that runs locally on 5G User Equipment for operating through untrusted 5G networks in hostile and challenging foreign environments. SCORE software hides secret messages in ordinary text or images using advanced steganography techniques.

Description

SCORE offers dual uses for military and non-governmental organizations. Many times each day, members of the U.S. military and government need to communicate with locals in foreign countries using the public 5G mobile Internet services. The communication can be of various types, from arranging a meeting, to hiring an interpreter, or sharing information about troop movements. These communications, including encrypted messages, can be easily identified and monitored. Authorities can intercept or disrupt communications and put people in harm's way.

Differentiators

SCORE hides messages from prying authorities by making them appear as innocuous social media posts. It automatically recommends and selects a mobile app and the next SCORE user to send the mundane-looking text and route to the destination. In case a device is checked or seized, SCORE software and messages will be wiped out. SCORE has an easy-to-use user interface and operates on commercial mobile devices without any hardware changes, compatible with existing wireless technologies (5G, 3G/4G, Wi-Fi, Bluetooth) and Future G as well.

SCORE advances the state of the art in secure and covert communications. SCORE's most significant innovative claims are provable security and verifiable reachability. SCORE's cryptographically secure steganography (based on the team's prior work
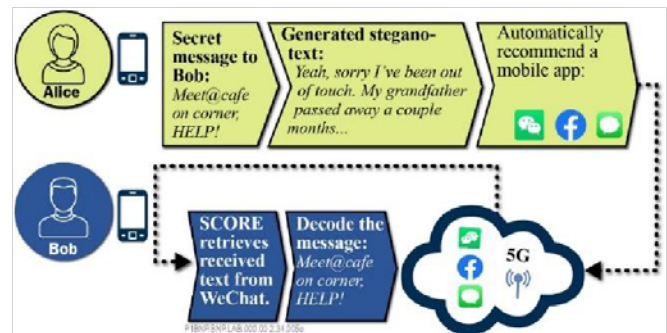
SCORE uses Stenography to securely and undetectably hides sensitive messages in machine learning generated innocuous text or images and uses Reinforcement Learning to automatically selects a popular mobile app over which the encoded messages is routed to its destination.

Meteor), powered by Artificial Intelligence generative models, transforms sensitive messages into mundane-looking, natural human language. SCORE Meteor achieves chosen hidden text security, meaning that an attacker cannot distinguish between normal generative model output and stegano-encoded model output, which is a strict strengthening of semantic security. The SCORE team is the first research group to develop a mathematical proof of this security property, which is very strong against different levels of adversaries including nation-states.

In Phase 1, SCORE developed a comprehensive stegano-encoder and decoder on iOS devices, using OpenAI's GPT-2 language transformer and is achieving good results. In Phase 2, the team will improve computation and bandwidth efficiency to make SCORE successful for commercialization and transition to end-users.

SCORE is a unique and new way of security that provides stronger guarantees than existing secure messaging apps, such as Signal and WhatsApp. The metadata associated with using these apps (i.e., the fact that there is communication between parties) is leaked, i.e., the security weakness of metadata leakage. SCORE's provable semantic security strengthens typical encryption schemes, which means that an instantiation

of SCORE Meteor provides the same confidentiality guarantees as commonly used symmetric ciphers like Advanced Encryption Standard (AES)-128 or AES-256. Additionally, SCORE allows for secure communications when encrypted apps are not available. In some countries, mobile apps with end-to-end encryption are not implemented by the most prominent messaging platform. SCORE software is local on users' device and does not need a "server" or "client" to make it work. It does not leak any metadata or rely on any special infrastructure, such as Virtual Private Network (VPN) or the Tor bridge.

SCORE enables practical steganographic deployment. Since Simmons' first formulation of steganography, significant effort has been devoted to theoretical steganography. Steganographic techniques include protocol obfuscation, domain fronting, or mimicry. Although these tools allow users to circumvent censors today, they are quite brittle. For example, protocol obfuscation is not cryptographically secure. Moreover, these protocols can all be identified as something other than typical human communication.

Road Map

The team has developed a low-fidelity prototype of SCORE in Phase 1, instantiated on iOS platforms. In Phase 2, they plan to develop an integrated SCORE high-fidelity prototype and demonstrate it in a lab environment in Year 1 and refine the design and development to improve usability for operation and deployment in Year 2. The team will have a solid path forward for commercialization of SCORE Product by the end of Phase 2.

Partnerships

SCORE is led by Peraton Labs, a leading industry research lab, and academic collaborators at Boston University, University of Arizona, and University of Texas at Austin. In Phase 1, the team focused on use-inspired research to enhance and refine SCORE key technologies. In Phase 2, the SCORE team will be joined by two new partners from small business, Global InfoTek Inc. (GITI) and Dexter Edward LLC (DE). GITI will assist to enhance usability and engage military clients. DE will provide their product Fognigma to host and distribute SCORE software covertly to end-users. Additionally, they will also look for partners in the internet freedom community, to expand SCORE's

outreach to activists, journalists, and anyone else who needs a safe, easy, and robust way to communicate.

Intellectual Property

The SCORE project has generated valuable intellectual property (IP) assets, including published research papers and confidential information related to how to develop the SCORE prototype. All SCORE organizations do not have any prior or existing data right assertion (i.e., technical data or computer software). They have IP agreements that all IP developed under this project will be owned by Peraton Labs. In Phase 2, the SCORE team will file patents, trademarks, and trade secrets to protect the project's IP asset. The team will also consider establishing a nonprofit organization to manage and commercialize SCORE solution.

SE-RAN

Security-Enhanced Radio Access Network

Lead PI: Phillip Porras
porras@csl.sri.com

Ashish Gehani
gehani@csl.sri.com

Rahul Jahdav
r@accuknox.com

Zhiqian Lin
zlin@cse.ohio-state.edu

Vinod Yegneswaran
vinod@csl.sri.com

Overview

The SE-RAN (Security-Enhanced Radio Access Network) team's vision is to introduce a transformative network management service that will provide 5G operators with an unprecedented depth of threat identification, policy enforcement, and compliance monitoring, spanning their entire 5G network infrastructure. The team's project, SE-RAN, will deliver a defensive shield against the most sophisticated adversaries that mission-critical 5G operators may encounter.

Description

SE-RAN will provide a comprehensive Open-RAN compliant 5G-Native Application Protection Platform for monitoring and inline policy enforcement across mobile devices, base stations, RAN operations, and the 5G control plane. It will substantially enhance the trustworthiness of 5G networks, including security with respect to mobile device confidentiality and privacy, 5G communications integrity, resistance to attacks, including attempts at control-plane infiltration, and live attack detection against the mobile infrastructure and its users. The team is actively collaborating with the open-source stakeholder community to integrate their specifications and modules with top-tier 5G open-source O-RAN projects. The team is also seeking collaborations with 5G integrators throughout the government and the Department of Defense (DOD) to demonstrate how SE-RAN addresses mission-critical use cases. Finally, the team is seeking partnerships with startups, industry leaders, and investors, who are actively developing novel and disruptive 5G security and privacy technologies.

Differentiators

SE-RAN is based on four groundbreaking security services:

1. MobiFlow: provides 5G operators a transformative visibility into the fine-grained security-relevant interactions between mobile devices, base stations, and RAN operations.

2. 5G-Spector: introduces the first (MobiFlow-driven) comprehensive 5G protocol exploit detector and AI/ML device analyzer.

3. 5G-KubeArmor and xIM: lock down the 5G control plane by automating the creation and enforcement of least-permissive policies that will prevent software-vectored 5G control plane hijacking.

4. 5GNAPP: unifies the above security services under a comprehensive 5G-native network management interface that simplifies the task of managing the security posture of all assets within 5G networks.

SE-RAN will deliver modular O-RAN-compliant security services, with low-integration cost, novel, and synergistic security coverage, and can be incrementally adopted by users and technology partners.

Road Map

The proposed deliverables will be in the form of system specifications, software prototype releases, system demonstrations, and quarterly reports. The team's plan is to open source their core sensor suite (MobiFlow Auditor, 5G-Spector, and 5G-KubeArmor) as part of the project. The productization focus will be on providing scalable and efficient deployment, configuration, and runtime management of the team's security services in large 5G network deployment scenarios. System architecture specifications will be released in Months 9 and 15. Demonstrations will be provided in months 6, 12, and 21.

Partnerships

Project SE-RAN is composed of a university, a research laboratory, and a commercial startup company, each with an ability to lead the establishment of a diverse set of partners. Throughout Phase 1, the team pursued
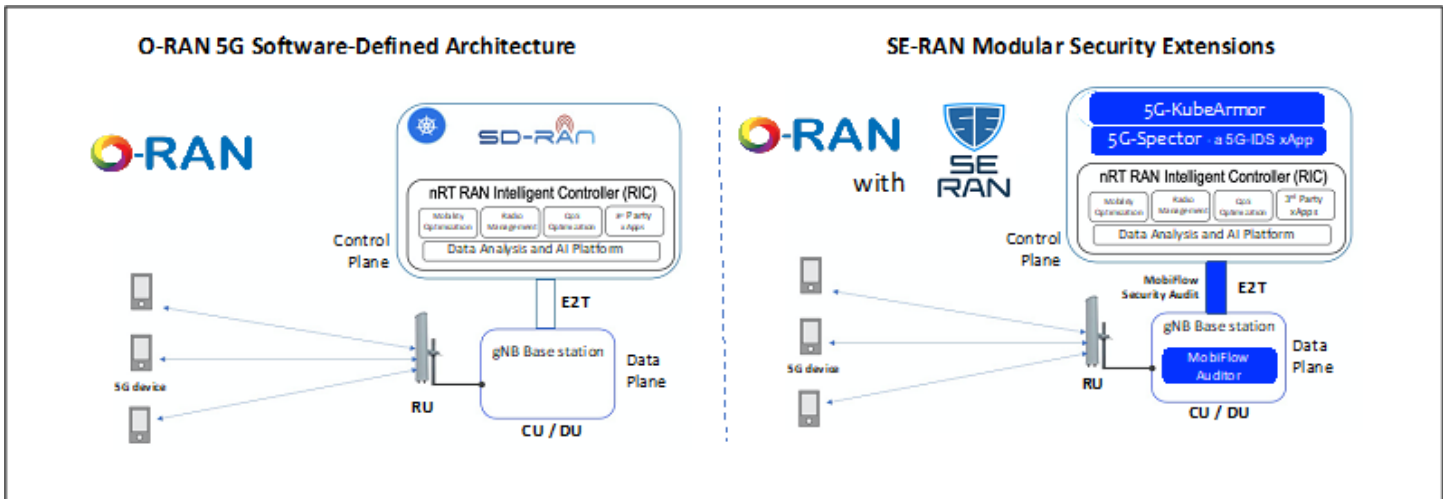
Figure 1 - before and after illustration of the modular SE-RAN services integrated with the O-RAN 5G architecture: 1) MobiFlow Auditor deployed within the base station CU/DU, 2) 5G-Spector is an xApp, and 3) 5G-KubeArmor integrates into the RIC's host OS.

academic outreach and partnerships with universities that are active in the 5G Security research community, culminating in a 2023 Network and Distributed System Symposium Bird-of-a-Feather session that drew over 50 participants. In addition, the team established partnerships with top tier 5G open-source community members. The team is now active community partners with the Linux Foundation Networking (LFN) 5G Super Blueprint project and the LFN Centralized Unit/Distributed Unit (base station software) project. The team is also a partner contributor within the Nephio project. In fact, the team is working with LFN to incorporate one of their core security services into the 5G Super Blueprint 2023 Integration Sprint.

The team has also established an official collaboration with the 5G Open Innovation Laboratory (5GOILab). The 5G Open Innovation Lab focuses on working with a global ecosystem of technology experts, 5G-focused visionary startups, enterprises, industry leaders, academia, and government institutions to fuel the development of new 5G capabilities, use cases, and market categories. The team will leverage 5GOILab to establish partnerships across the 5G startup community. Finally, the team has also established commercial partnerships with several key market leaders in the IT domain. The team has established partnerships with VMWare and Hashicorp, received an Intel Network Builders award, is an official International Business Machines Corporation (IBM) OpenHorizon Edge Workload contributor, is an Amazon Web Services Elastic Kubernetes Services Bottlerocket collaborator,

has an established partnership with Oracle Kubernetes Engine (OKE) and Oracle Cloud Infrastructure, and has a NetApp Excellerator partnership.

Intellectual Property

Project SE-RAN will produce at least six primary intellectual property contributions. Given that this project is collaborative and multi-institutional in nature, the majority of these technologies will be jointly owned by the institutions that collaborate on their development. All of the team's technologies will be made available for DOD testing and transition. DOD testing and integration activities will be led by Stanford Research Institute (SRI), which has a substantial track record of successful DOD/Intelligence Community technology transitions from advanced research projects.

SONIC

Securely Operate through 5G with Intelligence & Control
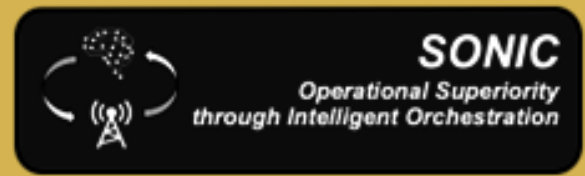
Lead PI: Kobus Van der Merwe
kobus@cs.utah.edu

Henning Schulzrinne
hgs@cs.columbia.edu

Monisha Ghosh
mghosh3@nd.edu

Zhi-Li Zhang
zhzhang@cs.umn.edu

Overview

Lack of visibility into network and environmental impairments and lack of control to act on impairments present a fundamental vulnerability to securely operating through 5G. SONIC (Securely Operate through 5G with Intelligence & Control) addresses these challenges by treating the collective 5G system-of-systems as a set of "Lego pieces" that can be composed by an Intelligent Orchestrator using intelligence from the system combined with information about U.S. Department of Defense (DOD) operational/situational priorities. SONIC provides the "best" operate-through path available, given current conditions and DOD situational objectives.

Description

SONIC exploits emerging "software-defined" technologies, for networks and devices, to realize its objectives. At a fine-grained level, Open Radio Access Network (RAN) technologies provide network specific data and allow for control within a specific network. At a coarse-grained level, network operators are increasingly providing Service Abstraction Application Programming Interfaces (APIs) to enable programmatic interaction between networks and their users, allowing SONIC control across different networks. From a device perspective, SONIC exploits inherent multi-radio-access-technology and multi-band capabilities in 5G devices. SONIC also uses emerging eSIM functionality that provides software-defined network association. SONIC monitors, controls and composes these building blocks through a modular orchestration framework.

Differentiators

SONIC is unique in taking a holistic system-of-systems approach across the complete operate-through 5G ecosystem, i.e., both public and private 5G networks, radio-access networks, backhaul networks, 5G devices and auxiliary sensing devices, and to drive the use of that system-of-systems explicitly based on DOD

objectives. The SONIC team has performed initial prototyping of key components, i.e., spectrum aware control of an Open RAN network, spectrum & network measurements from standard 5G devices, and eSIM provisioning. The SONIC team is composed of a unique set of experts and stakeholders with deep expertise and experience of the DOD operational environment and 5G operational networks.

Road Map

SONIC will have minimum viable product (MVP) prototypes of key subsystems after six months and additional MVP prototypes after nine months. Integration demonstrations, in a relevant environment, of spectrum-aware orchestration of an Open RAN private 5G network and remote provisioning of 5G devices using eSIM capabilities will be available after twelve months. Demonstration, in a relevant environment, of an eSIM-enabled 5G backhaul gateway will be available after fifteen months. A fully integrated capstone demonstration in a relevant environment will be available after twenty-one months.

Partnerships

SONIC involves a strong "stakeholder partnership" between four universities, a government institution and four industry players. Each of these partners has a unique role to realize the SONIC vision: University of Utah is leading the realization of the SONIC Intelligent Controller, Open RAN control development, and integration of subsystems in a relevant environment (University of Utah's Platform for Open Wireless Data-driven Experimental Research testbed). University of Notre Dame is leading efforts related to endpoint spectrum and network monitoring. Columbia University is leading eSIM provisioning and management efforts. University of Minnesota is leading the realization of the 5G backhaul gateway system. The National Institute of Standards and Technology is applying the NIST Risk Management Framework to the SONIC design process and will perform vulnerability/threat analysis

of SONIC and more broadly the 5G system-of-systems operate-through ecosystem. Spectrum Exchange is a small business focused on spectrum management and spectrum sharing and is providing the spectrum intelligence in SONIC. Celona is a private-5G vendor and provides RAN equipment with appropriate Open RAN control interfaces. L3Harris is a defense contracting company and is providing a converged standards-5G and military waveform capable RAN system with Open RAN control interfaces. Highstreet technologies is a network software company and provides consultation on provider network APIs and software stacks.

Intellectual Property

The SONIC team represents the "many stakeholders reality" of the 5G operate–through ecosystem. As such each of the partners, especially the industry partners, bring significant existing intellectual property (IP) to the project. The SONIC technical approach lends itself to an "architectural partitioning" of both existing IP and IP to be developed during the project.

SONIC also focuses on making use of open standards and interfaces, which further contributes to a clean partitioning of IP.

Nonetheless, SONIC's IP management plan handles jointly-developed IP based on the colloquial "what you do you own, what we do we own, what we do together we own together" principle.

SWAYAMBHU

SMART 5G Network Overlays

SWAYAMBHU NETWORKS

Lead PI: Dinesh Verma
dverma@us.ibm.com

Elisa Bertino
bertino@purdue.edu

Thomas La Porta
tlp@cse.psu.edu

Overview

Swayambhu provides secure overlays through untrusted indigenous networks. It leverages modern edge computing techniques, multiple network paths, policy-based management, and payload encryption to create a self-managing trusted overlay mesh. These overlays are useful for military, first responders, Industry 4.0, and financial firms, who all need to exchange sensitive information over untrusted networks.

Description

In any mission, client end-devices such as phones, laptops, or Intelligence Surveillance and Reconnaissance sensors need to communicate with servers over a communication network. The traditional Department of Defense (DOD) approach has been to deploy its own trusted network, as shown in the upper half of Figure 1.

Figure 1. Operation without and with Swayambhu Software

Swayambhu enables a different concept of operations—shown in the bottom half of Figure 1. Linux servers installed with Swayambhu software act as intermediaries between clients and servers. Swayambhu enables the use of an indigenous 5G network, augmenting the security and resiliency of the network and making it safe for DOD to use when conducting its operations.

In addition to support of DOD operations, this software can also improve the connectivity of first responders and other enterprises, such as industrial manufacturers, critical infrastructure providers and financial companies. Like DOD, these enterprises need to exchange sensitive information over commercial networks.

Swayambhu's software consists of an extensible policy-based framework enabling a flexible zero-touch processing of network packets. The policies route network packets through various differentiated packet transformation capabilities to provide additional security and resiliency. Policies are self-generated using Artificial Intelligence-based techniques to enable a zero-touch model of operation.

A network administrator can override policies that the system generates for its operations. The network administrator can also monitor the status of the network. End-users are able to override default policies for their communication and obtain a different trade-off between performance and security during critical conditions.

Differentiators

The software provides the following capabilities:

Multi-channel Exploitation: Multiple channels (e.g., a DOD satellite link and an indigenous 5G link) for communication are usually available. When a trusted channel is available, sensitive information (e.g., key exchange) is directed over it, and resulting keys are used to encrypt data over untrusted channels. If no trusted channel is available, sensitive information and encrypted data is distributed across multiple untrusted channels to minimize vulnerability.

Continuous Monitoring: Swayambhu continuously monitors all connected devices, the radio-frequency spectrum characteristics, and overlay links connecting different instances of the software. Advanced AI-based techniques watch out for anomalous behavior of connected devices to detect security risks, and automatically react to them using pre-defined policies.
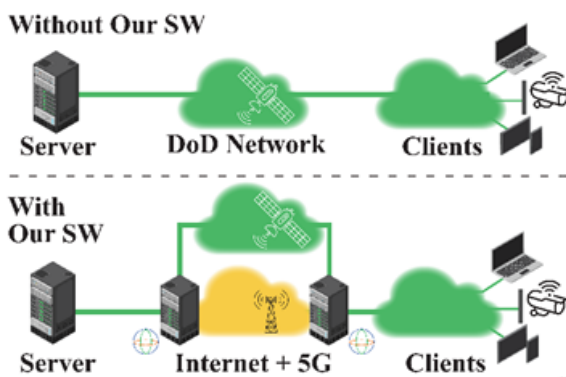
Network Edge Enablement: Under policy-control, Swayambhu moves selected services from the server side to run closer to the client. This improves performance and thwarts packet capture & denial of service attacks in indigenous 5G networks.

Other key differentiators include information hiding, zero-touch operations and self-protection of software under policy control.

Road Map

Phase 2 software development will happen in two stages. In stage 1, the team will develop a baseline software implementing the differentiating capabilities designed to operate in a zero-touch manner in a zero-trust environment.

To develop the software, the team will leverage two existing software components developed previously for U.S. defense and intelligence customers: a policy management library that simplifies the task of defining, analyzing, and using policies; and a network insights system which uses machine learning on network packet streams to understand the situation within the network by monitoring traffic, including the monitoring of radio frequencies. The stage 1 software will be derived from early versions of capabilities designed during Phase 1 of the convergence accelerator program.

Concurrently in stage 1, the team will be conducting research to develop enhancements for all of the capabilities. These research explorations would lead to improved self-management and an augmented set of capabilities. Stage 2 effort will incorporate the research output from stage 1 to enhance the software and demonstrate it on 5G testbeds accessible to the team.

Partnerships

The team consists of IBM, Pennsylvania State University (PSU) and Purdue University. During Phase 1, all three partners worked together to create system design and initial prototypes. PSU researched continuous monitoring of overlays, multi-channel communications, and user interfaces. Purdue provided insights into policy-based management. IBM researched radio-frequency monitoring, information hiding and zero-touch operations.

During Phase 2, the bulk of software development for the system will be done by IBM leveraging operational

5G deployments from AT&T and Verizon at IBM locations. Purdue and PSU will provide research support to improve the system implementation. IBM, PSU, and Purdue will continue to create enhancements for the capabilities that they have designed. All partners will meet periodically to review the progress and recommend improvements to the software.

Intellectual Property

The software will be provided with Government Purpose Rights for any U.S. Government use. IBM will retain rights for potential commercial exploitation of the software. Partners have agreed to share any created intellectual property cost-free for contract execution and at fair and reasonable terms for other uses.

WindTexter

Covert, Resilient Messaging

Lead PI: Kai Zeng
kzeng2@gmu.edu

Ziyu Yao
ziyuyao@gmu.edu

Irwin Gerszberg
lg2364@att.com

Huacheng Zeng
hzeng@msu.edu

Brian Mark
bmark@gmu.edu

Overview

U.S. personnel working overseas in the military, the foreign service, non-governmental organizations, or as foreign correspondents, frequently need to communicate sensitive information over a non-cooperative network. WindTexter is a mobile app that provides secure, covert, and resilient messaging over 5G and other radio access networks, which will not attract the attention of a curious, hostile or compromised service provider. WindTexter fills an important gap in communications over non-cooperative networks because conventional unencrypted messages can be intercepted by the mobile network operator (MNO), while end-to-end encrypted messages can be identified and blocked.

Description

WindTexter works by hiding messages in plain sight. The original content of the message is transformed into a "cover" message, which appears ordinary and mundane in the local context and language such that an adversary will not be able to identify the message as being suspicious. To provide a required level of security strength, the original content will be encrypted prior to conversion to the cover content. WindTexter will greatly enhance the ability of overseas U.S. personnel to communicate securely and reliably among themselves as well as safeguard their privacy in mission-critical scenarios. The team is developing a WindTexter mobile app and software system that will achieve the goal of secure, covert, and resilient messaging.

In addition to hiding text in text, WindTexter leverages indigenous multimedia apps such as simple SMS/MMS messaging apps or even encrypted messaging apps such as WhatsApp and Signal, by hiding dialog in mundane text-based conversations, mundane text-image mixed conversions, and hiding voice communication in voice in the local language. Furthermore, WindTexter obfuscates the traffic pattern generated by the wireless device by sending dummy cover messages which carry no real content at appropriate times through the indigenous apps available on the mobile device. This effectively hides the WindTexter user among crowds of ordinary users of the network even as the user is sending mission-critical information in plain sight. If available on the user device, WindTexter can leverage multiple network interfaces to increase the speed, resilience and covertness of mission-critical communications.

Differentiators

Existing secure messaging apps such as WhatsApp and Signal provide secure message through end-to-end encryption. However, messages sent by these apps may be identified and subsequently blocked by the MNO and may reveal metadata that could compromise the safety of the sender and/or receiver. By contrast, WindTexter first encrypts the message and then employs state-of-the-art Artificial Intelligence and natural language processing (NLP) techniques to convert the original message to a mundane cover message in the local language that can hide within crowds of ordinary consumer messages. The traffic obfuscation feature of WindTexter ensures that the traffic pattern generated by the smartphone does not attract the attention of an eavesdropper that can perform traffic analysis to detect users exhibiting anomalous behavior. WindTexter is a scalable solution because it does not require a system of servers to store messages in the network. Rather it makes use of existing message services available on the smartphone.

Road Map

The roadmap for Phase 2 can be organized into five main categories:

Months 1-23: Research and development

Months 9-17: Integration and optimization

Months 11-19: Performance evaluation and testing

Months 1-20: Customer discovery

Months 10-20: Compliance support

Major milestones and deliverables include a design requirements document after month 3, WindTexter software modules after month 12, and an integrated WindTexter software system after month 17. A beta version of WindTexter will be released just prior to the end of Phase 2.

Partnerships

The Phase 1 partners consist of George Mason University (GMU), Michigan State University (MSU), Ericsson, and AT&T. Ericsson contributed the initial WindTexter concept of a hardware/software solution that hides messages in cover messages transmitted over multiple paths on a military-grade user device with multiple network interfaces. Led by GMU, the WindTexter concept was developed further into a mobile app that runs on an ordinary smartphone which may have only a single network interface. All partners contributed to arranging customer discovery interviews with potential users and stakeholders of WindTexter, which greatly influenced its technological development. AT&T and Ericsson both contributed insights into Department of Defense (DOD) requirements for WindTexter.

For Phase 2, Ericsson will be replaced by Widelity, a wireless consulting company that has worked with GMU in the past. The academic partners will assume primary responsibility for the research and development, prototyping, and system integration of WindTexter into a mobile app product. Widelity will contribute to program management and customer discovery for the consumer-grade WindTexter. AT&T will facilitate rigorous testing on its network and contribute to marketing of WindTexter to DOD customers.

Intellectual Property

Based on Phase 1 work, three invention disclosures were made. Two were made to Ericsson covering the initial WindTexter concept. The third, made to GMU, covers the later Phase 1 development of WindTexter into a mobile app that incorporates encryption, AI and NLP, and traffic obfuscation to hide sensitive messages in ordinary text, image, and voice transmitted using other available messaging smartphone apps.

Management of all intellectual property developed as a result of the U.S. National Science Foundation Convergence Accelerator grant will be overseen by GMU's Office of Technology Transfer.

ZENIX

Mission-Driven Edge Intelligence to Counter Advanced Persistent 5G Threats

Lead PI: Junaid Farooq   Casey O' Brien
            mjfarooq@umich.edu

            Indrajit Ray   Quanyan Zhu

Overview

ZENIX is a cutting-edge software solution for zero-trust continuous monitoring, security analytics, and access controls for 5G networks to counter increasingly sophisticated advanced persistent threats and lateral movements. It empowers next-generation network operators to effectively manage mission-aware risks associated with 5G networks by leveraging fast data analytics at the edge and enforcing end-to-end zero trust access across all levels of the network stack.

Description

By 2030, 5G networks may be connecting close to 500 billion devices in varied mission-critical operational environments, e.g., manufacturing, logistics, battlefields, etc. These devices will generate massive amounts of data that can be stolen, destroyed, or manipulated by advanced persistent threats. The estimated financial loss from attacks using lateral movement, such as ransomware could reach $265 billion annually by 2031. Moreover, cyber risks and the concerns over operating through untrusted networks can jeopardize the growth and productivity potential of the 5G-Internet of Things ecosystem, which is currently growing at 54% annually. ZENIX enables network operators and 5G asset owners to securely operate through untrusted networks and components within their communication ecosystem using the following modules:

ZENIX Argus is a suite of background monitoring tools that ensures real-time activity monitoring the entire 5G network stack including system users, Open Radio Access Network, 5G Core, cloud/infrastructure, administrators, operators, vendors, and third-party managed services. With its endpoint software deployed on devices, ZENIX Argus discovers relationships and maps them into end-to-end paths that inform cybersecurity analytics and decision-making.

ZENIX Reflexión provides mission-driven insights about the evolving threat landscape, creating scalable, adaptive, and data-informed workflows to continuously analyze the 5G stack and end-to-end paths for indicators of cyber threat activity ensuring fast and real-time detection. It provides constant feedback on the current security posture of the 5G network, allowing operators to proactively identify potential vulnerabilities and threats, enabling them to quickly respond and take appropriate actions.

ZENIX Sentinel is a suite of decision support tools that enables 5G operators to automate security control through dashboards and allows them to take proactive steps in mitigating potential threats. By prioritizing threat categories and security requirements, ZENIX Sentinel prevents legitimate access from being abused to gain access to critical infrastructure, enabling network operators to respond to potential threats before they can cause damage.

Differentiators

Network security is typically focused on securing specific systems or applications without having a holistic view of the entire network. ZENIX adopts a comprehensive cybersecurity strategy by having an end-to-end view of all devices and systems connected to the 5G network. This includes understanding how these devices are interconnected and what data is accessed and processed by each device. ZENIX uses a zero-trust approach, by assuming the attacker is already in the system, and prevents lateral movements by continuously assessing vulnerabilities and proactively managing access controls. It enables network operators to quickly uncover hidden attacks, anticipate potential threats, and proactively respond before the adversary can take advantage.

Road Map

ZENIX software suite will be built upon integration and enrichment of existing tools and methodologies, which have been developed and tested by the project team. During Phase 1, they have created the first prototype of ZENIX, that includes end-point software, access visualization, policy enforcement, and end-to-

end security risk assessment. In Phase 2, they have technical and commercial plans to develop a market ready solution in two years with the following major milestones:

Year 1

- Month 6: Deploy early minimum viable product on the testing partner's sandbox infrastructure

- Month 8: Demonstration of capabilities on Beta partner's test system

- Month 10: Beta partner feedback

- Month 12: Adjustment and calibration based on feedback

- Month 12: Identify U.S. Department of Defense partners and end-users

Year 2

- Month 14: Complete initial customer discovery

- Month 16: Early commercial versions of ZENIX modules

- Month 18: Development of missing commercially relevant features

- Month 20: Ready for robust commercial grade pilot

- Month 22: Commercial grade packaging

- Month 24: Prepare for commercial venture

The team is committed to launching a startup towards the end of Phase 2 that will commercialize ZENIX. They plan to leverage public/private funding and early customer revenue to support the business operations beyond Phase 2.

Partnerships

During Phase 1, the team has established contacts with strategic enterprise partners and have also identified field testing partners (Manufacturing x Digital USA and Metropolitan Transportation Authority NYC) and testbeds specifically designed for cybersecurity testing. They have successfully worked with an industry leading zero-trust network segmentation provider to complete a prototype software that can visualize the interactions between devices, applications, and workloads within

a cloud-based environment. They have also proven and tested the capability of enforcing zero-trust access control policies on the emulated network setup. In Phase 2, they will continue the partnership to build upon ZENIX modules on top of their APIs.

Intellectual Property

University of Michigan (UM) Office of Tech Transfer will take the lead in managing the intellectual property (IP), including filing of patents, negotiations, and setting up agreements with partner universities. Preliminary invention disclosures have already been filed at each of the partnering academic institutions and UM has set up agreements to protect the IP that will be leveraged in the development of ZENIX. The startup that will be formed towards the end of Phase 2 will then license the technology from UM.

ZTX

Shielding Communication Pathways

Lead PI: Taejoon Kim
taejoonkim@ku.edu

Remi Chou
remi.chou@wichita.edu

Sonia Fahmy
fahmy@cs.purdue.edu

David Love
djlove@ecn.purdue.edu

Vuk Marojevic
vuk.marojevic@ece.msstate.edu

Overview

Today, public 5G networks are not trusted by the U.S. military because they are not designed for many of the electronic warfare scenarios common in military-hardened networks. The Zero Trust X (ZTX) team addresses this challenge by proposing a software solution, called Zero Trust Chain (ZTC), that enables military squads to securely share situational awareness through high-performance, but often untrusted, 5G networks. It allows military operators to detect malicious network activities in near-real-time and provide communication mechanisms to avoid adversary's control over their network traffic.

Description

Through a minimum amount of cooperation with the network operator, part of the ZTC solution leverages Open-Radio Access Network (O-RAN) and 5G core for new threat monitoring and mitigation solutions specifically designed for 5G networks. This O-RAN- and core-centric approach is complemented by a device-centric approach to ensure that Department of Defense (DOD) devices also implement their own layer of security and do not solely rely on the network provider's security protocols that could possibly be compromised by adversaries. Such a combination will substantially enhance the security of the whole network system. Importantly, the device-centric solutions do not require cooperation from the network providers, nor any changes to the existing 5G standards.

Specifically, the ZTC solution employs different methods to monitor and prevent potential threats at wireless channels and protocol stacks. This includes verifying devices and the network for threats before communicating, using different methods to avoid and mitigate threats during communication, and continuously monitoring the network while in use. The solution uses a closed-loop mechanism to ensure everything is working properly and to detect any issues that may arise. The solution ensures that adversarial efforts to locate any user are nullified and enables recovery from unanticipated denial-of-service (DoS) attacks in 5G.

While the team believes that the true impact of the solution cannot be quantified in numbers, they expect that the lives of many DOD field operatives (e.g., military squads) will be made more secure, and therefore safe, with the shield the network solution will provide.

Differentiators

The proposed ZTC solution has seven key features that differentiate it from other solutions:

1. Focus on exploring Open Artificial Intelligence Cellular (OAIC) capabilities at O-RAN for threat monitoring and mitigation that can be applied to commercial and military 5G networks

2. Implement DOD's own layer of security with add-on software

3. Protected communication through innovation at the application layer rather than modifying existing 5G physical (PHY)-layer protocols and algorithms

4. Location privacy and recovery from unanticipated DoS attacks

5. No modifications to public 5G networks and 3GPP standards

6. Ensure portability, reproducibility, and broad dissemination through open-source software-defined 5G testbed and O-RAN community

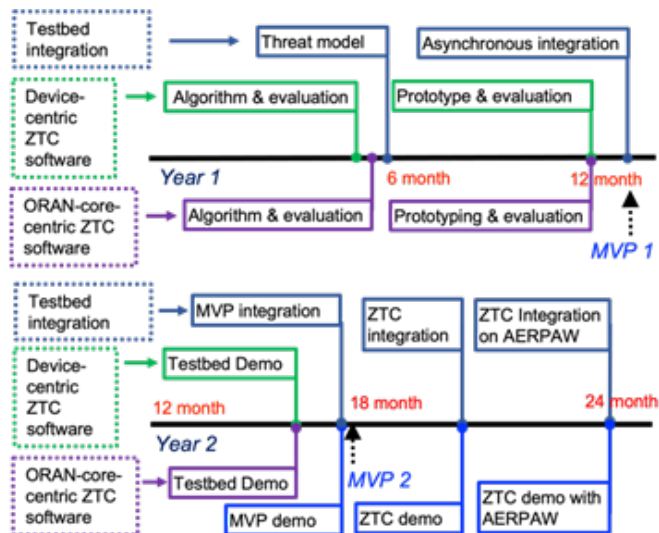7. Ensure easy integration with other Track G solutions

Road Map

Figure 1: A timeline showing principal tasks, associated interactions, and key milestones.

Figure 1: A timeline showing principal tasks, associated interactions, and key milestones.

Figure 1 shows the 24-month timeline for the main technical development. The tasks are grouped into testbed integration, device-centric ZTC software, and O-RAN-core-centric ZTC software developments. The first version of MVP, MVP 1, consisting of stand-alone features, will be delivered at the end of the first year. The ZTX team will promote and license the MVP 1 to generate early revenue. The fully integrated MVP, MVP 2, will be delivered at the 18th month, tested on available 5G testbeds at the 24th month, and commercialized through ZTX's own company.

Partnerships

During Phase 1, Raytheon BBN has been serving as a task leader for Task 2.3b. BBN Principal Investigator Vander Valk also actively participated in the Phase 1 curriculum and use-inspired research by connecting the team with DOD customers and stakeholders sharing the same interests in DOD 5G uses.

In Phase 2, BBN will continue to lead Task 2.3.b. and demonstrate ZTX's location privacy solution on the available testbeds. BBN is also a transition partner of the ZTX team. BBN will actively participate in

establishing an implementation plan for the transition to practice of the proposed research to sustain and grow the project beyond Phase 2.

Intellectual Property

The team has started early intellectual property (IP) agreement negotiations and has almost settled in the final signing-up. The project involves the one granted IP:

- System and Method for Channel Statistics Dependent Frequency Hopping, U.S. Patent issued with number 9,819,387 B2, November 14, 2017.

The Phase 1 effort led to the following four provisional IP applications:

- Frequency hopping for 5G and beyond wireless communication systems, U.S. Provisional Patent Application, 63/521,815, June 2023.

- Double-layer encryption for 5G and beyond wireless communication systems, U.S. Provisional Patent Application, 63/521,812, July 2023.

- Resilience against unknown denial-of-service attacks via multipath communications, U.S. Provisional Patent Application, 63/512,810, July 2023.

- Secure authentication via nonorthogonal message and tag transmission in wireless networks, U.S. Provisional Patent Application, 63/513,025, July 2023.

Zeta Security

Programmable Zero-Trust Security for Operating Through 5G Infrastructure

ZETA

Lead PI: Guofei Gu
guofei@tamu.edu

Hongxin Hu
hongxinh@buffalo.edu

Walt Magnussen
w-magnussen@tamu.edu

Cristina Nita-Rotaru
c.nitarotaru@neu.edu

Narasimha Reddy
reddy@ece.tamu.edu

Overview

Recently, the request for enhanced security in 5G is becoming a critical issue when users such as Department of Defense (DOD) want to operate through the current 5G infrastructure securely. The goal of this proposal is to provide the DOD (and any 5G users and operators) with new, flexible, and programmable zero-trust (ZT) security capability when operating through the existing 5G infrastructure. More specifically, the proposed system will provide unified, infrastructure-wide, dynamic, and fine-grained programmable security control across the 5G infrastructure including 5G Radio Access Networks (RAN) and 5G Core networks. Based on the proposed system Zeta Security, the 5G users and operators can quickly develop and deploy security applications/services to customize their specific security needs and realize both zero-trust security features and secure end-to-end network slicing. Such new security applications/services can continuously maintain and evaluate risks of accesses, and provide finer-grained, programmable access control and isolation of resources in 5G infrastructure.

Description

Transitioning from existing research collectively done by the team, this project proposes to build an innovative programmable zero-trust security solution called Zeta Security to enable unified, dynamic, and granular security control across the 5G infrastructure including 5G RAN and 5G core networks. Zeta Security provides new enhanced and programmable ZT capabilities using Open RAN (O-RAN) and Open Network Automation Platform (ONAP) on cooperative 5G networks. Zeta Security enables 5G users and operators to rapidly and securely deploy, configure, and manage 5G network slices. It supports time-sensitive, zero-trust security for joint operations through flexible and programmable capabilities and is compatible with 5G industry standards. This project enables new innovations in programming dynamic and intelligent

security applications/services to protect the entire 5G infrastructure and diverse communication use cases. Overall, this project will provide a solid foundation and collaborative community for existing and future 5G security operation and research, as well as key broader national security and mission outcomes and societal benefits including improved economic outputs, safety, security, privacy, cost of regulation, liability, interruption protection, and distribution of access. The team also includes an HBCU (Prairie View A&M) and seeks to broaden participation in the convergence accelerator research by engaging with diverse marginalized, racially, and economically vulnerable community members through student seminar series and involvement with Zeta Security project activities, as well as through workforce development programs.

Differentiators

To date, an increasing number of Zero Trust Architectures (ZTAs) have emerged in the industry, such as Google Beyond Corp and Palo Alto Zero Trust, which help organizations better serve a more practical, step-by-step approach as incremental deployment. However, existing ZTAs have mainly focused on enterprise network security and there has been little work to implement a zero-trust framework for 5G systems security. Zeta Security is the first zero-trust framework for 5G by integrating with O-RAN and Management and Orchestration framework. Furthermore, Zeta Security can provide finer-grained access control in 5G infrastructure and new programmable capabilities for different customers with diverse security needs.

Road Map

Year 1 will focus on developing and delivering infrastructure layer building blocks and controller layer security components. Year 2 will concentrate on developing and delivering security operations/applications and human actors layer components. The integration and transition of Zeta Security are carried out from Year 1 to Year 2.

Partnerships

This multi-institutional project includes experts in security, networking, telecom operation, convergence research, public policy, user study, team science, and national security applications from academic institutions such as Texas A&M, University at Buffalo, Northeastern University, and Prairie View A&M, Federally Funded Research & Development Centers, and DOD liaisons such as MIT Lincoln Laboratory, Joint Base San Antonio, and Bush Combat Development Complex, and industry partners such as T-Mobile, Erillisverkot, Ericsson, Qualcomm, JMA Wireless, Athonet, Software Radio Systems, and Palo Alto Networks. The diverse yet complementary team of leading 5G and security researchers, the high level of commitment from industry partners, and the deep existing relationship with the defense industry will contribute to the overall success of this project.

Intellectual Property

The team will prioritize the development of intellectual property (IP) and solutions with appropriate partners and people with the necessary knowledge and skills. As IP is developed, the team will pursue IP protection as necessary, including all the partners involved in the development of the IP. Zeta is mindful that some of the developed technology, if widely adopted and used, will have a higher utility. Zeta will carefully weigh and evaluate the benefit of IP protection versus participating with open-source communities. The team will publish open interfaces of its application framework to encourage external parties, and developers to develop new apps over the Zeta Security framework. Zeta has developed some IP over Phase 1 and the team will pursue protecting that IP over the next few months.

Sustainability

Sustainability beyond the two-year horizon of this project will take several forms. The first is via direct engagement with the Army Future Command - University Technology Development Division with which Texas A&M already has a contract for transitioning alpha and beta level products. The second is via the STTR/SBIR route, where the team will respond to calls for 5G security and zero trust proposals, such as those from the Office of the Under Secretary of Defense via the National Spectrum Consortium. Finally, the

team will continue the commercialization and product refinement by forming a consortium with industry membership, which will expand to industries beyond DOD such as emergency and humanitarian response. This would enable a sustainable research portfolio with real commercial impact within the 10-year period. The consortium membership levels can range from premium, full, base, and in-kind (only available to small businesses). The consortium can meet at least twice a year, attend the on-site meeting (once/year), and also help develop and evolve an ongoing SWOT analysis to support the Zeta Security platform research, development, and tech transfer operations.

TRACK H: ENHANCING OPPORTUNITIES FOR PERSONS WITH DISABILITIES

People with disabilities compose a large and diverse population in society. In fact, an estimated 1.3 billion or 1 in 6 people globally experience significant disability, according to the World Health Organization. Despite the wide range of skills, talent and potential, persons with disabilities (PWDs), especially women and those in underrepresented groups, remain significantly underemployed or unemployed. Regardless of the type of disability, PWDs experience major barriers hindering their ability for achieving better economic opportunities, quality of life, health, and wellness. Recent studies show that expanding opportunities for PWDs creates the potential for securing economic benefits as well as meeting our moral and legal responsibilities.

The U.S. National Science Foundation Convergence Accelerator's Track H: Enhancing Opportunities for Persons with Disabilities is developing new technologies and tools to enhance quality of life and employment access and opportunities for PWDs by bringing together a wide range of disciplines and sectors to develop use-inspired solutions. The track's end goal is to create sustainable solutions through strong public-private partnerships and to enhance equity, inclusion, and accessibility for PWDs.

Enhancing Opportunities for Persons with Disabilities funded Phase 1 teams include:

ASL AI—Led by Northwestern University, ASL AI is an affordable ASL video communications tool that empowers the deaf and hard-of-hearing personally and professionally by allowing privacy and enabling sign search from videos.

DEAF PODS—Led by Purdue University, DEAF PODS (Developing Experiential Accessible Framework for Partnerships and Opportunities in Data Science for the Deaf Community) is an online deaf community accessible learning space that develops data science skills and fosters relationships allowing mentors to guide students. This model may be replicated through curriculum development, technical project creation, building of industry partnerships, and shared best practices to expand the deaf workforce in data science.

DriVR—Led by Mississippi State University, DriVR, a virtual reality software, prepares persons with disabilities to drive in the real world. Using versatile clinical data, DriVR provides a customized driving experience with tailored scenarios, such as navigating crosswalks and police stops. The result builds confidence, reduces anxiety and prepares individuals for the real driving experience, ultimately providing independence to thrive personally and professionally.

HeardAI—Led by Michigan State University, HeardAI's vision is to transform voice-artificial intelligence technology accessibility for 80 million people who stutter, and eventually benefit all users. Their extensible sociotechnical framework offers accessibility guidance for compliance checking, a realistic stuttered speech testbed for product evaluation, and an app and an API to make voice-activated products and services accessible.

Inclusio—Led by Saint Louis University, Inclusio transforms how we create and consume accessible content in classrooms, workplaces, and homes. Their platform solution reimagines accessibility by enabling

AI-powered automated content creation while fostering collaboration through streamlined communication and a quality-controlled content marketplace, with a core mission of serving those with low vision and blindness.

MABLE—Led by Lehigh University, MABLE (Mapping for Accessible Built Environments) is providing people with disabilities independence to experience large events, conferences, and educational programs. Using crowdsensing, AI and robotics, MABLE empowers an individual with a responsive map and turn-by-turn instructions through a digital app to help them navigate indoor environments successfully.

MicroBoost—Led by Ohio State University, MicroBoost enhances the employment opportunities of persons with disabilities by boosting the accessibility, flexibility, and multi-operator coordination of on-demand transportation. By leveraging AI, advanced routing algorithms, and industry collaborations with VIA and TappyGuide, MicroBoost significantly reduces the travel time for users when traveling to and from work.

PACT—Led by University of Southern California, PACT (Providing Access to Computing Technologies) provides an accessible web-based platform for people with disabilities with three embedded services: an AI-powered recommender tool with recommendations for optimal accessibility interfaces, AI enabled tools for personalization and training on accessibility technology devices, and a user-centric community support forum for people to connect together in using computing technologies.

Project DRIVE—Led by Northwestern University, Project DRIVE imagines a future where power wheelchairs are accessible to everyone that needs one. By connecting current and future technologies, Project DRIVE enables safe independent power wheelchair operations using intelligent robotic assistance.

RAFAS—Led by Harvard University, RAFAS' (Restoring Arm Function After Stroke) vision is to create an at-home rehabilitation solution to restore arm function after a stroke. Their solution is a wearable technology that supports an end-user to practice reaching with their affected arm during daily activities and also remotely monitors recovery and provides feedback to encourage behavioral change.

RELAIT—Led by University of Arkansas, RELAIT is committed to ensuring communication is accessible to all individuals, including those who do not have functional speech as the result of a communication disability. RELAIT leverages the power of AI to support communication through technology that is context aware, multimodal, and personalized.

SocialSense XR—Interpersonal communication is not accessible in extended reality (XR) for blind and low vision people. Led by Cornell University, SocialSense XR makes nonverbal communications such as eye contact, body language, and facial expressions perceivable using audio and haptic cues, with a focus on workplace scenarios.

Touché—Led by Stanford University, Touché helps people to live more independently by providing a low-cost, easy to use, wearable technology to relieve intolerable muscle contractions common after a stroke. The technology uses low-power vibration as a more accessible therapeutic modality compared to the gold standard, botulinum toxin injections.

UNav—Led by New York University, UNav revolutionizes navigation for visually impaired users through precision localization technology that maps and provides wayfinding for indoor and outdoor environments. As a mobile app or hands-free wearable (VIS4ION), UNav communicates directions and hazards with multisensory feedback, improving travel equity by cutting travel time, reducing injuries, and increasing environmental awareness.

Universal Pathways—Led by Utah State University, Universal Pathways supports greater opportunities for individuals with disabilities by providing planning organizations with custom data on the community mobility network. The solution combines AI and human workflows to map and assess mobility conditions. Universal Pathways is dedicated to facilitating inclusive, connected mobility networks that ensure equitable community access for all.

WeCAN Socket—Led by Rocky Tech, LTD, WeCAN Socket empowers amputees to live an active healthy lifestyle by providing a customized prosthetic socket that adapts to everyone. Using e-skin sensing technology, the solution's 3D printed prosthetic socket adapts to an individual by using sensors to monitor pressure, moisture, and temperature in real-time, reducing discomfort, frequent replacements, and overall cost.

ASL Digital Equity

Empowering Deaf Signers

Lead PI: Dimitris Metaxas
dnm@cs.rutgers.edu

Matt Huenerfauth
matt.huenerfauth@rit.edu

Carol Neidle
carol@bu.edu

Overview

The >500,000 Deaf & Hard-of-Hearing (DHH) individuals using American Sign Language (ASL) as their primary language face obstacles to digital communication and information access, since ASL has no standard written form; information is conveyed by hands, arms, face, and head. Building on prior U.S. National Science Foundation-funded research on linguistically-informed computer-based analysis and recognition of ASL from video, the Principal Investigators (PIs) propose sustainable artificial intelligence solutions to overcome such obstacles, to empower signers personally and professionally.

Anonymization Prototype

Description

The ASL Digital Equity team proposes web-based tools:

(1) Privacy is a serious issue since the face cannot be obscured without loss of information. Their privacy tool will anonymize ASL videos, enabling signers to disguise their identity for sensitive communications while preserving linguistic information.

(2) Furthermore, looking up a sign in a dictionary is not straightforward. ASL dictionaries are frequently organized based on English translations (although there is no 1-1 correspondence between ASL signs and English words); however, the user may not know the sign's possible English translations. ASL Digital

Equity is developing technology for sign-search-by-video-example. The user uploads a video, and the system returns the top-5 most likely sign matches; the user confirms the selection and is taken to the appropriate entry in, e.g., an ASL dictionary. They successfully identify the sign in the top-5 96% of the time. This will be invaluable to learners of ASL (the 3rd most studied "foreign" language in the U.S.), including hearing parents of deaf children. Ninety percent of deaf children are born into hearing families.

The team will also expand their publicly shared data and software. They will enhance their software for linguistic annotation (Sign-Stream®), to facilitate analysis of ASL gestures and integrate search-by-video-example, so annotators can look up signs,and then directly insert into their annotations the stored properties from the team's expanding Web-accessible Sign Bank. This is the first such annotation tool, with the potential to revolutionize annotation of ASL video data, thereby advancing and accelerating research that relies on such annotations, and applications enabled by such research.

Differentiators

Privacy is a serious concern in the Deaf Community. Prior attempts to disguise identity use crude face masks or similar methods, but these are quite unnatural and of limited utility. Nothing like ASL Digital Equity's video anonymization exists. There is also no other tool to enable sign-search-by-video-example. Prior research on sign recognition has not attained the accuracy of their research; it is this high accuracy that makes their tool useable in practice.

Road Map

With input from user studies, prototypes for the tools just described will be developed in Year 1. In Year 2, ASL Digital Equity will extend relevant technologies and complete implementation of deliverables, with appropriate mechanisms for dissemination and sharing of software and data. In Year 1, they will also

reimplement SignStream® as a Web-based application, with the features in their Phase 1 prototypes and additional functionalities based on feedback from their collaborators. By end of Year 1, they will release a beta version. Year 2 will focus on debugging and extending functionalities, culminating in a public release.

Partnerships

ASL Digital Equity is consulting with deaf-owned companies, such as Convo (relay & messaging services), which would benefit from video anonymization; and the Deaf Studies Digital Journal, since anonymization of signed submissions would enable double-blind review (taken for granted in printed journals). They are also working with DawnSignPress (DSP), a major distributor of ASL cultural & educational materials. They will develop collaboratively, for the first-of-its-kind all-ASL dictionary that DSP is developing, an add-on for search-by-video-example access to dictionary entries. DSP is also interested in anonymization, to present neutral definitions (dissociated from the person signing the definition). They have contributed valuable video data for ASL Digital Equity's projects. In Phase 2, the team will also work with the ASL Education Center—offering services to clients nationwide, e.g., standardized ASL assessment and training for educators. The ASL Education Center would like to incorporate ASL Digital Equity technology into their products/services. The team will explore how their technologies may benefit other potential partners as well.

For AI methods, the team is collaborating with several major companies (Adobe, Amazon, ByteDance, Google, Meta, Microsoft & Nippon Electric Company) with strong interest in 3D human shape and motion estimation from video and generation methods for ASL and other applications.

Intellectual Property

These tools, for privacy and search-by-video-example, will be publicly accessible from ASL Digital Equity's website, running on Rutgers servers. Uploaded data will be deleted immediately after relevant files have been returned to users for download.

The team will establish a not-for-profit entity through Rutgers to enable licensing of these tools for use in commercial products. Income will be channeled back into this project for maintenance and enhancement of data and software. They also anticipate receiving several forms of support from the tech companies, with whom they will maintain long-term collaborations.

SignStream®, to be significantly enhanced with powerful new features also making it accessible to a larger set of users, is distributed under a Massachusetts Institute of Technology license. The team's expanding linguistically annotated video corpora (accessed by users in 38 countries) are shared for education and research.

DEAF PODS

Unlocking the Impact of Data Science for the Deaf Community

Lead PI: Mark Daniel Ward
mdw@purdue.edu

Bonnie Jacobs
bcjntm@rit.edu

Caroline Solomon
caroline.solomon@gallaudet.edu

Overview

DEAF PODS (Developing Experiential Accessible Framework for Partnerships and Opportunities in Data Science for the Deaf Community) enables data sciences in the deaf community. The teams use experiential data science learning, in domain-specific, real-world research projects. As a result, the students have increased skill development and experience with partners that expands the workforce.

Description

The Data Mine (TDM) coordinated three research teams comprised of 19 student researchers altogether, working with three Corporate Partners, in Spring 2023. Also, TDM coordinated six teams including 30 student researchers altogether, working with five Corporate Partners in Summer 2023.

The TDM model brings together students from all disciplines and backgrounds, to work with industry partners in an experiential learning environment. Students learn data science skills and put their knowledge to work on real-world data-driven problems. The students learn first-hand about the value of teamwork and the importance of learning domain knowledge, as key aspects of data science. As the students learn data science problem solving skills, they also learn soft skills, including professional development, a mentor/mentee research framework, business etiquette, and the norms of working in corporate environments.

The positive impacts of the team's TDM model are not limited to the student researchers: companies find significant return on investment from work with students. The companies also learn about how to create a working environment that is accessible and welcoming to early-career members of the deaf and Hard of Hearing community.

Differentiators

DEAF PODS is student-centric and emphasizes Deaf-led partnerships. This effort firmly grounds the student experience in work that is immediately applied in industry settings.

Partnerships

Deaffriendly: The only Deaf-owned and operated customer review platform in the United States. The deaffriendly platform enables reviews and insights about the degree to which businesses are friendly to the Deaf community. By scraping reviews from deaffriendly.com, and using sentiment analysis, the students developed a classifier for positive and negative reviews of businesses, industry sectors, and metro areas.

Nagish: Tech company that creates cutting-edge tech to make communication better and more accessible to people who are deaf, to people who are hard-of-hearing, and to people with speech impediments. The students worked on a corpus of audio and captions, researching the comparative performance of publicly available captioning engines versus the Nagish captioning engine. Their five-phase approach included data analysis of both the textual and audio aspects of the captioning process, as well as analysis of the transcription quality.

Innivee Strategies: Deaf-led, Deaf-operated organizational and leadership development company. Innivee consults with organizations and leaders to create and achieve goals, manage change, obtain and utilize data, cultivate community buy-in, and nurture and retain inspiring and transformative leaders. The students used publicly available data to bolster Innivee's database, as well as creatively thinking thru different ways to achieve a larger database using tools like webscraping.

Indiana Family & Social Services Administration (FSSA): The FSSA enables the delivery of health care and social services throughout the state of Indiana. The Data and Analytics team within the FSSA focuses

on data-informed strategic and operational decision-making that improves the health and well-being of Hoosiers. The students and their mentors analyzed food insecurity (e.g., within food deserts), and studied the need for affordable housing and utility assistance. A second team of students worked with the FSSA's Bureau of Disabilities Services (BDS). The students studied the degree to which BDS dental services are a good indicator of overall preventative care that an individual is receiving. They also studied accessibility to care and quality of service.

DEAFCYBERCON: Creates a pipeline of equitable opportunities for deaf women in cybersecurity. In addition to hiring, the focus is on mentoring and supporting deaf women as leaders, from early career internships through senior executive positions. The team built a Power BI interface for a wide variety of data visualization. This tool will enable data-driven analysis of internet resources for cybersecurity employment of deaf women.

ASL Education Center (AEC): A small business that produces educational tools in American Sign Languages (ASL) that transform the ways ASL signers explore and learn. The students' goal was to document evidence that children who are learning ASL have the same level of language comprehension as English learners. The students analyzed a computer-based standardized ASL assessment containing 11 subtests, managed by the AEC.

5 Star Interpreting: deaf and Child of Deaf Adult (CODA)-owned ASL interpreting agency, serving the states of Utah, Idaho, and Illinois. The students built a prototype dashboard to identify and visually convey insights about business patterns. The dashboard will provide accurate forecasts and predictions to meet interpreter need and maintain profitability on a per-interpreter and/or per-customer basis.

Nationwide: A large insurance and financial services company, based in Columbus, Ohio. The Enterprise Analytics Office at Nationwide is an organization within the Office of Finance that provides advanced mathematical techniques to support key business drivers. The students investigated the significance and location of food insecurities by age, race, and economic status. They performed an in-depth geospatial and temporal analysis of food insecurity in four United States counties. They delivered a

nuanced analysis of the distribution, location, and intensity of food insecurities in the stakeholder regions that they analyzed.

Summary: Each of these partners contributed mentoring for the students about research, applications of data science, and business growth/professional development. The companies each worked closely with The Data Mine staff to help prepare the students with domain knowledge and the data acumen to excel in their projects.

Intellectual Property

The Data Mine's legal document can be found at datamine.purdue.edu/corporate/sponsoracknowledgment.docx.

DriVR

Free to Drive. Free to Live.

Lead PI: Kasee Stratton-Gadke
kks196@msstate.edu

Zach Ahonle
zja34@msstate.edu

Lalitha Dabbiru
ld212@msstate.edu

Kris Geroux
kgeroux@mdrs.ms.gov

Adam Jones
aj33@msstate.edu

Overview

DriVR is a virtual reality (VR) software application that prepares individuals with disabilities to drive in the real world, offering customized driving experiences and scenarios tailored to their needs and abilities. By building confidence, reducing anxiety, and providing real-time feedback, DriVR enhances autonomy, access to employment and improves the overall quality of life for people with disabilities.

Description

In rural America, where 20% of the population resides, the lack of reliable transportation necessitates driving independently. This is essentially true for one in four adults living with a disability that may impact their ability to drive. Public transportation is seldom available in rural areas and if ride share services exist, they are inaccessible to users of wheelchairs or mobility aids.

Rooted in universal design, DriVR offers a safe, customizable way to train for independent driving that directly addresses the unique abilities of each learner, including those with physical, intellectual, and emotional disabilities. DriVR presents a continuum of options for different users through numerous VR scenarios modified to meet individual requirements. From navigating crosswalks, mastering parking skills in bustling parking lots, to simulating encounters with law enforcement during traffic stops, DriVR equips users with the necessary skills for real-life driving situations.

DriVR's ability to harness clinical data is truly what sets it apart as a rehabilitation tool. Certified driver rehabilitation specialists can fine-tune the application to each user's needs from the number of trials prepared, to driving with hand-controls for those with spinal cord injuries. This level of customization is particularly impactful for individuals with disabilities, including those with intellectual or physical impairments who may require additional support and practice.

Phase 2 of DriVR will accelerate the progress of Phase 1 with a strong focus on meeting the needs of those living in marginalized communities with disabilities. During Phase 2, the core team will continue to foster original partnerships and expand to add new collaborators to develop the most robust, affordable VR application on the market by integrating data analysis, VR development, national data testing, improved functionality, and use of clinical hardware such as hand controls used for driving.

Differentiators

DriVR is distinctly different from other solutions in three primary ways. First, it's affordable. Driving simulators are often used in research, not for clinical training due to their high cost ($500,000+) and limited ability to accommodate disabilities. DriVR, on the other hand, provides vast customization while costing under $100. It could also potentially be available no cost through rehabilitation programs such as the Administration for Community Living. Second, DriVR is portable and widely accessible via any commercially available VR headset, allowing for increased practice and options to drive with adaptive equipment such as hand controls or high-tech modifications. Users no longer need to wait months to receive drivers training in specialized vehicles to practice their driving skills. Lastly, and highly sought after by instructors, DriVR provides real-time clinical data for easy quantification, analysis, and improvement a driver's training regimen.

Instructors will have access to reaction time, error analysis, gaze-tracking, use of hand- controls, and other data to properly plan next steps toward real-world driver training.

Road Map

In Phase 1, the framework for DriVR, a prototype of five driving scenarios, and a clinical data system were developed. In Phase 2, DriVR will officially launch with two primary deliverables: 1) a VR software application

with 15 driving scenarios available in the Meta and Steam app stores and a 2) clinical evaluation tool building in adaptive hardware and haptics for users driving with hand controls.

In year one of Phase 2, the team will finalize a minimum of 14 of the 15 driving scenarios with data analytics and national beta testing with current and future partners including users with disabilities and adapted driving instructors.

In the first quarter of year two, they will finalize the last driving scenario with beta testing and continue to advance DriVR's capabilities with data analytics to deliver valuable clinical, real-time data, based on the outcomes of their Phase 1 human-centered design needs. In quarters 2-3, they will develop their market readiness strategy at a national scale and prepare to launch DriVR in quarter four in all VR application stores. After Phase 2, they will focus on expanding DriVR to meet more "high-tech" driving needs with hardware support for individuals with complex disabilities.

Partnerships

DriVR is co-developed by a diverse group of academic (Mississippi State University), governmental (Mississippi Department of Rehabilitation Services), research, clinical organizations, and disability centers. DriVR has leveraged their partners in preparing for Phase 2, fully embracing a team science approach to include additional governmental partners (National Council on Independent Living and the Association for Community Living, Veterans Affairs-Tampa), industry leaders in VR development (Top Right Corner) and adaptive driving (Association for Driver Rehabilitation Specialists, National Mobility Equipment Dealers Association, and Strowmatt Rehabilitation Services) and nonprofit disability organizations (e.g., Arc of Mississippi) to ensure human-centered design occurs at a national scale through beta-testing and refinement of DriVR. Additionally, governmental, and nonprofit partners will assist with roll-out of their clinical evaluation tool.

Intellectual Property

An Intellectual Property Management Plan was created in consultation with Mississippi State University's Office of Technology Management to ensure a balance of intellectual property protection and timely disclosure and dissemination of project results to the public.

HeardAI

AI That Understands Everyone

Lead PI: Nihar R. Mahapatra
nrm@msu.edu

Hope Gerlach-Houck
hope.gerlach@wmich.edu

Caryn Herring
caryn@friendswhostutter.org

Ann Marie Ryan
ryanan@msu.edu

J. Scott Yaruss
jsy@msu.edu

Overview

In this era of ubiquitous voice-activated artificial intelligence (voice AI), current designs based on standard speech patterns disadvantage nearly 80 million people who stutter worldwide, exacerbating their exclusion from technological innovations, job opportunities, and potential to maximize quality of life. HeardAI bridges this gap by pioneering adaptive voice AI solutions and innovative guidance and assessment resources, as they champion a digital realm where every voice is recognized, understood, and empowered.

Description

In the burgeoning global voice AI market (nearly $60 billion by 2030), a glaring oversight persists: the exclusion of people who stutter, a community that already experiences societal stigma and discrimination. Common disfluencies such as part-word repetitions ("li-li-like this"), prolongations ("lllllike this"), and blocks ("l—ike this") are not decoded correctly by existing voice AI systems. What can be a technological marvel for many is a source of frustration and exclusion for people who stutter, with wide-ranging effects, from being unable to refill prescriptions via speech-based phone systems to greater exclusion in AI-based hiring processes.

To address this critical need, HeardAI leverages cutting-edge advances in AI, combined with a deep understanding of psychosocial and human aspects of stuttering, as well as legal, ethical, and labor market implications of using voice AI, as they produce three synergistic deliverables: (a) a stakeholder-driven guidance frame¬work that promotes accessible, equitable, and universally usable voice AI; (b) a testbed platform of diverse speech samples and benchmarks for evaluation of voice AI systems; and (c) an inclusive, adaptive speech recognition app and Application Programming Interface (API), based on proprietary procedures for multi-level processing of input signals to account for disruptions in speech fluency.

With HeardAI, the team is not just making voice AI accessible to those who stutter; they are laying the groundwork for universal voice AI technology to address the needs of an additional 180 million people whose speech differs from the norms. Because everyone has moments of disfluency, HeardAI's work will benefit all users of voice AI technology, ensuring that every individual can be truly and accurately heard and understood.

Differentiators

People who stutter confront many accessibility hurdles with current voice AI systems, spanning functionality, usability, equity, and efficiency. Challenges include activation barriers due to stuttering on trigger words, premature cutoffs, and phone tree navigation difficulties, as well as mistranscriptions and misinterpretations that lead to inaccurate characterizations. Speakers must grapple with inappropriate system responses, restrictive response times, and repetitive, tedious prompts.

At present, there is no voice AI system that addresses these multifaceted accessibility issues for people who stutter or exhibit other disruptions in speech fluency. Other initiatives target specific accessibility issues in contexts like home automation for selected speech differences, but these efforts miss the needs of people who stutter or exhibit disfluent speech. Also, current voice AI designs prioritize optimization of technical metrics like word error rate that do not correlate well with end-user experience. Moreover, while there are robust accessibility guidelines for web content, there are none for voice AI. What sets HeardAI apart and makes their project transformative is their focus on addressing accessibility challenges holistically, in a human-centered manner, through their guidance framework, evaluation testbed, and dedicated voice AI solutions.

Road Map

Phase 1 Milestones: International stakeholder symposium • End-user discovery • Barriers and facilitators study • Guidance framework infographics • Data collection app • Transcription training and workflow • Initial speech sample collection • Low fidelity prototypes • Branding and project marketing video • Initial voice AI models • Initial intellectual property (IP) protection

Phase 2 Deliverables: Guidance framework and resources • Evaluation testbed • Adaptive proprietary voice AI app and API

Phase 2 Milestones: Increased end-user and stakeholder engagement • Rigorous product refinement • Sustainability planning

Year 1: IP protection • Advisory board • End-user and stakeholder workshop • Minimum viable product development • Pilot testing • Sustainability plan • Soft marketing • Legal and ethics plan • Usability tests and validation • Define minimum marketable product (MMP)

Year 2: MMP development • Scalability strategy • Beta testing • End-user/stakeholder workshops • Product refinement • Legal/ethics strategy • Risk identification/contingencies • Soft launch • Product and sustainability plan refinement

Partnerships

HeardAI's network of more than 25 national and international partners represents numerous sectors: advocacy groups for people who stutter; speech language pathologists; adjacent disability groups and experts; data providers; employers; experts in human resources, legal/policy issues, hiring tech, and employment/disability advocacy; major tech companies involved in voice AI and responsible AI; engineers and domain experts; and federal (National Institute of Standards and Technology, Office of Disability Employment Policy) and state agencies. Many participated in HeardAI's first international symposium on needs and advances in voice AI for stuttered speech and provided guidance about desired system capabilities. Ongoing partner activities include serving in an advisory capacity as their deliverables evolve, providing feedback and insights related to Phase 2 milestones, and support with pilot and beta testing and dissemination.

Intellectual Property

HeardAI is working closely with Michigan State University Innovation Center for IP protection and technology transfer and commercialization.

Additional Information

Although HeardAI's focus on stuttered speech is unique within Track H, their extensible framework ensures versatility in accommodating speech patterns associated with a range of disabilities. Therefore, their project has powerful synergies with many other endeavors, particularly as voice AI becomes an ever more prominent user interface method.

Inclusio
Access Reimagined

inclusio

Lead PI: Jenna Gorlewicz
Jenna.gorlewicz@slu.edu

Jeff Croxell
jcroxell@gmail.com

Dan Gardner
Dan.gardner@viewplus.com

Nicholas Giudice
Nicholas.giudice@unarlabs.com

Hari Palani
Ha.palani@northeastern.edu

Overview

Imagine trying to read charts, maps, and graphics without seeing them. Access to visual information is one of the biggest challenges facing individuals with blindness and visual impairment (BVI) today. Inclusio changes the way visual content is created and consumed, using artificial intelligence and community to generate accessible content that can be felt, heard, and seen across multiple platforms.

Description

Current practices for creating accessible content, particularly graphics, are time and resource intensive, requiring certified paraprofessionals. Inclusio's software application reduces the barriers to finding and creating accessible content by incorporating three key components:

- **Timely creation of new content** through Inclusio's combination of accessible authoring suite and automated conversion with AI

- **Choice in the way content is received** through Inclusio's ability to intake multiple file types (e.g., text, image, numerical) and output to multiple platforms including text description, tactile graphics, multimodal touchscreen displays, and refreshable haptic displays

- **One-stop shop for finding accessible content** through Inclusio's vetted content marketplace

These key components address chronic pain points for two initial user groups: Teachers of Students with Visual Impairments (TVIs) and individuals with BVI, who are often omitted in the accessible content creation process.Inclusio's platform creates value in accessible content generation by:

- Promoting independence and equal opportunity for individuals with BVI

- Reducing time and resources to increase the likelihood of adoption

- Bringing stakeholders together to create and share best practices and standards without compromising the ability for personalization

- Supporting access anywhere, anytime, and in any modality

Inclusio's platform addresses disparities in education and employment for individuals with BVI, due to the current fragmentation across the various stakeholders. The team's long-term vision includes reimagining access, not as an afterthought or conversion, but as an integral part of content creation and consumption—which extends beyond individuals with BVI to the broader persons with disabilities community, representing true inclusive design.

Differentiators

1) Team: Inclusio's team consolidates expertise across the accessibility ecosystem, with collective experience pioneering and commercializing current and next generation assistive technologies. They have researchers with expertise in inclusive technology, cutting edge start-ups including Vital and UNiversal Accessibility Research Labs, education practitioners including TVIs, industry leaders in assistive technology hardware (ViewPlus) and publishing and assessment (Pearson), and individuals with lived experience who understand the challenge the team is addressing first-hand.

2) Technology: Inclusio is a multi-pronged, integrated system that streamlines the content creation process around graphics. Through the combination of its three core technologies—automatic conversion, accessible authoring, and a content marketplace—Inclusio directly connects creators and consumers together to reduce the time and resources required to obtain accessible information. Inclusio provides a platform for standards

and best practices to take root in the community, while making high quality content readily available across multiple output platforms.

Road Map

In Phase 1, the team established a standardized file format specification, demonstrated an integrated workflow that automatically generates a graphic for display via multimodal touchscreens or as a tactile graphic, and identified high priority requirements for

Inclusio's application, informed by their use- inspired research. In Phase 2, the team will complete the following deliverables:

1) Convergence Framework: Modular, standardized technical infrastructure consisting of a common file format (Month 3), a core for input/output conversion (Month 6), and API endpoints for third party integration (Month 9), in collaboration with industry-leading organizations and consortiums (e.g., American Printing House for the Blind; APH) and Digital Accessible Information System; DAISY). Success will be measured by the number of compatible platforms Inclusio can support and the quality of content produced across platforms and third-party streams.

2) Inclusio Application Development: Implementation of the core technical infrastructure within three streams of content generation: existing content (Month 9), manual (Month 12), and automated content (Month 15). Success will be measured by the quantity and quality of accessible content pieces hosted and generated within Inclusio coupled with user ratings of "good" or higher on the System Usability Scale.

3) Field Testing and Launch: A series of monthly usability acceptance testing that culminates in end-to-end field testing at 7 partner school and vendor sites (Month 21) will support development of Inclusio. Launch of the Inclusio platform for early adoption among key partners (Month 24). Success will be measured by overall usage in classroom and vendor environments, with 10% increases in monthly usage and content added to Inclusio.

Partnerships

In addition to the strong, diverse team assembled for Phase 1, Inclusio has built out additional key partnerships targeting TVIs and BVI end-users to support iterative testing in Phase 2 and early adoption post-Phase 2. These key partners include:

Key Organizations in the BVI Community which produce trusted content: APH, Benetech, DAISY, San Francisco Lighthouse for the Blind and Visually Impaired, and Pearson

Diverse Educational Settings Servicing BVI Students: Francis Howell School District, Washington State School for the Blind, Alabama School for the Blind, Texas School for the Blind and Visually Impaired, and Foundation for Blind Children

Blind Product Design and Evaluation Specialists for rapid, iterative, in-house development and testing

Key Partners for Standards Creation and Third-Party Integration Testing: Highcharts and Desmos

Intellectual Property

Entities will retain pre-existing Intellectual Property (IP) and will provide access to any necessary IP for the Phase 2 work via API calls and integration endpoints. New IP, anticipated primarily in the form of trademarks and copyrights, will be jointly pursued by Inclusio. New partners that contribute content to Inclusio's platform will complete data sharing agreements and copyright agreements.

MABLE

Turning Unknown Places into Familiar Spaces

Lead PI: Vinod Namboodiri
vinod.namboodiri@lehigh.edu

Ted Conway
ted.conway@fau.edu

Nils Hakansson
Nils.Hakansson@wichita.edu

Siny Joseph
siny@ksu.edu

Monica H. Kang
Monica@innovatorsbox.com

Patricio Vela
pvela@gatech.edu

Overview

Wayfinding and navigation within unfamiliar indoor built environments is challenging for many persons with disabilities (PWDs), such that unknown places are a source of anxiety for PWD and a barrier to richer participation in social and economic life. Accessible spaces reduce barriers to services and amenities, increase independence and inclusion of PWDs in the workforce, enhancing health, well-being, and productivity.

Description

The Mapping for Accessibility in BuiLt Environments (MABLE) project has the goal of improving indoor accessibility for PWDs. MABLE will provide digital accessibility maps of indoor environments with interfaces for assessing, planning, and navigating within these environments based on the affordances and capabilities of the user. It will permit map augmentation by all stakeholders based on their observations and knowledge. MABLE will enhance the ability of PWDs and others to navigate within mapped environments so that they may feel at ease and accomplish navigation tasks efficiently, especially in large buildings spanning multiple floors (e.g., office buildings, shopping centers, commercial and sports venues). In their study, MABLE was determined to increase mobility by 56% for PWDs and improved exploratory activities by 50% for people without disabilities.

MABLE proposes to leverage advances in artificial intelligence, building modeling, robotics, augmented reality/virtual reality (AR/VR) visual scene reasoning, and low-power consumer electronics to fully realize its vision. MABLE will extract accessibility information from floor plans using deep-learning enhanced image-processing algorithms and augment missing information through (i) the use of robot mapping and surveying, and (ii) through stakeholder and user contributions facilitated by usable mobile interfaces. MABLE will thus realize accessibility enriched maps that

can be created anywhere in an affordable and scalable manner. Further, by the design, implementation, and evaluation of an entire suite of indoor localization technologies, the MABLE product can be customized to fit a stakeholder's budget and needs, thereby affording greater flexibility and adoption.

Differentiators

Commercial map products from Google, Apple, Pointr, Situm, etc. require voluntary contributions from entities managing the built environments and rarely include accessibility information. In contrast, community-driven indoor map efforts (Venues, Foyr, etc.) rely on voluntary labor, with Open Street Maps being a stand-out for its accessibility tags. However, such efforts are not designed for indoor navigation and wayfinding; they lack features such as routing information and real-time localization. Other commonly used apps such as SeeingAI (more for object and image recognition), Aira, and BeMyEyes, which require someone else's assistance, are not meant to be comprehensive independent wayfinding solutions. The wayfinding solution from GoodMaps is the only other known product with similar user independence goals as MABLE; yet its dependence on costly manual laser imaging for mapping and reliance on mobile device camera-based AR for localization limits accessibility. Market analysis illustrates a product gap when competing products are viewed with respect to scalability, sustainability, usability, and accessibility.

Road Map

Phase 1 products include a low-fidelity prototype of MABLE, consisting of a web browser application and wireframes for the mobile app, plus algorithms for map generation from floor plans. For Phase 2, functional web and mobile app versions will be developed, tested, refined, and deployed (see Figure 1). More advanced map generation algorithms and robotic solutions will be developed. Additional MABLE support tools to build include: (i) Map Creator—to facilitate rapid,

semi-automated map creation, (ii) Event Mapper — to enable local building managers/event planners to administer MABLE's configuration, (iii) Map Issues—to handle user-reported issues and change requests, and (iv) Accessibility Quotient (AQ)—to measure the accessibility of indoor space and to provide educational tips to hosts. Practicing Human-Centered Design through community-based, participatory research with key stakeholders throughout Phase 2 will motivate features and details for product development. To create an accessible and sustainable solution, the team plans on creating a nonprofit entity for partnering with corporations and nonprofits serving PWDs.

Intellectual Property

The team will follow the Bayh-Dole act for assigning intellectual property (IP) and further agree to the following: Human-Centered Design findings will be published and disseminated to contribute to best practice for accessible map design. Likewise, the software interface design will be open source. Any collaboratively developed core algorithms will be shared IP. Licensing options follows from these choices.
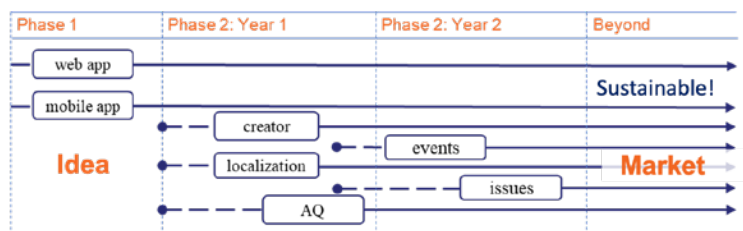
Figure 1. Project roadmap to sustainability.

Partnerships

MABLE's growing list of partners will support Phase 2 activities and sustainability insights by providing facilities for testing, disability population expertise and connections, business development expertise, stakeholder outreach, and/or technical expertise to the project. These partnerships will ensure that MABLE as a product has a viable sustainability roadmap, and benefits persons with and without disabilities.

Figure 2. Depiction of partners and their expertise.

MicroBoost

Accessible On Demand Transportation

Lead PI: Marco Brocanelli
brok@wayne.edu

Michael Bray
mikebray@wayne.edu

Daniel Grosu
dgrosu@wayne.edu

Weisong Shi
weisong@udel.edu

Dongxiao Zhu
dzhu@wayne.edu

Overview

Persons with disabilities (PWD) have historically faced significant employment challenges due to unfavorable transportation options. MicroBoost enhances the accessibility, flexibility, and multi-operator coordination of current on-demand transportation services for PWD. By leveraging artificial intelligence, advanced routing algorithms, and industry collaborations, MicroBoost will significantly reduce travel time for PWD and the cost of these mostly publicly funded transportation operators.

Description

According to recent estimates, only 37.8% PWD are gainfully employed nationally, which stands in stark contrast to the 80.0% employment rate for adults without disabilities. Several studies have pinpointed a lack of reliable transportation as one of the main causes. Microtransit companies struggle to maintain low operating costs, as these bespoke rides each cost an estimated $20-$70. MicroBoost provides two innovations to microtransit companies to improve their performance while reducing operating costs: flexible and accessible Pick-Up/Drop-Off (PUDO) locations for PWD and autonomous inter-operator coordination.

Flexible PUDO differs from door-to-door because it may ask a rider to walk a specific distance to a designated location to reduce operator costs and travel time. However, flexible PUDO can be challenging for PWD and requires this team to analyze how environmental factors (e.g., sidewalks) affect accessibility. Moreover, it requires wayfinding services to help PWD riders coordinate with shuttles. MicroBoost enables flexible PUDO for PWD by providing 1) AI-based algorithms that generate accessibility graphs from satellite/aerial imaginary around the door-to-door locations, 2) algorithms to find the most accessible PUDO locations that minimize the rider waiting time and operating costs, and 3) integrated wayfinding services.

Importantly, a lack of coordination between operator zones leaves PWD struggling to reach locations, even in short trips. MicroBoost improves the inter-operator service by providing a software framework and coordination algorithms that can automatically interact with multiple operators to establish coordination and reduce the scheduling effort overhead as well as the PWD total travel time.

Differentiators

MicroBoost overcomes several limitations of existing U.S. transportation options for PWD. Uber or Lyft are expensive for low-salary PWD, lead to trust issues for people with vision impairment, and remain inaccessible for people on wheelchairs. Public fixed-route transportation is affected by the first/last mile problem. Hybrid programs do not address trust, accessibility, or rural transit issues. Local microtransit provides cheap, flexible rides but has limitations with advanced reservations and small service areas.

Software-as-a-Service (SaaS) companies in transportation (e.g., VIA) can alleviate these limitations by enabling on-demand microtransit. However, while flexible PUDO is the default option for riders without disabilities, PWD rides are door-to-door due to the lack of accessibility algorithms, resulting in higher costs, lower availability, and longer transit times. Additionally, geographically adjacent operators either manually coordinate cross-area rides with long buffer periods or do not coordinate at all, especially when using different SaaS providers. Thus, MicroBoost is an essential innovation that can lead to higher shuttle availability, shorter transit time for PWD riders, and cost reductions for operators.

Road Map

During year 1, the team will work on MicroBoost's software. Between the first and third quarters (i.e., Q1-Q3) they will develop the first version of the framework integrated with the selected SaaS software (Deliverable

1). During this time, the AI-based accessibility and coordination algorithms will also be completed, which will be integrated and tested into the MicroBoost framework by Q4 not only in Michigan, but also in Delaware. Thus, by the end of Q4 the team will have a complete MicroBoost prototype (Deliverable 2). In parallel, between Q2 and Q5, the team will finalize the business and intellectual property (IP) plan (Deliverable 3).

During year 2, the team will test the performance of MicroBoost with small-scale and large-scale tests in Oakland County, Michigan leveraging industry partners, which will end in Q8 with a refined MicroBoost prototype (Deliverable 4). In parallel during Q7 and Q8, the team will also work on exploratory partnerships to reinforce MicroBoost with more scale-up features (e.g., cybersecurity, payments).

Partnerships

In Phase 1, the team explored PWD transportation limitations and proved MicroBoost's usefulness through proof-of-concept. Phase 2 will expand on these findings and involve several partners for innovation delivery. MicroBoost will involve three microtransit operators in Michigan (North Oakland Transportation Authority, Western Oakland Transportation Authority, Suburban Mobility Authority for Regional Transportation) and a designated SaaS company for on-demand shuttle tests. John Petrous (TappyGuide) will integrate wayfinding services. Michael Bray (Michigan Developmental Disabilities Institute), Anahita Lord (Michigan Rehabilitation Services), and Beth Mineo (University of Delaware) will outreach to PWD communities. Marco Brocanelli, Dongxiao Zhu, Daniel Grosu (Wayne State University), and Weisong Shi (University of Delaware) will contribute academic research experience in AI, algorithms, mobile, and cloud computing. Ken Massey (WSU) will finalize the sustainability plan for growth beyond Phase 2.

Intellectual Property

The successful launch of MicroBoost, potentially as a nonprofit entity, requires collaborations between academic and commercial stakeholders to develop the necessary IP. If deemed patentable, it will be jointly owned between entities in the MicroBoost consortium. It includes patents, copyrighted software, trademarks, trade secrets, and creative assets. MicroBoost will own and manage the collected data, and an IP committee will oversee the plan's implementation.

PACT

Digital Access, Personalization, and Independence For All

Lead PI: Gisele Ragusa
ragusa@usc.edu

Stephen Aguilar
aguilars@usc.edu

Heather Culbertson
hculbert@usc.edu

Sook Lei Liew
sleiw@usc.edu
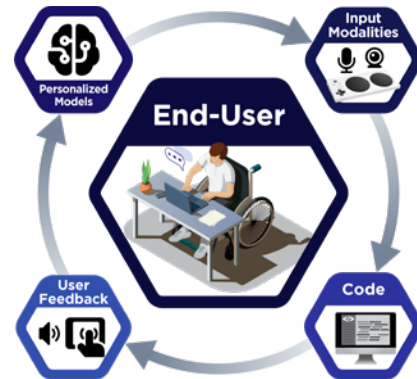
Jesse Thomason
jessetho@usc.edu

Overview

Providing Access to Computing Technologies is the team's PACT! The team intends to alleviate pronounced barriers to uses of digital technologies for people with physical disabilities through development and deployment of a multi-dimensional, accessible web platform, the Personalized Support Platform (PSP). This platform will be equipped with artificial intelligence powered computing technologies and interfaces that are personalized and fully accessible for individuals with diverse physical abilities, strengths, challenges, and needs.

Integrated User-centric Design

Description

At least 80% of people with disabilities are currently not part of the labor force. This disparity is particularly pronounced in technology-related jobs. While employment opportunities in technology industries abound, they are largely inaccessible to those with disabilities. This is primarily because standard computing interfaces are nearly impossible to operate for many individuals with physical disabilities. PACT addresses the needs and barriers of people with disabilities using universal design to recommend, adapt, and build accessibility tools so that individuals with diverse abilities may join digital workforces. PACT's user-centric PSP comes equipped with (1) a recommender tool with artificial intelligence-driven recommendations for optimal accessibility interface tools; (2) AI-enabled tools for personalized accessibility devices (both hardware and software); and (3) a computing community forum with end-user profiles (personas), descriptors, training tools, and support for connecting, collaborating, and using accessibility devices and software. PACT's PSP will include training and set-up videos for each hardware and software recommendation generated from the recommender tool and provide users with an option to perform walk-throughs for new technologies and interfaces.

It will showcase curated resources for end-users, services, and care providers. The PSP's computing community forum will include "personas" based on authentic user profiles with videos that describe lived experiences of people utilizing AI-powered interfaces and haptic enabled devices. The PSP will be usable on computers and on portable devices, and will ubiquitously support people with disabilities, their therapists, and care providers. With national distribution, the PSP and its tools have the potential to reach up to 4,500 individuals with disabilities nationally in its first two years of dissemination.

Differentiators

Team PACT's work outpaces other accessibility hardware and software because it pairs affordable, off-the shelf assistive devices with AI-powered software that provides customization and personalization to meet and adapt to end-users' needs over time. Its first-of-its-kind software wrappers enable hardware that is typically unable to work synergistically to "communicate" seamlessly and facilitate optimal technology use for people with significant physical challenges. Through this, end-users can perform complex computing tasks which in turn will enable them to participate in digital workforces with equity and full access. Through the PSP's computing community

forum, users can receive support, gain access to resources, and support one another in computing advancement.

Road Map

The Personalized Support Platform was prototyped in Phase 1 and will ubiquitously support people with disabilities, their therapists, and care providers. Embedded within the PSP (deliverable 1), are seven interrelated, additional deliverables including: (1) a set of personas enabling users to relate to and specify their needs, abilities, and desired use; (2) personalized recommendations of hardware with connections to selected personas which includes end-user choice; (3) AI-enabled software wrappers to improve personalization for assistive devices; and (4) an interactive computing community forum with support, challenges, and training; and (5) curated resources for where to obtain hardware/software and options for funding such resources. Moreover, the PSP's recommender tool (6) will be trained in a testing arena using end-user computing data, video analyses and qualitative surveys from actual users to learn what works well for particular people with given abilities, goals, and needs. The recommended devices will be easily set up and customized by people with disabilities leveraging a set of user-centric setup videos and associated explanations (7). A virtual social agent (8) will provide anticipatory support for people on the PSP and will be informed by the AI in the recommender tool. These eight interrelated deliverables were prototyped in Phase 1 (April 2023-November 2023), and will reach full development between November 2024-April 2025, with dissemination efforts beginning in May-December 2025. PACT will offer end-to-end access to technology so people with disabilities can be equitably employed in lucrative computing jobs, thereby profoundly improving their quality of life.

Partnerships

University of Southern California's team PACT spans the expertise necessary for end-to-end success. Key Phase 2 team dimensions include university faculty researchers who together with end-users co-develop, prototype and test PACT's tools, community partners including medical and therapeutic practitioners, who assess the developed tools, and community-focused, national service organizations who will bring the PSP and its tools to practical use across the U.S.

Intellectual Property

The intellectual property provided through PACT will be AI-powered software overlays and wrappers and adaptations for off-the-shelf accessible devices to enable personalization. PACT's PSP will include developed web-tools to support people with disabilities to engage in computing, to support one another, and receive training resources to obtain employment.

Project DRIVE
Intelligent Robotic Wheelchair Assistance

Lead PI: Brenna Argall   Jered Dean
brenna.argall@northwestern.edu   jered@luci.com

Overview

Project DRIVE's objective is to expand independent, functional power wheelchair mobility to everyone who wants to DRIVE. They will bring to market and release open-source innovations that provide (1) artificial intelligence solutions for advanced driver assistance, (2) a digital and open wheelchair communication standard, and (3) a flexible control interface that conforms to an individual's abilities and preferences.

Description

There are millions of potential power wheelchair drivers today for whom independent mobility is difficult, or even entirely impossible. The result is deprivation—for persons with disabilities, and their caregivers—of independence and engagement within the community and workforce. Project DRIVE will deliver:

T1: Wheelchair intelligence that provides active, as well as fully autonomous, driving assistance. The wheelchair industry lags behind the rest of society in harnessing artificial intelligence and driver assistance tools that help to ensure safety and efficacy. In Phase 2, the team will evaluate in end-user studies assistance paradigms developed in Phase 1 and deploy them within LUCI's commercial product already on the market.

T2: An open-source and digital Application Programming Interface (API) that allows for bilateral communication between wheelchair control systems and any digital input device. Current commercially-available power wheelchairs offer rudimentary methods for third-party technology integration with the wheelchair. In Phase 2, they will advocate for adoption of their Wheelchair Digital Interface (WDI), developed and released open-source in Phase 1, as the International Organization for Standardization/ Rehabilitation Engineering and Assistive Technology Society of North America (ISO/RESNA) standard for wheelchair communication.

T3: Development of a flexible and multimodal controller. There is a deficiency in current commercial drive methods' ability to effectively capture control commands from bodies with limited movement ability. Informed by their low-fidelity prototype interviews in Phase 1, the team's novel controller will (1) conform to the user and capture control signals from nearly any place on the body with residual movement, (2) issue proportional and discrete control commands in multiple dimensions, simultaneously, and (3) be used in concert with existing control interfaces.

Differentiators

T1: In 2020 LUCI became the first, and remains the only, commercial, Food and Drug Administration (FDA)-registered driver assistance system for power wheelchairs on the market. Project DRIVE's work expands LUCI's capabilities to active steering corrections and fully autonomous driving, leveraging advances in AI and decades of smart wheelchair research.

T2: The communication between current commercial power wheelchairs and their control interfaces is serial, unidirectional, and cannot be brought into the digital world. Their work provides an open API that allows for bilateral and digital communication between the wheelchair and any input device.

T3: Commercial controllers accessible to those with severe motor impairments typically are based on switching finite-state devices, with limited dimensionality and continuity, and can only capture some movement types. There exists no interface that fully conforms to the user and captures control signals from anywhere on the body with residual movement. The team's work will develop a wearable, flexible controller that fills this market gap.

Road Map

Year 1 Milestones:

TI: The corrective driving assistance paradigm is evaluated in the lab and pulled into the LUCI product. Licensing agreement is signed.

T2: The WDI is proposed to the RESNA Assistive Technology Standards Board (ATSB).

T3: An initial hardware, software, and usage guidance prototype of the flexible interface is developed.

Year 2 Milestones:

TI: Corrective driving assistance is rolled out first to LUCI beta users, and then to all LUCI users. Autonomous assistance is evaluated in the lab, pulled into the LUCI product, and rolled out to beta users.

T2: WDI adoption by current LUCI customers and clinical partners is facilitated. Advocate for industry adoption.

T3: A preproduction prototype is produced, based on iterative design cycles with end-users, clinicians, and caregivers. A commercialization pathway is identified.

Partnerships

Industry: LUCI Mobility, Inc, provides the first and only commercially available, FDA-registered driver assistance system for power wheelchairs. Co-Principal Investigator (Co-PI) Dean is the CTO and co-founder. The work for T2 and deployment efforts for T1 will happen at LUCI. In Phase 1, LUCI led all WDI development. Function Engineering has 25 years of experience in mechanical design and engineering for product development, and in Phase 2 will perform technical development subprojects under T1 and T3. Life Drive, LLC, creates adaptive technology for people with disabilities. They have been the first adopter (outside of LUCI) of the WDI and will continue to test and contribute to the WDI open-source API in Phase 2.

Nonprofits: The Shirley Ryan Ability Lab is the #1-ranked rehabilitation hospital in the United States. It houses Principal Investigator (PI) Argall's lab, will be the site of all T3 development and T1 end-user studies, was the site of T1 and T3 development in Phase 1, and employs occupational therapist (OT) Van Dyck and physical therapist (PT) Butts who will contribute clinical expertise on T1 and T3. AbleGamers is a charity dedicated to creating opportunities that enable play for persons with disabilities. Players from their network will provide interface design feedback on T3.

Academia: Northwestern University is an R1 research institution with leadership in engineering and medicine. PI Argall a member of its faculty, and will continue to lead the project itself, the work on T3, and the end-user studies of T2.

Individuals: Daniel Vance, LOTR, ATP, is an OT with expertise in assistive technology who has been with Project DRIVE since day one and will lead clinical efforts on T3. Kevin Rowland has been actively developing code, evaluating hardware, and contributing to ideation in Phase 1, and will continue to be a core team member in Phase 2. He is living with Amyotrophic Lateral Sclerosis (ALS).

Intellectual Property

T1: Driver assistance methods have been developed using LUCI's open source Sandbox development environment with drive paradigm software IP owned by Northwestern University and the Shirley Ryan AbilityLab. Discussions are underway for LUCI Mobility to license this IP from Northwestern University and the Shirley Ryan AbilityLab, for release within their commercial product.

T2: The WDI API has been released open source under an Apache 2.0 License, within a github repository maintained by LUCI. It will continue to be supported throughout and beyond Phase 2.

T3: IP that results from the flexible interface development will be jointly owned by Northwestern University and the Shirley Ryan AbilityLab. Two commercialization pathways are being explored: (1) spin-out a new start-up company, or (2) acquisition by an existing industry manufacturer.

RAFAS

Restoring Arm Function After Stroke

Lead PI: Conor Walsh
walsh@seas.harvard.edu

Kristin Nuckols
kristin@imagorehab.com

Molly Hester
mjh@post.harvard.edu

Patrick Slade
slade@seas.harvard.edu

David Lin
dlin7@mgh.edu

Overview

The vision of Restoring Arm Function after Stroke (RAFAS) is to create an at-home, connected wearable rehabilitation solution to restore arm function and independence for stroke survivors and others with upper limb disability. The team's solution is called Reachable. This wearable technology (1) supports stroke survivors to use and incorporate their impaired arm during daily activities, supporting the goal of high-repetition therapy, and (2) remotely monitors recovery and provides feedback to encourage behavioral change.

Description

Stroke is a pervasive neurological condition. It affects approximately one million Americans annually, with higher risk and incidence rates for minorities (Black, Hispanic, and Native American) and those of lower socioeconomic status. An estimated 75% of stroke survivors have long-lasting upper-limb impairments and are unable to incorporate the affected upper limb into meaningful activities of daily living (ADLs). The number of arm repetitions during a conventional therapy session is an order of magnitude below what is required to recover meaningful arm function. To address this issue, the team has developed a hybrid hardware-software wearable solution–Reachable–to enable and encourage increased use of the arm during ADLs. Reachable includes a soft wearable robot, which provides antigravity support and collects wearable sensor data as a user moves their arm. The robot's controller is tuned with machine learning algorithms to properly detect user intention using wearable motion sensors while performing ADLs and provide support based on a user's function such that the support can be reduced over time as user gains more function, thereby enabling rehabilitation of the arm. Reachable also introduces new digital therapeutic capabilities that uses wearable sensors to track upper limb movement and suggests ADLs based on individualized goals and intact function of the users via an app to induce behavioral change.

Differentiators

RAFAS' convergent research approach brings together partners from academia, nonprofit, industry, and innovation hubs. The team is composed of experts in six distinct disciplines, and brings over 50 years' experience in high-risk, interdisciplinary, collaborative use-inspired research and product commercialization as well as fervent commitment to diversity, equity, inclusion, and accessibility. Leveraging their team's expertise and history of commercializing wearable technologies for stroke rehabilitation, RAFAS is in a strong position to build a sustainable technology for at-home stroke rehabilitation. Reachable addresses the limitations of previous wearable rigid robotic approaches, which lack portability. Notably, RAFAS enables a paradigm shift from the current 'in clinic' model of rehabilitation to one of remote physical rehabilitation for persons with upper limb disability, where everyday activities are transformed into therapy.

Road Map

By the end of Phase 2, RAFAS will deliver:

1. An advanced prototype of Reachable that provides both support from a soft wearable robot and information from a digital therapeutic app.

2. Data quantifying advanced prototype performance on stroke survivors in terms of the biomechanical impact (from motion capture studies) and usability (from at-home testing and focus groups).

3. Translation pathways and a timeline for technology transfer to industry.

4. An open source, large-scale data set of motion capture data for both impaired and unimpaired upper extremity movement.

5. An online, continuing educational module training therapists in telerehabilitation.

6. New programming for outreach to school students aimed at reducing stigma associated with disability.

Infrastructure and capabilities for sustaining research and development in cloud-connected wearable technology to enable new approaches to research, including the analysis of large datasets from studies in the real world.

Partnerships

RAFAS' core team includes Harvard University and Massachusetts General Hospital who combine their expertise in stroke recovery, industrial design, functional apparel, wearable robotics, and machine learning to conduct use-inspired research and develop low-fidelity prototypes and concepts of the at-home rehabilitation solution Reachable. University of New Hampshire brings leadership in experimental psychology while Imago Rehab, an established leader in telehealth and commercialization, leads the RAFAS effort to assess system performance and usability with a diverse population of end-users. New England Medical Innovation Center, SIMBEX, and C3 Medical deliver exquisite product development and medical technology commercialization experience central to program sustainability and product commercialization. The Bionic Project and Cecropia Strong are two nonprofits: Bionic has a niche platform for raising awareness and reducing bias towards persons with disabilities and advances the team's broadening participation goals while Cecropia Strong supports persons with disabilities. The company's president is a stroke survivor and patient advocate and advises RAFAS on end user engagement.

Intellectual Property

RAFAS has existing intellectual property (IP) related to the soft wearable robot design, robot control algorithms, and quantifying movement of human movement using wearable motion sensors with Harvard. During Phase 2, the team's partner institutions will collaborate to file additional IP related to the advanced prototypes. Harvard's Office of Technology Development will work closely with the Move Lab, a translational research initiative, to explore licensing and partnership opportunities in the specific field of upper extremity rehabilitation as well as other markets (e.g., injury prevention in industry) to translate the technology.

RELAIT

Artificial Intelligence. Genuine Communication.

Lead PI: Christine Holyfield
ceholyfi@uark.edu

Eduard Dragut
edragut@temple.edu

Elizabeth Lorah
lorah@uark.edu

Stephen MacNeil
stephen.macneil@temple.edu

Slobodan Vucetic
slobodan.vucetic@temple.edu

Overview

Communication for millions of Americans and many more worldwide is restricted by speech and language limitations. They require access to modes of communication that augment or provide an alternative to speech. Current augmentative and alternative communication (AAC) technologies require significant time and effort to learn, personalize, use, and relate to the immediate communicative context. RELAIT envisions a new generation of AAC technologies that reduce learning and use barriers by leveraging artificial intelligence innovations to provide users and communication partners with more personally meaningful, relevant, and accessible ways to communicate.

Figure. Convergent approach for next-generation AAC technology

Description

Over 7 million Americans and 97 million people worldwide have restricted speech and language resulting from a developmental disability, such as autism or Down syndrome, or an acquired disability, such as sustaining a stroke or a traumatic brain injury. Communication limitations profoundly affect individuals' daily lives, restricting not just their ability to convey thoughts, but also their participation in education, employment, and social interactions.

This project will spearhead a converging effort to spur the deployment of use-inspired, evidence-based, next-generation AI-powered AAC technology innovations. To achieve this, research and development among AAC and computer science fields must converge, and

innovations must be transferred into the hands of AAC users through a multi-pronged effort that includes partnerships with users, other stakeholders, and the AAC industry.

The key insight guiding RELAIT's approach is that AAC devices are currently disconnected from the contexts in which they are used. The new technology will sense and analyze contextual information about the user and their environment to produce new capabilities that support a wide range of end-users. The AI innovations include approaches that seamlessly transform information between various modes of communication, the applications of large language models to improve communication speed and foster richer interactions, and finding solutions for safeguarding user privacy. RELAIT's work is guided by human-centered design practices with deep participation from end-users.

RELAIT will specifically focus on designing context-aware solutions that leverage communication partner speech, the physical environment, and users' natural communication.

Differentiators

RELAIT's team is uniquely equipped to deliver high-impact, high-efficacy AAC technology innovations into the hands of users. RELAIT represents an unprecedented convergence of AAC experts, AI experts, human-computer interaction experts, AAC users, clinical partners providing AAC services to a diverse range of users in a variety of contexts, and leading AAC hardware and software companies. Recognizing that the diversity of existing AAC technologies stems from user heterogeneity, RELAIT's multi-pronged convergence research and sustainability efforts will design, prototype, and evaluate new technologies through strategic partnerships, with an eye toward simultaneously lifting as many boats as possible in the AAC community and industry. The team and partners will work collaboratively to move AAC technologies one step closer to meeting the needs and mirroring the

dreams of the individuals who require them. RELAIT will do so under an accelerated timeline, delivering technology innovation, transfer, and support to end-users.

Road Map

During Phase 1, RELAIT embraced use-inspired research and engaged with over one hundred participants for interviews, ethnographic observations, and participatory design workshops. RELAIT designed several AAC prototypes that integrate communication partner input, the physical environment, and user natural communication. In Phase 2, RELAIT will continue to engage end-users to design and evaluate the team's innovations.

In year 1, RELAIT will focus on increasing the rate and quality of communication while ensuring self-determination of users. RELAIT will develop and clinically evaluate AI-supported solutions that integrate the natural communication of users, speech of communication partners, and contextual information pertinent to conversation.

In year 2, RELAIT will combine user and communication partner input and contextual information, use AI to integrate natural communication, including speech and gestures from users, and continue to evaluate the team's innovations. RELAIT's sustainability efforts will combine technology transfer to industry partners, in-house product development, and open sourcing of the code and know-how to the AAC community.

Partnerships

RELAIT developed three types of partnerships. First, RELAIT will collaborate with several AAC industry leaders to accelerate conversion of RELAIT's innovations into novel AAC products and features to ensure the work benefits end-users. Second, RELAIT will collaborate with several clinical partners who will support the human-centered design process through recruitment of participants, interviewing, and evaluation of the designs and prototypes within educational, medical, vocational, and community settings. Third, RELAIT will collaborate with several advocacy groups to gain feedback and guidance from a large and heterogeneous group of end-users to ensure sustainability and strengthen broader impacts.

Intellectual Property

RELAIT developed a plan to govern Intellectual Property (IP) management across all collaborations and partnerships. The plan is in accord with guidelines set forth by the U.S. National Science Foundation and provides a foundation for the agreements that have been and will be established during the project. It recognizes the significance of IP management in fostering innovation and collaboration.

SocialSense XR
Perceive the Invisible

Lead PI: Shiri Azenkot
shiri.azenkot@cornell.edu

Charles LaPierre
charlesl@benetech.org

Sean Dougherty
SDougherty@lighthouse-sf.org

Andrea Stevenson Won
a.s.won@cornell.edu

Overview

Social virtual reality is the next step in the evolution of platforms to connect people remotely for teamwork, but it is currently inaccessible to blind and low-vision people. While existing research has investigated how to address some aspects of accessibility in virtual reality, such as navigation, many areas are unaddressed; for example, how to communicate social information such as nonverbal behavior. In addition, current research on accessibility has generally not been translated into guidelines in a way that makes broad industry adoption possible. As social virtual reality becomes more widely used, now is the time to invest in accessibility for these platforms.

Description

To address this need, the SocialSense XR team will work with industry and community partners to conduct research, design prototypes, develop guidelines, and provide educational resources to make social virtual reality platforms truly accessible for blind and low vision (BLV) users. Their work will be informed by research on the needs of BLV users in video-conferencing platforms, such as Zoom, as well as participatory design with members of the BLV community. It will result in six categories of outcomes: VR Accessibility Research, Guidelines and Demonstration Modules, Industry Adoption, Promotion and Advocacy, Professional Development, and Sustainability.

Differentiators

This project is unlike any current projects in both scope and aims. Although other research has addressed some accessibility aims for social virtual reality, adoption by industry has been hampered by a lack of organization and dedicated resources to develop and publicize guidelines. In addition, there is a dearth of research addressing needs specific to social interaction. The team's ability to develop and disseminate research and prototypes will not only provide guidelines to address

pressing accessibility needs but will also provide a framework on which other researchers and industry members can build.

SocialSense XR's work is a unique and essential component of the track's overall portfolio. Most efforts in their track aim to leverage new technologies to address accessibility challenges faced by people with disabilities. These are critical efforts, and the team fully supports them. However, as technology advances, the research and development community must also ensure that the new technologies themselves are accessible. That is, they must be fully inclusive and usable by people with disabilities. In this proposal, SocialSense XR focuses on the critical problem of making the XR technologies themselves accessible. This is essential for the full inclusion of people with disabilities in modern life.

Road Map

The team will complete two cycles of yearly internal assessments, public symposiums, and educational offerings, releasing demos and guidelines each year after a cycle of research.

Partnerships

Current industry partners who have signed letters of collaboration include Google and Microsoft. Members of these companies, as well as Apple, Meta, and Mozilla, were part of the team's Phase 1 research, and their contributions through interviews and focus groups highlighted the need for research and prototypes to inform industry adoption of guidelines and standards. These partners will participate in the annual industry roundtable and provide feedback on prototypes and plug-ins for both social virtual reality and related work in videoconferencing.

Intellectual Property

As the goal of the project is to create public guidelines and prototypes and encourage maximum adoption, it would be antithetical to pursue aggressive intellectual property restrictions. Thus, the team plans to use an open-source license such as the Attribution-ShareAlike 4.0 International License from Creative Commons or the Massachusetts Institute of Technology Creative Intellectual Property (IP) License Framework. These would enable others to share and adapt the material at no charge; would require users to give appropriate credit to the SocialSense XR team, empowering their promotion and advocacy work; and would require users to utilize the same license if they remix, transform, or build upon the material to ensure it remains open source. All IP contributed by partners included in this proposal would utilize this license and be considered to belong equally to each of the organizations. This applies to future partners as well. This would apply to things such as their AI training dataset and methodology as well; however, to safeguard the distinctive methodologies and extensive research and development behind the work, certain codebases and tools, especially those of Benetech, will remain proprietary.

Deliverables

To achieve their goal of making VR accessible, the team has planned a series of deliverables related to their six outcomes described above. Each deliverable will be documented on their website, in one or more academic papers, or through an internal report. They will continually assess the efficacy of their deliverables using measures that generally fall into three categories: the deliverable features (e.g., number of seminars held), views and engagement data (e.g., views of a webpage), and self-reported user feedback (e.g., as collected through a survey). These measures will be reviewed by the team to adjust their ongoing plans.

Critical Convergence

The critical convergence for each of the major deliverables shows why their team is uniquely suited to succeed in this project. These include the strong VR accessibility research skills of Azenkot, Won's history of research on VR embodiment and social interactions, the user research experience and BLV community ties of Dougherty and the LightHouse team, and the software development and experience authoring guidelines of LaPierre's team at Benetech. In addition, they will build on Slater's experience with spatial sound design and the landscape of VR products, and Slater & Dougherty's BLV community ties and advocacy. A core principle of access is that it evolves. Building a community of experts and end-users who will continue advising SocialSense XR's development beyond the next two years is essential will be the foundation on which many more years of inclusive design can be built.

Touché

Empowering Stroke Recovery Anywhere

Lead PI: Allison Okamura
aokamura@stanford.edu

Asad Asad
asadasad@stanford.edu

Sean Follmer
sfollmer@stanford.edu

Maarten Lansberg
lansberg@stanford.edu

Thad Starner
thad@gatech.edu

Overview

Stroke is a leading cause of serious long-term disability in the United States, resulting in millions of Americans with motor impairments. Touché is a hand-worn device designed for people with a history of stroke who want access to rehabilitation effortlessly and anywhere. This technology reduces muscle contractions due to stroke through vibration stimulation, allowing some users to open a hand that has been closed in a fist for years.

Description

Many people with a history of stroke have difficulty independently performing activities of daily living, such as eating and dressing. A common cause is immobilizing muscle contractions (spasticity) for which there is currently no treatment that is safe, affordable, and portable. Touché is a new, effortless way to treat spasticity without painful and costly injections or visits to a rehabilitation clinic. Studies have demonstrated significant, meaningful reduction in spasticity after 20 minutes of wearable stimulation and persistent reduction after weeks-long treatment.

Touché can be charged, donned with one hand, and used at home. The low-power vibrations are comfortable and can be applied for hours each day. Persons with disability after stroke can use Touché even if they have no ability to move their affected hand. The device is paired with a mobile app for assessment, motivation, and communication with doctors. The team is designing their solution in a way that is accessible to people who are medically underserved and disproportionately impacted by the challenges of disability after stroke.

Differentiators

With other treatments, many stroke survivors have residual spasticity and debilitating side effects. The gold standard to treat spasticity is recurrent botulinum toxin (Botox) injections. The downsides of Botox injections include side effects, high costs, and diminishing efficacy over time, requiring subsequent injections. Clinical studies indicate that Touché is equally effective as, and lasts longer than, Botox injections to treat spasticity at a much lower price point.

Other approaches are at-home treatments that replicate physical therapy exercises used in the clinic. These require significant effort to move that is impossible for some and quickly abandoned by others. Touché treats spasticity in any setting with a lightweight and portable device that is low-effort and used in the background of daily life.

Touché is a wearable, take-home device that uses low-power vibrations to reduce spasticity after stroke, which is a leading cause of long-term disability in the United States

Road Map

The team will achieve four key milestones in Phase 2:

1. Advance device engineering to a design freeze and prepare for manufacturing and distribution. Key deliverables include finalizing and executing a contract with a design firm (Q1-Q2, 2024), creating 25 fully functional prototype devices (Q3-Q4, 2024), identifying a contract manufacturer (Q1-Q2, 2025), verification testing (Q3-Q4, 2025), and creating 200 devices for a clinical trial (in 2026, post-Phase 2).

2. Complete integration of the smartphone app alongside the hand-worn vibrotactile stimulation device. Key deliverables include completing the app (Q1-Q2, 2024), integrating it with the device (Q3-Q4, 2024), ensuring the hardware and software meet privacy and policy requirements (Q1-Q2, 2025), and incorporating revisions based on learnings (Q3-Q4, 2025).

3. Test Touché in communities of interest and assess social impact via quality-of-life metrics developed from Phase 1 surveys and interviews. Key deliverables include completing three participatory design workshops with the device prototypes and smartphone app (Q1-Q2, 2024), user testing with 25 participants using the integrated device and app (Q3-Q4, 2024) and implementing changes from the results of the user testing (Q1-Q2, 2025).

4. Implement a sustainable business model for long-term impact. The key deliverables include establishing a company or, alternatively, a nonprofit or licensing approach (Q1-Q2, 2024), deciding on a regulatory and reimbursement strategy (Q3-Q4, 2024), applying for post-Phase 2 clinical trial funding (Q1-Q2, 2025), finalizing funding for post-Phase 2 activities (Q3-Q4, 2025), and commencing scaled manufacturing and distribution (in 2027, post-Phase 2).

Partnerships

In Phase 1, the primary partners were Stanford University and Georgia Tech. Stanford was responsible for the vibrotactile stimulation device design, human-centered design activities, measuring social impact and gathering user feedback. Georgia Tech was responsible for developing the smartphone spasticity assessment app, revising the electrical hardware and firmware of the hand-worn device, and supplementing user studies. The team will continue these responsibilities in Phase 2. New partners in Phase 2 include Cornell Tech for mobile health software focused on patient motivation, nonprofit Stroke Onward to provide perspectives of end-user stroke survivors and their supporters, and additional Community Partners to allow the team to understand and deliver solutions to medically underserved users. All partners will meet regularly, help define project goals, and provide guidance and feedback on the device and app. A design firm will be selected in Phase 2 to accelerate manufacturing and deployment.

Intellectual Property

The team has implemented an intellectual property (IP) management strategy and filed for patents to protect innovative features. Notable IP includes tactile stimulation methods for rehabilitation therapy from Georgia Tech and Stanford University. The team received two separate Freedom to Operate assessments of the relevant IP landscape, indicating that there is no pre-existing external IP that would prevent the commercialization of their current technologies. The project may generate additional IP, mainly related to measuring spasticity using mobile phones. Both Stanford and Georgia Tech value the inventor's will and have expressed that a company by or related to the inventors would be a preferred licensee.

UNav

Empowering Journeys, Beyond Sight

Lead PI: John-Ross Rizzo
JohnRoss.Rizzo@nyulangone.org

Chen Feng
cfeng@nyu.edu

Maurizio Porfiri
mporfiri@nyu.edu

Sundeep Rangan
srangan@nyu.edu

Yao Wang
yw523@nyu.edu

Overview

UNav's VIS⁴ION wearable and VIS⁴ION mobile platforms revolutionize commuting, situational awareness, and navigation for indoor and outdoor spaces for people who are blind or low vision (pBLV). This is done using the UNav team's software for detailed environmental maps and collections of artificial intelligence microservices, hosted both locally on the device, and in cloud servers. Users use spoken interactions, audio alerts, and haptic feedback to better navigate the world, improving workplace opportunities and their quality-of-life.

Description

A core driver of high unemployment among pBLV (as high as 81%) is the difficulty, even danger, inherent in navigation. This includes navigating to work, around the office, and home again. Office spaces contain many obstacles that render spaces inaccessible. These issues extend to other crucial infrastructure for work opportunities and quality of life, such as navigating universities, hospitals, and public transport. For outdoor and indoor travel, efficient wayfinding is essential. Navigation apps often rely on GPS, which provides poor outdoor localization in cities and is useless for indoor travel. However, UNav's unique camera-based approach to mapping and navigation offers new solutions.

Solutions for pBLV—VIS⁴ION uses the team's UNav mapping, user localization, and wayfinding software to leverage images from a user's device to locate and then guide safely and efficiently to destinations of interest. The team offers additional AI-services locally on VIS⁴ION. However, internet connectivity allows for server access to provide enhanced functionality. Their AI-services only require standard camera images, making VIS⁴ION accessible for a wide range of smartphones and users.

The team's VIS⁴ION wearable integrates additional sensors (relative to the mobile platform), a bone-

conduction headset, and haptic feedback. It hosts more AI-services locally on the system and unlocks more advanced features via network connectivity. The VIS⁴ION wearable gives users a discreet, hands-free option that allows users to keep their phones safely stored away.

Concept Diagram for VIS⁴ION platform
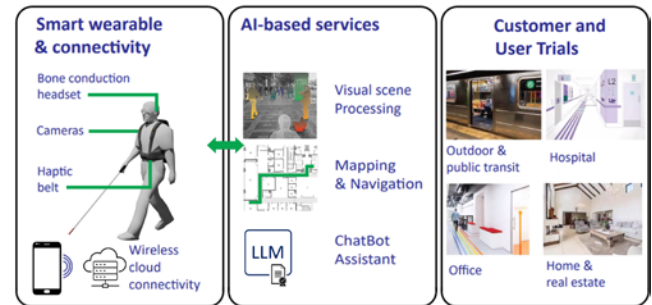
Differentiators

VIS⁴ION is unique in the pBLV-assistance space, owing to its combination of custom AI-services available locally on mobile/wearable platforms and cutting-edge advanced features hosted remotely on edge-/cloud-servers. This set of integrated services goes beyond micro-navigation support for nearby objects to macro-navigation support that requires global environmental understanding (e.g., office or subway layout)—an industry first. VIS⁴ION locates and guides the user within these indoor or outdoor spaces where GPS frequently fails, providing a complete, uninterrupted navigation solution.

The closest competitors include human-assistance offerings, such as Aira or BeMyEyes. Here pBLV 'facetime' sighted assistants to solve tasks. However, these require human volunteers, create a feeling of dependency, can lack privacy, and always require network connectivity, not to mention the limited field of view for the remote agent, which increases risk. In addition, human volunteers fatigue over time.

Other AI-powered Apps such as SeeingAI or OKO are focused on tasks solvable by single-image frame content—e.g., text reading, image description, or crosswalk status. However, they lack knowledge beyond single images, such as how to navigate to a place that is not in line-of-sight or global navigability/hazard assessments.

Road Map

Deliverables focus on integrating AI-services and field tests with pBLV and stakeholders:

Month 6: Integrate AI systems on servers (map navigation, image understanding, natural language).

Month 12: User testing and revision of each system.

Month 14: Integrate 'offline' lightweight AI systems.

Month 18: User testing and revisions for entire journey, including drops in network connectivity.

Month 24: Commercial/pBLV VIS^{4}ION systems.

Partnerships

This multifaceted project involves stakeholders throughout a wide spectrum of domains. To create and host the team's AI services, both locally, and remotely on servers, they partnered with TaggedWeb, Qualcomm, AT&T and Dell. To map and user-test key areas for pBLV, they partnered with New York University (NYU), The Lighthouse Guild, VISIONs, New York City Metropolitan Transportation Authority, NYC Department of Transportation, and Johns Hopkins to map offices, transport hubs, universities, and hospitals. For commercial stakeholders, they partnered with Elegran Forbes, Windsor Inspections, and EwingCole to evaluate how their AI-services assist real-estate industries.

Intellectual Property

NYU Langone Health has a comprehensive intellectual property sharing and management plan. The UNav project features patent 'US9646514B2' at its core with access to 'WO2016034999A1', and external open-source projects from Google.

US9646514B2—Patent owned by NYU, exclusive license to TNT. This covers systems that receive 3D information about the environment and convert to a 2D array of vibrotactile actuators as part of a wearable system.

WO2016034999A1—Patent owned by industrial partner, ARxVision, LLC. This covers a head-mounted multi-camera wearable with processing unit to perform multiple functionalities and/or analyze the 3D structure of a scene, which is communicated to the user.

Additional Information

Business Models: To monetize their technology, the team has a for-profit corporation, TNT. Their UNav mapping technology creates detailed 'digital twin' representations of both indoor and outdoor environments. Alongside automatically identifying and classifying environmental objects and information, it creates valuable models and data for government, business, nonprofit, and research entities.

Universal Pathways

Empowering Accessible Mobility through AI driven Insights

Lead PI: Brent Chamberlain
brent.chamberlain@usu.edu

Jon Froehlich

Keith Christensen

Xiaojun Qi

Yochai Eisenberg

Overview

Access to transportation is crucial for quality of life, especially for the 30 million working-age people with disabilities. Current systems are disjointed because of poor data and a legacy of exclusionary practices. Community planners are working to improve these systems, but they need reliable data. Universal Pathways' process offers a cost-efficient solution for data collection and services to help planners make equitable and just transportation decisions that benefit people with disabilities.

Description

There is a pervasive absence of multimodal transportation data about the existence and quality of sidewalks, intersections, and transit stops—critical infrastructure which significantly impacts the efficiency of travel and creates inequitable barriers. The Universal Pathways team asserts that quality data—on public transit, crosswalks, and sidewalks—is key to thriving, just, and equitable communities. It informs better planning, promotes equitable access to employment, enhances public safety, and reduces legal risks. Universal Pathways' software tools and processes efficiently detect transit stop and sidewalk accessibility features with high accuracy using computer visioning and nationally available street imagery. Key goals include: (1) Develop software that uses crowdsourcing and machine learning to automatically identify pedestrian and transit features related to accessibility, (2) Develop and integrate a model for workforce development of people with disabilities into AI+Human workflows, and (3) Create a Comprehensive Mobility Assessment Model for community analysis and infrastructure priorities.

Together, these deliverables will culminate in launching the Universal Pathways initiative. The initiative will be a streamlined, production-ready process that automates and validates pedestrian and transit feature identification into usable maps and scoring analytics to assist transportation and community planners in identifying and prioritizing inaccessible areas of their mobility network. This initiative will be supported by disability professionals and people living with disabilities to improve AI+Human validation of transportation elements. The related workforce program will offer training and professional experience for transitioning youth with disabilities interested in Science, Technology, Engineering, and Mathematics (STEM) or mobility advocacy fields.

Differentiators

There are few companies working on techniques to develop sidewalk data, but they primarily rely on painstaking crowd-sourcing or extensive on-site manual inventories. In contrast, Universal Pathways' work starts with a far more cost-effective computer vision approach using existing street imagery.

This is then aided by expert validation to improve data quality and reliability. Universal Pathways' less manually intensive approach allows them to tap into a broader range of markets (urban to rural). Unlike competitors, their tools and processes are also the first to move beyond sidewalk data by integrating other transportation infrastructure, land use, and demographic data to deliver geospatial analytics about the broader mobility network system. Further, their validation process is aided by the expertise of people living with disabilities to address known artificial intelligence biases. Universal Pathways also offers ongoing assessments for implementation of federally required Americans with Disabilities Act transition plans (no other competitor provides these).

Road Map

During the Convergence Accelerator Phase 2, Universal Pathways' primary aim is to advance the Universal Pathways' prototype to a market-ready solution. In the first year they will have the community data collection

protocol completed and have developed product offerings via feedback from partners and internal research. During this time, the Universal Pathways workforce initiative will be launched, in connection with Easterseals affiliate partners. By Q2, 2025, their primary products will be completed and associated services trialed internally. Beta trials (from request to final service) will commence with transportation partners, existing and anticipated new recruits, starting Q3, 2025. Universal Pathways is expected to move to a fee for service model by the end of 2025. They anticipate working with new customers, and to have secured additional grant or startup funding by 2026.

Partnerships

The Universal Pathways team is spearheaded by leading academic institutions across the U.S., including Utah State University, University of Washington's Allen School of Computer Science, and University of Illinois Chicago. They have a decade of prior related accessibility focused research. Collectively they have received millions in funding from the National Science Foundation and the National Institute on Disability, Independent Living, and Rehabilitation Research. Their Phase 1 partnership with Easterseals is solidified in Phase 2. They also continue collaborating with the advocacy nonprofit, Disability Rights Washington. In Phase 2 these partners will be joined by the Shirley Ryan AbilityLab, as welltransportation organizations, Frontier Municipal Planning Organization and Fort Smith Transit Agency (both from Arkansas) and the Wasatch Front Regional Council (Salt Lake City Metro) in Utah to pilot test Phase 2 products prior to an official launch. Finally, Utah State University's Center for Entrepreneurship will consult on business development and sustainability beyond the Phase 2 funding period.

Intellectual Property

Code, assets, and process that fall within Universal Pathways' software ecosystem span different licensing structures from open source to proprietary. The procedural processes holding the primary value are proprietary with licensing options being explored. University joint ownership across intellectual property is being negotiated. Universal Pathways is open to external investment, but partners will be required to sign nondisclosure agreements, and levels of access to information will be negotiated.

WeCAN Socket

Reshaping the Future of Prosthetics

Lead PI: Yinghua Jin
jin@rockytechs.com

Alena Grabowski
alena.grabowski@colorado.edu

Joseph Johnson
jjohnson@opquorum.com

Jianliang Xiao
jianliang.xiao@colorado.edu

Wei Zhang
wei.zhang@colorado.edu

Overview

The WeCAN Socket team tackles a critical challenge in the prosthetics field—creating an adaptive socket that maximizes comfort and functionality for amputees. Traditional prosthetic sockets often lead to discomfort due to poor fit and limited adjustability. The WeCAN Socket provides amputees with a customized prosthetic that is long-lasting and comfortable. Utilizing advanced materials and e-skin sensing technology, the socket delivers instant sensory feedback on pressure, temperature, and moisture and adapts to an individual, reducing discomfort, frequent replacements, and overall cost.

Description

Amidst increasing sports injuries, obesity, an aging population, and conditions like diabetes and osteoarthritis, the demand for rehabilitation and assistive services is surging. Globally, limb loss affected 9 million people in 2015, a figure expected to rise to 45 million by 2050. In the U.S., 1 in 190 people currently face this reality. Addressing this pressing need, this project seeks to bring transformative changes to the prosthetics industry. This endeavor aims to overcome current socket design limitations, introducing a system that features an adjustable outer socket, a meticulously perforated inner socket equipped with e-skin sensors, and a breathable cooling liner. Further enhancing this innovation, the team is incorporating a user-centered mobile app, designed to provide real-time sensory data on pressure, temperature, and moisture. Through materials, engineering, and design innovation, they are developing a socket that offers adjustability and comfort unparalleled in the field. This breakthrough has the potential to transform the lives of amputees, enabling them to regain confidence and functionality, and bringing them significant cost savings.

Differentiators

What sets WeCAN Socket apart is the focus on dynamic adjustability. While some solutions exist, none offer the level of customizability this project is achieving. Traditional sockets lack adaptability, resulting in discomfort and limited movement. Using a new reshapable material and incorporating real-time e-skin sensory feedback, the WeCAN Socket can adapt to changes in residual limb volume and contour, aiming to reduce discomfort and improve mobility. Because of its reshapability, the socket requires less replacement, and it reduces patients' need to see a clinician, providing substantial direct and indirect cost savings. Sensory data can help clinicians pinpoint the issues and help patients better justify insurance claims.

Road Map

- Phase 1 (Completed): Developed proof-of-concept, secured industry partnerships, and conducted preliminary user testing.

- Phase 2: Refinement of prototypes, fabrication of socket and sensors, breathable liner development, market research, intellectual property (IP) protection, and regulatory preparation, testing of the system.

- Phase 3 (Upcoming): Finalize manufacturing processes, scale up production, initiate distribution, regulatory submittal, and seeking/securing funding and investment sources.

Partnerships

WeCAN Socket is backed by a strong network of collaborators, each contributing unique expertise:

RockyTech: As the project lead, RockyTech brings its dedication to research and innovation, complemented by its advanced materials.

Quorum Prosthetics: The team's industry partner, Quorum Prosthetics, offers valuable insights from the front lines of prosthetics care, with extensive clinical experience and additive manufacturing expertise.

University of Colorado Boulder: By tapping into the university's cutting-edge research and resources, they leverage a diverse range of expertise, spanning materials science, mechanical and electrical engineering, to biomechanics.

Advisory Expertise: WeCAN Socket team's advisory board comprises accomplished professionals from academia, business, nonprofit organizations (One Leg at a Time), and government agencies (Department of Veterans Affairs).

Intellectual Property

Currently, RockyTech has filed a patent for the reshapable socket material, Quorum Prosthetics owns two patents for their Quatro socket design, and University of Colorado Boulder owns a patent for their e-skin mimic device. Each entity participating in the project retains full ownership of their existing IP, including proprietary data, as well as any IP developed through their individual efforts. The WeCAN Socket team has established IP agreements with the partners for foreground IP. They will engage in discussions with future potential partners and interested stakeholders to explore licensing opportunities and technology transfer agreements. Through these agreements, they will gain access to the relevant IP, allowing them to incorporate the applicable technologies into their prosthetic solutions.

TRACK I:
SUSTAINABLE MATERIALS FOR GLOBAL CHALLENGES

The world is dependent on critical materials for every aspect of life and work, including manufacturing, energy, infrastructure, healthcare, and national security. However, current material design, production, and use are not sustainable for human or planet health. Instead, approaches that consider the circular economy are urgently needed and are intended to capture the full life cycle of "systems thinking" to produce environmentally and economically sustainable material and products. This includes circular economy principles, standards, tools, and metrics across all levels of the supply chain, as well as the need to educate and train current and future generations of researchers and workers on circular design.

The U.S. National Science Foundation Convergence Accelerator's Track I: Sustainable Materials for Global Challenges is focusing on developing use-inspired solutions to advance the development of environmentally sustainable materials by bringing together fundamental materials science with materials design and manufacturing processes; and incorporating circular design principles to create environmental and economically sustainable materials and products. Across the cohort of teams, the track is addressing challenges along the entire materials lifecycle including upstream solutions as well as reuse and recycling of materials. The environmentally sustainable development of new materials and manufacturing processes can mitigate the Triple Planetary Crises of pollution, climate, and biodiversity loss.

NSF is partnered with the Commonwealth Scientific and Industrial Research Organisation of Australia (CSIRO) for Track I and is funding Australian researchers participating on two U.S. teams.

Sustainable Materials for Global Challenges funded Phase 1 teams include:

Brine Miners—Led by Oregon State University, Brine Miners converges an energy efficient technology platform to solve this challenge by producing fresh water, a limited but critical resource, from waste brines, while simultaneously extracting valuable materials, like lithium for energy storage.

COncrete2—Led by University of Alabama, Concrete2, is an innovative, easy-to-use concrete manufacturing solution, which aims to reduce the cost and the carbon footprint of concrete. Using a biomimetic CO_2 mineralization technology and circular economy principles, Concrete2 has the potential to fully recycle production waste, sequester CO_2 in the concrete, and produce cost-effective concrete with a much lower carbon footprint.

FUTUR-IC—Led by Massachusetts Institute of Technology, FUTUR-IC is a global sustainable microchip manufacturing alliance designed to drive convergence of Technology-Ecology-Workforce to establish a common ground for green business decisions that optimize for people, planet, and profits. The FUTUR-IC initial technical focus is a sustainable Electronic-Photonic Package that can provide a near-term sustainable solution for communication and electronics for computation.

MetaForce—Led by University of Florida, MetaForce is addressing critical challenges related to chip interconnect and advanced electronic packaging. Using a metaconductor solution enhances power efficiency by 500% and reduces material usage by 80% compared with the conventional copper counterpart, laying the foundation for sustainable energy and material practices.

MoMatS—Led by Massachusetts Institute of Technology, MoMatS is developing state-of-the-art computational methods and an opensource software platform for sustainable socioresilient materials design. The solution, which integrates and optimizes high performance technical properties, environmental life cycle assessment, and metrics for social impacts is initially focusing on one of the largest industrial polymeric materials.

NURTURE—Led by Stony Brook University, NURTURE's global research and solutions team uses zero-waste technology for agriculture and horticulture by converting food- and agro-waste into safe fertilizers, moisture-rich biogels, and nutrient-rich growing media. NURTURE has the potential to address climate variability and food insecurity with locally tailored solutions.

OpenMatFlo—Led by University of Florida, OpenMatFlo is an artificial intelligence tool that optimizes concrete design while reducing carbon and cost at the same time. The solution's smart contract-and blockchain-based platform for carbon emission verification serves as the foundation and data infrastructure of a transparent supply chain of concrete, while the concrete e-commerce platform has the potential to revolutionize traditional concrete procurement.

OreCast—Led by Cornell University, OreCast is an advanced geo-mineral analysis tool linking remote hyper-spectral and microscopic X-ray imaging in a next-generation scientific computing framework. The solution's data infrastructure provides leaders in critical minerals, building materials, and communities valuable insights into mineral resource potential such as mine tailings, enabling decision-making and a transition towards a circular economy.

PFACTS—Led by IBM Corporation's Almaden Research Center, PFACTS accelerates efforts to replace, redesign, and remediate fluorine-containing "forever chemicals," or per- and polyfluoroalkyl substances (PFAS), used in many products and processes. The PFACTS knowledge base and AI tools enable stakeholders to assess PFAS hazards, prioritize replacements, and identify remediation materials to find faster solutions for forever chemicals.

Protify Textiles—Led by Rensselaer Polytechnic Institute, Protify Textiles combines engineered proteins made by fermentation with plant-based fibers to create new textiles with emergent properties. The solution aims to provide sustainability-minded consumers and fashion designers with cost-effective biobased alternatives to synthetic fabrics, as the textile industry currently relies on non-renewable materials.

ReCreateIt—Led by re:3D Inc., ReCreateIt, a net-zero manufacturing lab, is building a more circular economy by reducing landfill waste. Partnered with the Austin Habitat for Humanity ReStores, ReCreateIt enables low-income homeowners to design sustainable home goods, using recycled plastic waste through 3D printing. This team includes Australian researchers from University of Wollongong and Western Sydney University.

Redaptive Recycling—Led by Black & Decker (U.S.) Inc, Redaptive Recycling transforms inconsistent recycled plastics into high-performance materials using machine learning (ML), manufacturing methods, and polymer science. It enables real-time process control and cost reduction using predictive ML models. This platform allows manufacturers to seamlessly incorporate more recycled content into their products and reduce carbon emissions while meeting performance targets.

ReSpool—Led by University of Delaware, ReSpool delivers circular textile solutions through proprietary drop-in technology that turns discarded clothing into new fibers for applications in fashion, construction, agriculture, and geo-textiles. Their approach has the potential to grow regional economies for circular fashion.

SOLAR—Led by Battelle Memorial Institute, SOLAR (Securing critical material supply chains by enabling phOtovoltaic circuLARity) develops the technology needed to achieve sustainable solar panel recycling, while helping to secure domestic supply chains of critical materials. SOLAR enables a circularity for end-of-life panels by developing decision making tools for panel owners and recyclers, reducing recycling costs to rival landfilling, and ensuring valuable materials are repurposed.

SpheriCity—Led by University of Georgia, SpheriCity is a cross-sector tool that examines how plastics, organics, and construction and demolition materials flow through cities. Through SpheriCity, community members are trained in how to collect baseline data that can inform circular solutions, while accessing a global database to compare and connect with other communities across the world.

Topological Electric—Led by Massachusetts Institute of Technology, Topological Electric accelerates topological materials toward next-generation energy and information devices with sustainability, scalability, superior performance, and low cost. The aim is to accelerate the currently slow rate of industrializing topological materials and potentially apply the methodology to other classes of materials.

urbanREmine—Led by Ames National Laboratory, urbanREmine uses sustainable and economical technologies to recover rare earth elements from waste materials and electronics to refine and reuse them in crucial energy transition and defense components such as electric vehicles and fighter jets, thereby advancing the United States' priority of decreasing geopolitical risks due to foreign dependence.

Brine Miners

Extracting Value, Reducing Waste.

Lead PI: Zhenxing Feng
zhenxing.feng@oregonstate.edu

Astrid Layton
alayton@tamu.edu

Chih-hung Chang
chih-hung.chang@oregonstate.edu

Kelsey Stoerzinger
zinger@umn.edu

Overview

Brine Miners transforms salty waste from water desalination (increasingly the only option to access fresh water) into a value-added resource. Desalination produces an intensely salty "brine" wastewater that negatively impacts marine ecosystems when dumped back into oceans. Brine Miner's innovation reduces these environmental impacts and provides economic benefits, extracting valuable minerals and hydrogen and eliminating environmental and economic disposal costs.

Description

Brine Miners' innovative platform technology extracts critical minerals like lithium, magnesium, and green hydrogen from desalination wastewater. These have immense value as feedstocks for growth industries and are traditionally obtained via expensive and environmentally harmful processes. Mining these materials from brine waste offers a reliable and economically viable source that also eliminates an environmentally harmful waste stream, supporting U.S. circular economy efforts to reduce waste, reuse critical materials, and protect the environment.

The Brine Miners team of researchers, entrepreneurs, environmentalists, and end-users see abundant saline waste brines as a valuable resource. The team's technical and business capabilities combine existing processing technology with practical operational needs. The process' only byproduct is clean water that can contribute to habitat restoration.

Existing desalination plants around the world take in 86,458 million cubic meters of seawater annually. Data shows that approximately 16 million kilograms of lithium, representing a more than $2.2 trillion market value, is currently lying untouched in waste brines. The large number of minerals in hypersaline brine offers a unique opportunity to advance circular economy efforts via Brine Miners–a chance to produce a sustainable

supply of critical minerals and eliminate a harmful waste stream.

Secondary user-inspired market data also shows that the Brine Miners platform is suitable for other types of wastewater handling, such as those from semiconductor industries and oil and gas companies, offering a wide range of wastewater suppliers for whom Brine Miners can unlock millions of dollars in economic value.

Illustration of Brine Miners' use of waste inputs and creation of valuable outputs.

Differentiators

Brine Miners integrates multiple award-winning, patented innovations into a single, versatile platform that not only extracts lithium and other valuable minerals from extremely salty brine waste, but also generates clean water for industrial reuse or environmental rehabilitation. The team follows human-centered design principles in conjunction with a commitment to circular economy goals to develop their technology, remaining committed to using renewable energies and providing economically-effective options for brine waste producers. The Brine Miners solution is a robust platform different from historic water mining approaches, relying on a creative combination of heat and physical barrier-based desalinations. Electrically charged physical membranes are used to initially treat incoming brine waste, followed by a novel Zero

Liquid Discharge process powered by environmentally conscious heat sources. Through the team's partnership with SkyNano, an end-user that will use lithium carbonate produced by Brine Miners to capture and sequester carbon dioxide in the atmosphere, Brine Miners will move toward a near term goal of net carbon-negative operations.

Road Map

Year 1: Brine Miners will build a pilot-scale water-lithium separation system to produce concentrated lithium brines and clean water from seawater. The team will also demonstrate the removal of other target materials for use in growth sectors like concrete/construction, such as chloride and lithium carbonate, from brine waste. Production scalability and reliability will also be demonstrated.

Year 2: Brine Miners will focus on improving system performance, successful generation of cost-effective green hydrogen using proton exchange membrane electrolyzers, and integration of carbon capture. Further scalability, including reliable production to support carbon nanotube markets, will also be demonstrated. Brine Miners' market reach will also be expanded, demonstrating the viability of wastewater from partnerships with the semiconductor industry.

Years 1 and 2: Brine Miners will additionally develop circular economy models and indicators that will support these efforts at a national level, setting the stage for Brine Miners and the U.S. to be a leading supplier of critical minerals and sustainability efforts.

Partnerships

Brine Miners' multidisciplinary team is comprised of 15 researchers from academia, industry, and government and is supported by a project managing team and advisory board. Oregon State University (OSU) leads the technology development with Espiku, Membrion, SkyNano, MemPro, De Nora, and Challenger Biosciences. Research on water-mineral separation, mining, and green hydrogen production will be applied and scaled to maximize life cycle and circular economy benefits.

Partnerships from end-users such as the International Desalination & Water Treatment Group and Standard Lithium support pilot-scale prototypes. OSU's Advanced Technology & Manufacturing Institute, a massive innovation ecosystem of labs, industry startups, and state-of-the-art spaces, further catalyzes the research and development activities.

Texas A&M University leads the circular economy modeling and analysis, developing a systems level tracking and quantification approach for economic value retention and environmental benefits.

Intellectual Property

There has already been, and there is expected to be more, intellectual property created during Phase 2. The Brine Miners team is committed to openness and thus uses the least restrictive licensing to accommodate and encourage broad industry participation.

COncrete2

Strength Meets Sustainability

Lead PI: Jialai Wang
jwang@eng.ua.edu

Armen Amirkhanian
armen.amirkhanian@eng.ua.edu

Hongyan Ma
mahon@mst.edu

Siyuan Song
siyuan.song@ua.edu

Hongyu Zhou
hzhou8@utk.edu

Overview

COncrete2 develops a new and more sustainable manufacturing method for concretes, the biomolecule-regulated carbonation technology (BioCarb) method, which reduces the carbon footprint and cost of the concrete by sequestering CO_2, reducing cement content, and recycling all waste streams generated by new concrete production. This technique will help concrete producers to gain a competitive edge and meet market and global policy demands for concrete with reduced CO_2 emission. Moreover, given the ubiquitous nature of concrete within the built environment globally, COncrete2 offers significant environmental benefits to broader society.

Description

Concrete with ordinary Portland cement (OPC) as the main binder is the most widely used construction material in the world. However, the production of OPC based concrete is responsible for nearly 10% of anthropogenic CO_2 emissions, the consumption of more than 36 billion tons (Gt)/year raw materials and aggregates, and 2.2 Gt/year solid waste in the world. COncrete2 proposes a pathway to address this enormous environmental burden created by the concrete industry by harnessing the synergy of circular economy principles and a revolutionary manufacturing method of concrete, the BioCarb method. The BioCarb method engineers the cement slurry into a CO_2 absorbent, which can absorb and permanently store 25 to 50 times more CO_2 in fresh concrete than existing technologies. More importantly, the BioCarb method allows the concrete producers to use less cement in their concrete due to improved binding efficiency, recycle all waste fresh concrete and wash water back into new concrete, and use high-volume supplementary cementitious materials and recycled concrete aggregates in their concrete mixes. If all concretes (14.0 billion m3) are manufactured by this technique, there will be 0.25Gt CO_2 stored in the concrete and 2.03Gt

CO_2 is avoided every year. Therefore, this technology can reduce CO_2 emission up to 2.28Gt/year. In addition, 24 million cubic yards waste concrete and 9 billion gallons wash water can be recycled in U.S. every year, which can save concrete producers more than $2.6 billion per year.

Differentiators

Unlike any existing methods, COncrete2 proposes to add CO_2 into concrete before mixing through carbonating a cement slurry with a biomolecule added as a multifunctional admixture. This admixture can facilitate the carbonation of the cement slurry through chelating with calcium (Ca^{2+}) ions, not only accelerating the dissolution of Ca^{2+} from cement, but also further nucleating the formation of calcium carbonate ($CaCO_3$) during the carbonation process. As a result, the CO_2 uptake by the cement slurry is improved by at least one order of magnitude in comparison with existing methods. More importantly, the morphology and polymorphs of the $CaCO_3$ particles produced in the slurry are fine-tuned by the biomolecule so that more metastable $CaCO_3$ nanoparticles are produced. After being mixed with other ingredients of the concrete, these metastable $CaCO_3$ nanoparticles can trigger multiple mechanisms, making the produced concrete at least 20% stronger, which cannot be achieved by any existing method. As a result, less cement is needed to produce concrete, significantly reducing the cost and carbon footprint of the produced concrete.

Road Map

To accelerate the commercial adoption of the proposed technology, Concrete2 proposes an intensive research program based on feedback from multiple stakeholders to bring the BioCarb method to translation-readiness (TRL 7).

Key milestones include:

Milestone 1: Relationship between carbonation parameters and CO_2 uptake of the cement slurry is established (Q1).

Milestone 2: Relationship between the carbonation parameters and properties of fresh concrete is established (Q2).

Milestone 3: Underlying working mechanisms are confirmed (Q3).

Milestone 4: Over 20% improvement on the compressive strength of the concrete is reached by using the BioCarb method (Q4).

Milestone 5: Large-scale structural components with superior mechanical performance have been fabricated using the BioCarb method (Q5).

Milestone 6: Reactor needed to implement BioCarb method has been successfully fabricated (Q6).

Milestone 7: Completing LCA and TEA (Q7).

Milestone 8: The BioCarb method has been successfully demonstrated in at least one ready-mix concrete plant and one precast concrete plant (Q8).

Partnerships

A partnership consisting of stakeholders from academia, industry, and government has been formed to study the proposed BioCarb method in Phase 1. The project is led by University of Alabama, Tuscaloosa in partnership with University of Tennessee, Knoxville, Missouri University of Science and Technology, and Alabama A&M University (an HBCU). The team has also established an innovation ecosystem to collaborate with 15 stakeholders: end-users from ready-mix and pre-cast concrete industries, practitioners, local governments, owners, CO_2 suppliers, trade organizations, and technical societies. They will help the team to better understand the needs of end-users, ensure that the proposed technology complies with standards and building code, and provide real-world environments to test the proposed technology.

Intellectual Property

An intellectual property (IP) Management Plan has been made by the team. Any background pre-existing intellectual property will be owned by the originator. In this case, a non-provisional patent application on BioCarb was filed in Phase 1 by University of Alabama, Tuscaloosa. The new IP generated in this project will follow specific reporting requirements and will be reviewed for sole or joint ownership by the signatory parties. Any new partner is required to sign this plan.

FUTUR-IC

A Sustainable Microchip Manufacturing Alliance

Lead PI: Anu Agarwal
anu@mit.edu

Lionel C. Kimerling
lckim@mit.edu

Randolph Kirchain
kirchain@mit.edu

Elsa Olivetti
elsao@mit.edu

Samuel Serna
safes@mit.edu

Overview

For the first time in more than 40 years, the semiconductor microchip industry is confronted with limits to transistor size, to its environmental footprint, and to its workforce pipeline readiness. With the U.S. National Science Foundation Convergence Accelerator program, the team has established a global microchip sustainability alliance called FUTUR-IC, driving the convergence of Technology-Ecology-Workforce (TEW) in a three-dimensional (3D) fashion to establish a common ground for "green" business.

Figure 1. Illustration of Brine Miners' use of waste inputs and creation of valuable outputs.

Description

Microchip manufacturing and systems can be traced to 31% of global greenhouse gas emissions today. Mega Data Centers consuming tens of Megawatts of power and growing at 25-30% per year driven by video demand, will require 10% of the world electricity generation by 2030. Regulatory solutions threaten to disrupt the economics of an efficient global supply chain. Technology solutions require synchronized innovation along the supply chain from materials suppliers to system integrators to end-users. FUTUR-IC supports continued scaling of system performance while targeting Net Zero environmental impact by 2050 for the global community.

Semiconductor hardware, software and system architectures are undergoing simultaneous technology transitions today that present both opportunities and uncertainties. The information systems that drive Data Center workflows and ubiquitous sensing installations for the Internet of Things (IoT) aim to do the impossible: scale down costs, energy consumption, and latency to nearly zero, while simultaneously amplifying bandwidth and connectivity to seemingly infinite levels, within a constrained environmental envelope. Solutions defined by concurrent TEW constraints will build converged pathways on which to base decades of progress. The time to surmount these roadblocks for the microchip industry is now!
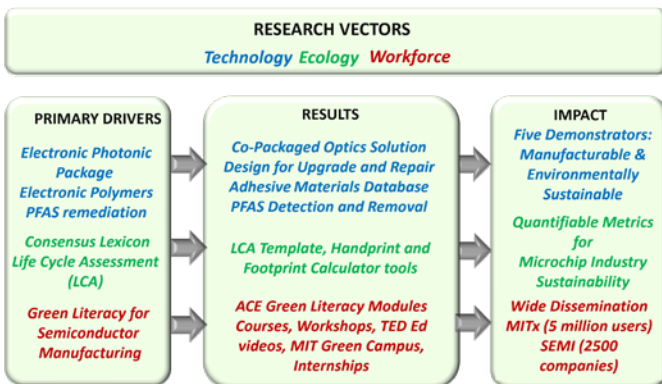
Differentiators

FUTUR-IC Global Alliance is a member-led association of thought leaders from industry, academia, and government working together to assess and remedy common risks presented by technology change, ecology boundaries, and workforce competency. This unique Alliance creates consensus for investments with its 3D-TEW research model. FUTUR-IC accelerates convergence of materials science with life-cycle analysis to drive materials and process design towards sustainable production and products.

Road Map

Technology: FUTUR-IC has adopted electronic-photonic package integration as its hardware driver. It has targeted scaling chip package Input-Output (I/O) to > 1 Petabit/second within a Net Zero ecology envelope. Investment examples are: 1) PFAS-free materials and process flows to meet package scaling requirements; 2) adhesive materials database for low temperature assembly; and 3) demonstration of new chip package architectures that mitigate end-of-life waste with capability for repair and upgrade under a new Design for Upgrade, Repair, Reduce, Reuse, Recycle (DfUR4) initiative.

Ecology: FUTUR-IC will 1) create data analytics for environmental and social impacts of microchip product lifecycles; 2) develop a consensus set of figures of merit; 3) develop the tools and processes for timely Life Cycle Assessment (LCA); 4) provide data and analysis for a guidance roadmap; and 5) provide tools for decreasing footprint burdens and increasing handprint remediations. The handprint is an innovative and holistic approach to facilitate the measurement, evaluation, and communication of the ecological, economic, and social sustainability impacts of products.

Workforce: FUTUR-IC provides a multidimensional TEW awareness that is transformed into solutions by its new educational curricula and content. Examples are: 1) SEMI (the microchip supply chain consortium) Green Literacy programs, 2) summer schools and bootcamps, 3) university courses, 4) Problem Based Learning (PBL) for community colleges, 5) TED-Ed videos and Virtual Reality (VR) sustainability games for K-to-Gray learners, 6) two Massachusetts Institute of Technology (MIT) green campus demonstrator sites for e-waste mitigation and green manufacturing materials and processes, 7) full spectrum internships for high school and community college students, and 8) annual workforce needs reports for each participating community.

Partnerships

FUTUR-IC's partners have developed programs across all three TEW vectors. Examples are:

Technology: iNEMI (industry association for joint development projects) for adhesive package materials.

Ecology: Tools and processes for LCA and handprinting throughout the microchip supply chain.

Workforce: SEMI sustainability literacy for executives and incumbent workers.

Intellectual Property

FUTUR-IC has filed three patents for assembly and architecture for advanced packaging. Continued intellectual property development is governed by three agreements: 1) shared rights under MIT's Industrial Consortium; 2) exclusive rights under negotiated research agreements; and 3) Joint Development Project rights under standard iNEMI protocols.

Figure 2. Current FUTUR-IC Partners

The Package Scaling Era

The Chip Scaling Era has ended, and the Package/System Scaling Era is now in full implementation with no long-term technology roadmap. To maintain performance scaling: i) incremental technology change is insufficient, and ii) supply chain sustainability in terms of workforce quality, materials criticality, and manufacturing effluent has no inherent scaling vector. Economic risk for the nation has never been so large, and rarely been so dependent on a particular technology evolution.

This transformation to chip/package scaling is not a task that any one sector can tackle in isolation; it requires a robust global alliance that unites academia, industry, government, and community. FUTUR-IC offers such a collective effort to pave the way for innovative solutions, ensuring a resilient and prosperous technological future.

MetaForce

E-MC² of Sustainable Electronics

Lead PI: Yong-Kyu Yoon
ykyoon@ece.ufl.edu

Gloria Kim
gloriakim@eng.ufl.edu

Jin W. Choi
choijw@mtu.edu

Jeongwon Park
jepark@unr.edu

Overview

Interconnection technology is critical in electronic chip packaging. Current interconnects suffer significant power losses at high frequencies for cutting-edge high-speed computing and broadband communication, where energy efficiency is critical. MetaForce's metaconductor interconnects deliver 500% increased power efficiency while using 80% less material, vastly outperforming their copper counterparts. This technology is compatible with existing semiconductor fabrication processes and is scalable to operating frequencies that correspond to 5G and 6G.
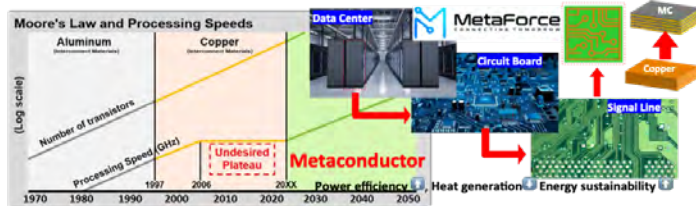

Figure 1: Transition of interconnect materials: Aluminum, Copper, and Metaconductor (MC) (left), and its applications for future interconnects of high-speed computers, data centers, and broadband communications.

Description

Most semiconductor manufacturing takes place overseas, posing economic, environmental, and national security concerns. Electronic chip packaging accounts for nearly 90% of the production costs for a modern microelectronic system. Presently, only 2-3% of chip packaging activities currently occur within the United States. In the collection of packaging technologies, essential are those on interconnects applying to chip-to-chip, chip-to-board, to board-to-board. Since introduced by IBM and Motorola in 1997, copper has been dominating the industry to this day. However, copper-based interconnects suffer significant power losses at high frequencies. Technically, economically, and environmentally, solid copper cannot support the integrated semiconductor systems the future demands.

End-user and stakeholder interviews confirmed the major challenges in the semiconductor industry: hardware and technical limitations stemming from complexity and compatibility issues with proposed solutions; a dearth of sustainable solutions; a deficiency in readily available skilled workforce. The industry recognizes the hardware and technological problems are rooted in excessive power consumption, heat generation, and a lack of speed. With no viable solution in the market, these are currently being addressed through redundant, wasteful, and complex systems.

Metaforce is a leader in metaconductor technology, which employs multiple nanolayers of ferromagnetic and non-ferromagnetic materials to solve challenges posed by radio frequency resistance and power consumption in electronic interconnect materials. In collaboration with Cisco Systems Inc., the team developed a metaconductor-based next generation interconnect that outperformed its copper counterpart at 28 GHz, a break-through for next-generation 112 Gbps data transmission. The fabrication process is highly compatible with existing manufacturing practices. This platform technology will reshape industries reliant on electronic components, including data centers, communication networks, and Internet of Things (IoT) devices.

Differentiators

Unlike incremental solutions, Metaforce's metaconductor technology achieves an unprecedented leap in performance. While conventional solid copper interconnect materials struggle with power losses due to the skin effect at higher frequencies, Metaforce's multi-layered metaconductors suppress the skin effect, resulting in an astounding 500% increase in power efficiency.

Additionally, MetaForce distinguishes itself by delivering a substantial 80% reduction in material usage, addressing long-standing sustainability concerns within the electronics industry. Unlike traditional methods

that struggle to balance enhanced power efficiency and material conservation, Metaforce's solution redefines the boundaries of sustainable electronics. Amid various research efforts in the field, Metaforce's project's comprehensive scope, transformative impact, and strong partnerships with industry leaders position MetaForce at the forefront. While others offer incremental improvements, the team still need to match the substantial gains in power efficiency and material reduction that they've achieved. Metaforce's unique collaboration with strategic partners ensures Metaforce's research swiftly transitions to real-world applications, solidifying Metaforce's competitive edge and potential for global impact.

Road Map

In year 1 of Phase 2, Metaforce's team will focus on: developing further metaconductor applications; reliability verification and standardization; and manufacturing of metaconductors and associated electronic components. A full lifecycle approach to technology development will be implemented by adding partners in the domain. In year 2, the team will focus on the commercialization trajectory. This will involve intellectual property (IP) licensing and the initiation of a technology startup. Concurrently, the team will implement the inclusive education and workforce development program.

Partnerships

MetaForce has established critical alliances that remain pivotal in Phase 2. University of Florida (UF), University of Nevada, Reno (UNR), and Michigan Technological University (MTU) will drive the core technology development. Cisco and Raytheon will guide Metaforce's technology's requirements, aligning its solutions with cutting-edge advancements. BRIDG, SkyWater, Calumet Electronics, and Applied Materials will offer manufacturing expertise, expediting lab to market transition. The regional county will serve as a technology growth hub, nurturing local talent. Brookhaven National Laboratory will collaborate in reliability verification and standardization.

Intellectual Property

The Principal Investigators' group holds four granted U.S. patents and six pending non-provisional applications in this technology. Collaborating institutions are aligned in supporting all jointly owned IP created by this project, and participating team members have agreed to work together on the protection, maintenance, and commercialization of IP according to applicable laws and policies. As the leading institution, UF will coordinate these efforts. A memorandum of understanding (MoU) has been signed as part of the U.S. National Science Foundation Convergence Accelerator's Phase 2 program efforts. This MoU establishes the framework for managing IP originating from the collaborative efforts of the team, comprised of members from UF, UNR, and MTU. IP matters will be governed by the provisions outlined in the MoU.

MoMatS

Intelligence for Sustainable and Socioresilient Material Futures

Lead PI: Christine Ortiz
cortiz@mit.edu

Alina Gavrilov
alina@station1.org

Francisco Martin-Martinez
f.j.martin-martinez@swansea.ac.uk

James Saal
jsaal@citrine.io

Ellan Spero
eduefs8@mit.edu

Jingjie Yeo
jingjieyeo@cornell.edu

Overview

A critical challenge in fostering materials sustainability is the lack of standardized tools, data, metrics, and information for the holistic and comprehensive evaluation of a sizable number of materials sustainability-relevant factors across the materials value chain. To address this challenge, this transformative cross-disciplinary and cross-sector venture is developing the first socioresilient DECISION-support software system which integrates and optimizes hundreds of sustainability-related materials' technical (T), environmental (E), social (S), and financial (F) metrics, as actionable intelligence for accelerating materials research and development (R&D) sustainability and advancing materials value chain sustainability. Empowering a user base of R&D professionals, DECISION accelerates cost-effective sustainable new product innovation and development, advances market alignment with materials sustainability, mitigates product risks associated with lack of incorporation of sustainability factors, and aligns with dynamic regulatory requirements.

Description

The DECISION software platform is initially developing four end user-informed product software modules: 1) socioresilient (T+E+S+F) analytics, optimization, and scorecard reporting module, 2) materials sustainability community dialogue and sentiment analytics module, 3) conversational artificial intelligence for contextual navigation of multi-parametric materials sustainability design spaces module, and 4) materials sustainability retrospective analysis for risk assessment. State-of-the-art computational methods are utilized to build the platform including multi-objective optimization, machine learning (ML) and predictive analytics, and deep search, big data analytics, and high-throughput calculations. A beachhead market and testbed prototype for polyvinyl chloride was selected due to its widespread use and large market size, potential for

sustainability innovation and advancement, availability of data, and alignment with team expertise.

Through the creation of open source, Materials Data as a Service (MDaS), and Materials Computing as a Service (MCaS) data and software this project holds great potential to accelerate and converge the materials sustainability R&D ecosystem and act as a force multiplier for materials sustainability R&D, resulting in broad reaching planetary and societal impact.

Differentiators

The project team has benchmarked the capabilities of about 25 software platforms and formulated the product development roadmap and initial suite of software module offerings as uniquely differentiated from major competitors. Key differentiators include the integration and optimization of technical, environmental, social, and financial factors (socioresilience) (Figure 1) and cross-disciplinary and cross-sector team expertise.
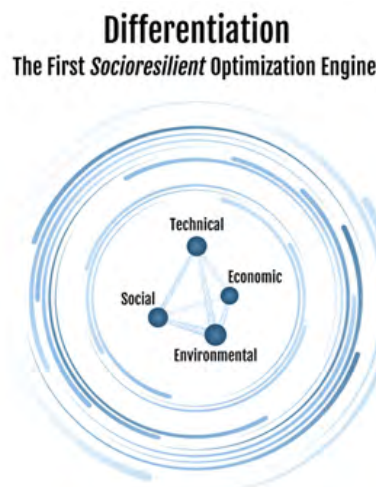

Figure 1: Differentiation: The first socioresilient optimization engine that can carry out multiparametric optimization of sustainability metrics across technical, environmental, social, and financial metrics.

Road Map

A timeline, project, and product development roadmap are shown in Figure 2.

	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4
1	█	█						
2	█	█			█	█		
3	█	█	█					
4		█	█	█				
5			█	█	█			
6				█	█	█		
7					█	█	█	
8	█	█	█	█	█	█	█	█
9	█	█	█	█	█	█	█	█
10				█	█	█		█

Figure 2: 1) Stakeholder co-created data credibility rubric; 2) Data identification and processing; 3) Metrics development (T/E/S/F); 4) Product #1 development; 5) Product #2 development; 6) Product #3 development; 7) Product #4 development; 8) End-user prototype testing; 9) Collaboration related to follow-on markets; 10) Distribution of project results to stakeholders and public.

Partnerships

Phase 1 led to a high performing cross-disciplinary and cross-sector project team with areas of contribution continuing into Phase 2 as follows: Massachusetts Institute of Technology (socioresilient metrics formulation, retrospective analysis for risk assessment), Citrine Informatics (data collection and integration, socioresilient multiparametric optimization), Cornell University (multiscale physiochemical materials modeling, conversational AI for contextual navigation of materials design spaces), Station1 (socially-directed collaborative research), and Swansea University (multiscale physiochemical materials modeling, deep search, big data analytics, topic modeling, sentiment analysis). All partners participated in stakeholder/ user engagement. Formal collaboration with materials production industrial consortia have been coordinated.

Intellectual Property

The DECISION team has developed intellectual property (IP) including an integrated material sustainability dataset and computational methods. The team is developing a unique portfolio of IP including materials sustainability data and software products. The project contains both open source and proprietary and licensable components and maintains a thorough IP management plan.

NURTURE
From Waste to Harvest

NURTURE

Lead PI: Benjamin S. Hsiao
benjamin.hsiao@stonybrook.edu

Dilip Gersappe
dilip.gersappe@stonybrook.edu

Darren Martin
darren.martin@uq.edu.au

Overview

NURTURE is a collaboration between Stony Brook University (SBU) and The University of Queensland (UQ). NURTURE aims to help farmers and communities protect the environment, reduce emissions and boost productivity. NURTURE will demonstrate two different scale-up models for turning agricultural and food waste into efficient farming products.

Description

Current farming practices create a broken nutrient loop, where most nutrients are lost into the environment or left behind in agriculture residues, and animal and food waste, creating multiple pollution problems.

Figure 1. Convectional farming practice creates a broken nutrient loop

This Phase 2 project aims to demonstrate a new approach that can close the nutrient cycle using NURTURE's zero-waste processing technologies, capable of rapidly upcycling natural organic waste into reproducible, sustainable, and safe fertilizers, growing media, soil amendments and biogels for farming.

Figure 2. NURTURE's zero-waste technologies to close the nutrient loop.

One third of all food produced in the world is wasted every year, totaling 1.3 billion tons of food waste annually (40 million tons worth over $161 billion in the U.S. alone). The world also produces 3 billion tons of agricultural residues and 5 billion tons of animal manure annually. These waste sources are ideal feedstocks for the NURTURE technologies.

NURTURE's vision is to turn waste into harvest, by converting plant, food, and animal waste into a series of products that provide circular, cost-effective, and sustainable solutions for horticulture and agriculture.

Differentiators

Based on 175 interviews with diverse end-users and stakeholders during Phase 1, NURTURE's U.S. members will focus on developing a mobile nitro-oxidation processing (NOP) facility, equipped with rapid nutrient analysis and machine learning capability that can convert diverse food waste into consistent growing media and soil amendments for horticulture.
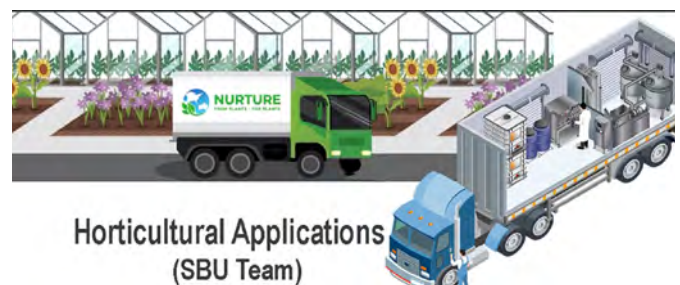
Figure 3. The SBU team aims to demonstrate a mobile NOP facility to convert food waste for horticulture applications.

This facility upcycles any organic waste in a few hours, including recovery of all nutrients and neutralizing harmful human pathogens in biohazardous waste, without producing odor or greenhouse gases. Techno-economic analysis (TEA) indicates that the NOP growing media can be 60% lower cost than peat, a popular but environmentally unsustainable growing medium.

NURTURE's Australian members will focus on a scalable green processing system that can convert agricultural and industrial waste into nutrient release

Figure 4. The UQ team aims to demonstrate a green extrusion facility to convert plant waste for broadacre farming.

biogels to reduce the impact of climate change for broadacre farming.

NURTURE's biogels can improve soil's water retention and nutrient availability and combat climate change. TEA results suggest these biogels are at least 80% more cost-effective than synthetic hydrogels.

Road Map

During Phase 2, Nurture intends to address the following core deliverables:

- The mobile NOP facility with rapid characterization capability will be completed by the SBU team for on-site demonstration in Q2, 2024, and the machine learning capability will be implemented in Q4, 2024.

- The green processing with integration of NADES chemistry and extrusion process will be completed by the UQ team in Q1 2024, while the integration of NOP will be completed in Q4, 2024.

- The formulation of NOP-enabled growing media, and soil conditioners upcycled from food waste, will be optimized for three selected plant trials (lettuce, tomato, and mums) in Q3 and Q4, 2024, respectively.

- The optimization of UQ's low-cost biogels with controlled-released nutrient capability for turfgrass and sorghum growth will be completed in Q4, 2024.

- The evaluations of safety, emissions & climate impact, biodegradability & carrier of beneficial inoculums for NURTURE products in soil will be completed between Q1-Q4, 2024.

- The tasks of field demonstration, community outreach, and education & workforce training

for NURTURE technologies and products will be completed in Q4, 2023.

- The tasks of TEA & life cycle analysis evaluation, business model development, sustainability plan (after the 2-yr funding period) will be completed in Q4, 2024.

Partnerships

The initial Phase 1 team consisted of 22 members from seven universities, five companies, and five government & nonprofit organizations, spanning from the U.S. and Australia to Sweden and Africa. With feedback from extensive interviews, the team realized the important value of locality, and the need to focus on the agricultural sector, and thus increased its roster.

In Phase 2, a cohort of expanded experts and collaborators with diverse backgrounds, complementary and relevant skills, well-established working relationships and shared vision, has been assembled to accomplish the research goals. The NURTURE team now consists of 17 researchers, five subsites (Connecticut Agricultural Experiment Station, North Carolina State University, Cornell Cooperative Extension, HydrOrganic Farms, Precisionworks), two consultants, and 18 collaborators (two universities, 14 companies and two nonprofits) to demonstrate and validate prototype technologies and products.

Intellectual Property

An Intellectual Property Management Plan was created by Stony Brook University and The University of Queensland and executed by all participating institutions to ensure a fair balance between protection of project intellectual property and timely disclosure and dissemination of project results to the public.

OpenMatFlo

AI-Optimized Green Concrete with Verifiable Carbon Footprint

Lead PI: Chaofeng Wang
chaofeng.wang@ufl.edu

Robert Ries
rries@ufl.edu

Chengcheng Tao
tao133@purdue.edu

My Thai
mythai@ufl.edu

Xinyue Ye
xinyue.ye@tamu.edu

Overview

OpenMatFlo is a data-driven comprehensive solution designed to revolutionize the concrete industry by bringing transparency, accuracy, and innovation to concrete optimization and carbon management. Addressing the urgent need for carbon footprint reduction in the concrete production process, OpenMatFlo provides the tools needed to accurately estimate, reduce, and verify carbon emissions of concrete, facilitating the global transition towards greener, more sustainable infrastructure.

Description

The concrete industry is facing a pivotal moment, as it is a significant contributor to global greenhouse gas emissions, accounting for over 8%. Numerous companies have claimed new concrete formulations that can reduce the carbon footprint. But most either cost too much or compromise the performance of the concrete, and the claimed reduction in carbon emissions is difficult to verify. As a result, low carbon concrete does not represent a significant share of the market. Carbon footprints as represented in Environmental Product Declarations are traditionally estimates based on coarse grained data, often outdated, and are usually filled with assumptions resulting in inaccuracies. Not only companies, but nations are often criticized for inaccurate carbon reporting, as observed during the implementation of the Kyoto Protocol and the Paris Agreement. Such issues threaten the success of global efforts toward carbon reduction. Accurate data is the key to tackle these issues and accelerate the innovation of the concrete industry. OpenMatFlo aims to tackle this challenge head-on by introducing a three-component solution: MatFlo.io, Reducible.ai, and CreteMart.co.

MatFlo.io is the first blockchain-based product-emission data infrastructure that provides real-time, fine-grained, transparently verified data for accurate carbon emissions estimation throughout the material production and construction life cycle.

Reducible.ai is the first real-time data-driven platform for dynamic concrete mix design that optimizes concrete mix design to significantly reduce carbon and cost without compromising performance.

CreteMart.co is the first online trading platform for green concrete, ensuring unparalleled transparency by facilitating seamless transactions of carbon-verified products. By driving the adoption of green concrete, instilling trust in the marketplace, and fostering rapid innovation, OpenMatFlo is not just a solution for the concrete industry; it's a step forward for the planet.

Differentiators

While there have been numerous efforts to reduce the carbon footprint of concrete, most either cost too much, compromise performance, or lack verification of the claimed reduction in carbon emissions. OpenMatFlo stands out by addressing all these issues comprehensively. Its blockchain-based infrastructure ensures transparent and accurate carbon emissions tracking, while the data-driven platform optimizes concrete mix design without compromising performance. Additionally, the online trading platform facilitates the market adoption of green concrete by linking producers and consumers and ensuring transparency in transactions.

Road Map

Phase 2 Milestones and Deliverables:

Q1-Q2, 2024: Complete the database development and connections with key data partners Cemex and Argos.

Q3-Q4, 2024: Complete the development and testing of Reducible-ai with Cemex and Argos. Complete the development and testing of MatFlo-io in collaboration with the American Concrete Institute Center of Excellence for Carbon Neutral Concrete (ACI NEU).

Q1-Q2, 2025: Launch CreteMart-co as a fully functional online trading platform for green concrete.

Q3-Q4, 2025: Conduct a comprehensive evaluation of the OpenMatFlo solution and prepare for scaling up in the following year.

Partnerships

OpenMatFlo is a collaborative effort involving various stakeholders unified in reducing carbon emissions in the concrete and construction industry.

OpenMatFlo has established strategic partnerships with international key stakeholders in the concrete industry. Cemex and Argos will serve as inaugural users and primary data providers of OpenMatFlo tools. ACI NEU Center will collaborate on the MatFlo-io platform to address carbon validation and verification processes. World Bank Global Program for Resilient Housing will leverage its network to raise awareness and facilitate broader adoption of OpenMatFlo's sustainable concrete solutions.

Representing the 80% share of the concrete industry, national and regional and small companies will also be a major focus of OpenMatFlo project. Ash Grove, Baker Concrete Construction, Construction of Buildings on Demand, Printed Farms, Silverback Concrete, Tiger Concrete and Screed are the inaugural users of OpenMatFlo platform and will be providing data and feedback to support the development.

These partnerships are crucial for the success of OpenMatFlo, as they provide the necessary expertise, data, and market access to ensure the solution is practical, effective, and widely adopted.

Intellectual Property

OpenMatFlo is currently in the process of filing patents for the unique algorithms and technologies developed for MatFlo-io and Reducible-ai. The intellectual property (IP) strategy is designed to protect the innovative aspects of the solution while promoting its widespread adoption in the industry.

Additional Information

OpenMatFlo is more than just a technological solution; it is a catalyst for change in the concrete industry. By providing the tools necessary to optimize concrete and to accurately estimate, reduce, and verify carbon emissions, OpenMatFlo is contributing to the global efforts to combat climate change and build a more sustainable future.

OreCast

Powering Mineral Resource Potential

Lead PI: Sriramya Nair
sn599@cornell.edu

Charles Bachmann
cmbpci@rit.edu

Louisa Smieska
lmb327@cornell.edu

Werner Sun
wms8@cornell.edu

Overview

As the world speeds forward with technological innovations and expanding infrastructures, the world's reliance on critical minerals has surged. Yet, traditional mining methods have scarred the environment, and valuable minerals remain obscured in over 200,000 waste sites across the U.S., in deposits ranging from decades to centuries old. Enter OreCast: an innovative data and computing hub tailored for mineral resources. This advancement in cyberinfrastructure revolutionizes how stakeholders use mine waste, transforming neglected byproducts into reservoirs of potential. OreCast empowers diverse stakeholders–from communities to industries–with accessible materials data, fostering data-driven decision-making.

Description

OreCast is a data and computing hub tailored for mine waste, unifying diverse datasets from disparate fields with scientific computing power. OreCast hosts diverse data inputs like hyperspectral imagery (HSI), microscopic X-ray fluorescence with micro-HSI data, and tests to evaluate suitability for building materials. OreCast ships with both standard and customizable workflows to obtain insights into mineral characterization, grain size, crystallinity, reactivity, and material variability, as well as preloaded example projects. Community science augments OreCast's efforts to populate its data hub for over 200,000 U.S. mine waste sites. Simple data collection methods, like mobile photos and drone imaging, are enabled through workshops and school outreach and provide an important role for community science input. OreCast's hub democratizes data, linking datasets, providing workflows, and enabling customization.

Designed around its users, OreCast engages stakeholders from critical minerals, building materials, and local communities for practical impact. It embodies convergence research, weaving together varied expertise to tackle the complexity of mine waste.

OreCast's goal is to redefine mine waste as a resource, enabling it as a driver of a circular economy. OreCast will help unlock rare-earth and byproduct elements like selenium, tellurium, and niobium from waste, while advancing identification of low-carbon construction materials, all aligning with OreCast's sustainability goals.

Differentiators

OreCast's new cyberinfrastructure transforms the perception of mine waste, tapping into this potential resource. Currently, businesses and communities alike lack necessary information for informed decision making. Knowing how minerals and critical metals are mixed at the microscale lets companies design efficient separation. In addition, understanding grain size, crystallinity, and reactivity are all important for assessing whether tailings can replace cements or be incorporated into concrete.

OreCast's computational framework changes this by making material characterization data accessible to all stakeholders. This revolutionized information sharing will enable new activities and address critical mineral needs and environmental issues. This democratization of data allows for informed decision-making regardless of expertise.

As OreCast evolves, the team envisions a future where it drives global shifts in mineral utilization and sustainability, redefining resource management and empowering communities.

Road Map

OreCast Cyberinfrastructure: A cutting-edge platform that focuses on revolutionizing the way users understand the geo-mineralogical domain by linking various data sources and equipping users with sophisticated tools to extract actionable insights.

Workflows: Precisely defined and structured

sequences of steps that guides users through project-specific analysis of complex datasets to provide comprehensive understanding of mining sites and enable accurate decision-making.

Preloaded Projects: OreCast comes ready to go with fully configured scenarios that serve as examples of analysis workflows that users can explore, interact with, and learn from.

Documentation: User resources include technical documentation, user guides, instructions, and workflow guidelines, all in an easy-to-use responsive knowledgebase.

Sustainability Planning: OreCast cohesively amalgamates strong community, capable governance, robust infrastructure, and financial health for long-term sustainability.

Partnerships

Orecast is a product of thriving collaborations. Cornell University, with support from the Cornell High Energy Synchrotron Source and College of Engineering, provides expertise in mineral characterization and cements. Rochester Institute of Technology contributes advanced remote sensing. Phoenix Tailings offers a wealth of industry knowledge on extraction techniques, while Essex County Government fosters community ties and facilitates mining site access. Australia's Commonwealth Scientific and Industrial Research Organisation adds a layer of geology characterization expertise. OreCast's collaboration with the U.S. Geological Survey ensures OreCast remains at the forefront of its mission.

Intellectual Property

OreCast prioritizes innovation by harmonizing management, accessibility, and protection of intellectual assets. Intellectual property (IP), whether pre-existing or newly conceived, are overseen by an IP Management Team with oversight by the Cornell Research and Innovation Division. Their efforts uphold the rights and interests of every contributor, making sure that the value of each contribution is recognized and preserved.

PFACTS

Faster Solutions for Forever Chemicals

Lead PI: Daniel P. Sanders
dsand@us.ibm.com

Stacy Glass
stacy@chemforward.org

Damian Helbling
deh262@cornell.edu

Carla Ng
carla.ng@pitt.edu

Jed Pitera
pitera@us.ibm.com

Lutz Weber
lutz.weber@ontochem.com

Ash Wright
a.wright@numat-tech.com

Overview

PFACTS is a resource for anyone seeking to replace, redesign, or remediate so-called "forever chemicals." These per- and poly-fluorinated alkyl substances (PFAS) are used in everything from non-stick coatings to compostable food containers to semiconductor manufacturing. Given their environmental persistence and impact on human health, there is an urgent need to find alternatives, but no central clearinghouse for data, tools, and community knowledge–until now.

Description

There may be as many as 7 million known PFAS substances with over 200 diverse industrial uses. These materials are stable, can be used in harsh environments, and offer unique capabilities. However, those attributes come at a cost. Many PFAS have no known environmental degradation mechanisms and estimated lifetimes of 1,000 years or more. There are strong regulatory pressures to significantly restrict PFAS use in the U.S. and the EU. This creates an enormous and urgent challenge for scientists and engineers to quickly find alternatives. In team discussions and Phase 1 interviews, the team identified two key concepts that PFACTS will address. The first is "regrettable substitution"–replacing a material with a new material that might itself be problematic. The replacement of persistent, low-toxicity PFOS with degradable, high-toxicity GenX surfactants is an example. The second is "over-engineering." In user interviews, PFACTS learned that PFAS were often selected not just because they hit performance targets, but because they were readily available at low cost. The community needs tools to easily identify both cases and provide suggested alternatives.

Differentiators

There are several other efforts in this space. The most significant is the ZeroPM program in the EU but that has a more diffuse focus on all persistent small molecule materials. ChemSec is a nonprofit that has compiled a range of data on existing PFAS materials, with a focus on hazards. Finally, the National Institute of Health PubChem resource has a PFAS classification tree allowing exploration of known PFAS in their vast database. The key differentiator for PFACTS is that all the above emphasize the identification and hazard of PFAS but provide limited information about alternatives.

Road Map

The road map for building and deploying PFACTS is informed by the team's learning in Phase 1. One of the key pain points identified in PFACTS' user studies is the question "is this a PFAS?" A simple, list-based tool (PFASid) will provide early identification of known PFAS and serve as the entry point to the wider PFACTS toolset. The tools will supply more detailed analysis of specific molecular properties, toxicity, environmental fate, and replacement. Furthermore, users that need formal validation of PFAS-free materials will be able to go beyond PFACTS to certification programs managed by PFACT's new partner ChemFORWARD.

Partnerships

In Phase 1, the team focused on refining the PFACTS concept around a set of 20 representative PFAS compounds plus CF4, a volatile PFAS. IBM will continue to lead the partnership in Phase 2, providing technical capabilities in artificial intelligence and risk assessment as well as user study and software development expertise. OntoChem (now a Digital Science

subsidiary) will annotate PFAS instances in both open and proprietary publications. The activities around PFAS toxicity prediction (University of Pittsburgh) and environmental degradation (Cornell University) will move beyond manual assessments of the representative PFAS to general-use automated tools. NuMat will extend their modeling of 10,000 CF4 capture materials to include competing matrix gases like CHF3 and SiF4.

PFACTS will add one funded partner in Phase 2, the nonprofit alternatives assessment experts at ChemFORWARD. They have experience developing targeted materials information services that combine collaborative community guidance with structured, validated hazard assessments. In addition, PFACTS will add five or more non-funded partners. One is the American Association for Alternatives Assessment. The other two are the Semiconductor Industry Association Semiconductor PFAS Consortium and Semiconductor Equipment and Materials International, industry organizations with specific interest in semiconductor sustainability, as well as Apple, HP, Google, and Sonos, companies interested in developing safer electronics. Finally, PFACTS has formed connections with other Track I teams, detailed in the full proposal.

Intellectual Property

PFACTS have focused on an open data resource for the entire PFAS replacement community, so all Phase 1 data assets will be made available by the end of 2023 at github.ibm.com.

Looking forward to Phase 2, PFACTS has identified distinctions between pre-competitive and commercial PFAS data, and worked with each partner to identify how best to create a sustainable intellectual property framework that will support a public PFAS alternative data resource.

Protify Textiles

Biomaterial Innovations for Sustainable Textiles

Lead PI: R. Helen Zha
zhar@rpi.edu

Mattheos Koffas
koffam@rpi.edu

Johnson Samuel
samuej2@rpi.edu

Ken Simons
simonk@rpi.edu

Dan Walczyk
walczd@rpi.edu

Overview

The Protify Textiles project aims to develop novel biobased fibers, fabrics, and dyes for increasing the sustainability of the fashion industry. The goal is to create environmentally benign textiles that match or surpass the qualities of fossil-based synthetics at broadly accessible prices.

Description

Sustainability is a top issue for fashion industry leaders. Consumer surveys show fast fashion as undesirable and strengthen the drive away from fossil-based materials and environmental harm. Since 2018, nearly 100 high-profile apparel brands have signed the United Nations Fashion Charter on Climate Change as a commitment to decrease their environmental impact. The top ten fashion brands worldwide all have environmental sustainability plans that include changing their materials usage. Such plans include increasing the use of recycled polyester, sustainable cotton and cellulosics, novel biomaterials, and sustainable dyes.

The overarching project objective is to develop and facilitate the commercial translation of plant-based fibers and textiles enhanced with bioengineered proteins. The specific objectives are: a) create silk-inspired proteins and protein-based dyes with good stability and performance in textile applications, b) explore pilot-scale fermentation of the proteins, c) design and construct systems for infusing yarns with the proteins in a high-throughput capacity, d) create various knit and woven fabrics using hemp yarn infused with silk-inspired proteins ("HempSilk" yarn), e) prototype HempSilk garments and accessories to showcase the desirability of the material for the modern fashion industry, f) perform lifecycle and technoeconomic analyses to quantify the sustainability and cost of the textile innovations, and g) analyze the economic and business landscape for the biobased textiles. Protify Textiles will also seek to establish a network of stakeholders along the fashion industry value chain (raw material suppliers, large-scale fermentation service providers, textile manufacturers/designers, and fashion designers, manufacturers, and retailers). They will also work towards developing an intellectual property portfolio to facilitate transition of the technologies outside of academic research.

Differentiators

The desire for sustainable fibers and textiles in the fashion industry has spurred the exploration of materials innovations in the past few decades. Recycling of plastic fibers, such as polyester and polyethylene, is the most common approach. However, recycled fibers can suffer from poorer strength, color, and odor compared to virgin plastic, all at a higher price than virgin plastic. Morever, recycled plastic does not resolve the problem of microplastic shedding during laundering and wear, as well as macroplastic pollution for waste textiles.

The fashion industry wants renewable, biodegradable textiles to meet their sustainability goals. Bioengineered and biobased textiles, including those derived from algae, mycelium, fruit fibers, and recombinant proteins, have rapidly gained research and commercial interest. However, biomaterial innovations focused on sustainability and fashion have only served a niche, affluent customer base, and their broad market success has been hindered by high production costs. The innovations combat high production costs by leveraging inexpensive plant biomass, such as hemp bast fiber, as a majority component with small amounts of fermented proteins added to dramatically improve fabric performance, hand feel, coloration, and aesthetics. The approach pursues specially designed proteins and manufacturing methods that minimize the amount of protein used while maximizing property enhancements. The preliminary cost analysis suggests Protify Textiles can achieve competitive pricing at commercial-volume production.

Road Map

Project deliverables in Phase 2 include: 1) novel silk proteins that enhance the properties of hemp-based textiles (month 6), 2) protein-based dyes that do not require toxic chemicals for fixation into fabrics (month 6), 3) bacterial fermentation systems for producing these dye and silk proteins (month 6), 4) processes for manufacturing these proteins and fibers at pilot scale (month 14), 5), fabric swatches made from HempSilk yarn (month 16) 6) test results documenting improvement of fabric properties by infused proteins (month 19), 7) prototype garment created using HempSilk fabric (month 24), 8) production cost estimates and strategy for further cost reduction, and documentation of sustainability impact via lifecycle analyses (month 24), 9) reports discussing economic and business factors that may affect introduction to the market (month 24), 10) business strategy for commercial impact of the innovations (month 24), 11) patent applications supported by the Office of Intellectual Property Optimization (ongoing throughout project), and 12) an digital archive of biobased textiles for educational outreach (month 20).

Partnerships

The team will partner with Battenkill Fibers for acquiring domestic hemp yarn, Craftwork Collective LLC and Lilly Marsh Studios for creating woven and knit fabrics using the HempSilk fibers, and The Texas Tailor for creating prototype garments using Protify Textiles' material. Academic and nonprofit partners will include State University of New York College of Environmental Science and Forestry for detailed lifecycle and technoeconomic analyses, University of Iowa Center for Biocatalysis and Bioprocessing for pilot-scale fermentation, and North Carolina State University's Wilson College of Textiles for independent testing of the fabrics according to industry standards. Protify Textiles will partner with Keep Earth Company LLC for expertise on biobased textile commercialization. They will also collaborate with Craftwork Collective to create the first free-to-access public educational digital archive of biobased textiles.

Intellectual Property

To date, the team has filed three relevant background patent applications and one relevant foreground provisional patent application. Three of these applications describe methods for recombinant silk protein production. One patent application describes equipment and decortication process for producing high quality natural fibers from bast fiber plants such as hemp.

ReCreateIt

Transforming Plastic Waste through Community-Led Manufacturing

Lead PI: Samantha Snabes
samantha@re3d.org

Charlotte Craff
charlotte@re3d.org

Kyriaki Kalaitzidou
kyriaki.kalaitzidou@me.gatech.edu

Carolyn Seepersad
carolyn.seepersad@me.gatech.edu

Michael Webbe
webber@mail.utexas.edu

Overview

ReCreateIt, a net-zero manufacturing lab, is building a more circular economy by reducing landfill waste. Partnered with the Austin Habitat for Humanity (AHFH) ReStores, ReCreateIt enables low-income homeowners to design sustainable home goods 3D printed directly from recycled plastic waste.

Description

ReCreateIt is building a more circular economy through the recycling and reuse of over 10,000 pounds of plastic waste otherwise destined for a landfill. This project brings together a collaborative team of researchers, manufacturers, and community leaders to creatively tackle plastic waste pollution.

The GigabotX large-format 3D printer manufactures with pelletized and granulated plastics. The ReCreateIt Gigalab net-zero manufacturing lab, built sustainably from a modified shipping container, houses the 3D printer as well as a granulator for grinding up plastics and a dryer for removing moisture from material—all the equipment needed to create high value items from recycled plastic in low-income communities where it is needed most.

ReCreateIt customers work with AHFH ReStores to fabricate their own functional home goods from recycled materials. Using an interactive design tool, customers can select their favorite home goods or customize them with an intuitive, web-based interface that modifies and refines designs in real time in response to customer preferences. The tool is powered by machine learning algorithms that ensure structural integrity and tally sustainability benefits without requiring any engineering expertise from the customer.

A sustainability dashboard collects and communicates the environmental impacts of this work fabricating from locally sourced recycled materials and expresses them in easily interpretable metrics, such as the number of water bottles saved from the landfill.

The team continually engages in polymer science and engineering research to enhance the printability of recycled materials while ensuring the structural integrity of 3D printed parts. For example, all the prototype chairs and stools printed by the team to date, even those with apparent imperfections, support at least 500 pounds of weight. Research into combining different plastics together or adding naturally sourced additives to improve results is distributed in a public database, thereby contributing to the knowledge base that will transition industry to more sustainable manufacturing methods.

Differentiators

By enabling 3D printing on site directly from granulated plastic waste, ReCreateIt minimizes the time and energy typically required in other resource intensive recycling systems. With the unique design tool allowing users to intuitively customize home goods, the innovation facilitates a path to circularity in a broad variety of communities, including those that typically do not have access to such technology. The ReCreateIt Gigalab is a flexible solution that can be built to adapt to location specific requirements. In pilot projects, Gigalabs are being built with both off-grid and grid connectable power solutions.

Road Map

During Year 1 of the U.S. National Science Foundation Convergence Accelerator's Phase 2, the team will build and install the ReCreateIt Gigalab at AHFH ReStore. In parallel, ReCreateIt will further expand the capabilities and catalog of designs for the design tool, create and integrate the sustainability dashboard, and engage in industry expanding research in recycled polymers. In Year 2 the design tool, dashboard and polymer databases will move to a public facing website accessible from anywhere. This work will culminate in an applied pilot in Year 2 where ReCreateIt trains and

upskills ReStore staff who will transform waste plastics through 3D printing, bringing value and real-world impact to their community.

Partnerships

As the end-user, AHFH has allowed research on their internal and external partners to direct the requirements of the ReCreateIt system within ReStore operations. Moving forward into Phase 2, AHFH will aid in the installation of the ReCreateIt Gigalab as well as provide staffing and training. The primary goal is enhanced revenue generation to support affordable housing throughout the Austin community while upskilling low-income workers and sharing the impact of sustainable manufacturing with the AHFH network.

Supporting AHFH in this project are the following partners, along with their technology focus areas:

Georgia Institute of Technology: Polymer science and human-centered design

re:3D, Inc.: Manufacturing and 3D printing from waste plastics

The University of Texas at Austin: Engineering design and life-cycle analysis

University of Wollongong Australia: Built environment building performance and life cycle analysis

Western Sydney University: Polymer science and engineering

Intellectual Property

ReCreateIt will be trademarked in Phase 2 to protect the brand of this collaborative project. The fundamental research from ReCreateIt will be published in peer-reviewed journals to accelerate feedback and iteration in this rapidly evolving niche. The design tool's foundational algorithms will be publicly available, but the upcoming website source code will only be shared by internal agreement of the project partners. GigabotX & Gigalab are open-source solutions protected by trademarks in the U.S., Canada, and Mexico.

Redaptive Recycling

Adaptive Recycling Through Predictive Machine Learning

RED◬PTIVE

Lead PI: Yannan Duan
yannan.duan@sbdinc.com

James Eagan
eagan@uakron.edu

Overview

Redaptive Recycling transforms inconsistent recycled plastics into high-performance materials. It combines real-time process control, predictive machine learning (ML) models, and performance-enhancing additives into a streamlined manufacturing add-on. This platform allows recyclers and manufacturers to seamlessly incorporate more recycled content into their products without redesigns and reduce carbon emissions while meeting performance targets with improved manufacturing efficiency and lower cost.

Description

Plastics are essential in many industries due to their versatility, lightweight, and durability. However, plastic waste is a major environmental issue, with less than 10% being recycled in the U.S. Mechanical recycling and re-use can reduce resource extraction and carbon emissions, but recycled resin quality is crucial. Polypropylene (PP) is one of the most widely used but least recycled plastics due to processing difficulties and polyethylene (PE) contaminants. Compatibilizers are nanotechnology additives for PP/PE waste blends which increase their recyclability and reuse.

Developing a product with recycled plastic is costly and time-consuming as manufacturers must determine the necessary additives for optimal performance and run several rounds of process-property adjustments. For example, Stanley Black and Decker required 2.5 years and almost $900,000 to develop a product made with 50% post-consumer resin. Typical mechanically recycled plastics do not deliver the required material properties, making it difficult to predict key properties from inconsistent feedstocks. Real-time monitoring and compatibilizer optimization can improve product consistency and quality, reducing recycling costs and enabling recycled plastics to replace virgin materials in demanding applications.

Redaptive Recycling's solution is a predictive platform that uses ML and nanotechnology additives to maintain consistent high-performance products from complex recycled feedstocks. The team's goal is to provide an advanced and sustainable recycling solution that can be easily adopted by industries. The project benefits recyclers and compounders by improving the quality and consistency of recycled resins, allowing manufacturers to use them as a "drop-in" solutions (to virgin plastics) without redesigns. It directly benefits product designers, managers aiming to reach their environmental goals, and process engineers to maintain specification windows in their product development. It has environmental impacts by increasing plastic reuse, reducing waste and carbon footprint, and saving energy.

Differentiators

Various plastic waste management methods, including energy recovery, monomer recovery, and mechanical recycling, have emerged as solutions to address the global waste crisis. Chemical recycling is still in development and requires complex processes and equipment setup with high energy consumption. Mechanical recycling is widely adopted, least energy-intensive, and can greatly reduce carbon emissions, but using traditional recycled resins with an additive approach is costly and labor-intensive for manufacturers.

The predictive platform, Redaptive Recycling, adapts to the specification windows of manufacturers and recyclers. This project offers a control system equipped with online monitoring instruments and an ML model that gives in-situ feedback for process control. The process is expected to greatly improve material consistency to reduce end-user manufacturer machine downtime and development cycles. The Redaptive system is capable of targeting virgin plastic properties so the resultant recycled material can be used as a drop-in solution with existing tools and designs.

Road Map

In Phase 1, the team successfully demonstrated the remanufacturing of contaminated PP using additives for controlled properties and built correlations between waste composition, processing, and material properties with ML models. In Phase 2, the team aims to:

T1. Implement post-consumer resins (Q1, 2024)

T2. Integrate in-situ instrumentation (Q2-Q4, 2024)

T3. Develop a user interface (Q3, 2024-Q1, 2025)

T4. Pilot the system on an industrial-scale line (Q1-Q4, 2025)

The key deliverables in Phase 2 will be:

1. Implement online monitoring and ML prediction for in-situ measurement and process optimization to deliver high quality recycled PP at an industrial scale.

2. Use ML in prototype and product design optimization and build a control system suitable for most industrial compounding recycle processes.

3. Provide a roadmap for designing next-gen compatibilizers for broader resin systems.

4. Develop educational programs for graduates, undergraduates, and underrepresented youths, as well as online training and in-person events to educate the community about recycled plastics.

5. Reduce energy/plastic waste, increase product quality, and improve the commercial viability of recycled products to encourage more recycling.

Partnerships

The team recognize this proposal requires knowledge and expertise in polymer chemistry, material science, manufacturing, statistical analysis, ML modeling, and process engineering. The project has assembled a multidisciplinary team of researchers at

1. Stanley Black and Decker, Principal Investigator (PI): leading construction tool manufacturer.

2. University of Akron: the top university for polymer science and plastics engineering, Co-PI Dr.Eagan's focus is improving recycled polymer blend performance.

3. AlDevLab: a network of seasoned artificial intelligence professionals specializing in ML, mathematics, and software engineering.

4. Polymer Center of Excellence (subcontractor): offers expertise in polymer science, engineering,

processing, and analysis/testing services.

5. KW Plastics (potential collaborator): plastics recycling company, specializing in recycling high-density polyethylene and PP plastics.

Intellectual Property

The intellectual property in this project includes but is not limited to: ML models for the control system, the interface between ML and online instruments, the use of unique combination compatibilizers to recycled PP systems, and their applications. A cooperative research agreement has been executed between the PIs and will serve as a model for the growing partnership.

ReSpool

Scaling a Circular Materials Model for Textiles from Fashion Waste

ReSpool

Lead PI: Kelly Cobb
kcobb@udel.edu

Abigail Clarke-Sather
abbie@d.umn.edu

Huantian Cao
hcao@udel.edu

Kedron Thomas
kedron@udel.edu

Overview

Clothing is a basic human need, yet the way people clothe themselves today is unsustainable. The fashion industry yields more than 100 million tons of textile waste each year, much of which is burned or landfilled. ReSpool develops the technologies, processes, and partnerships that enable textile-to-fiber recycling to turn fashion waste into new, high-value products.

Description

In Phase 1 of the U.S. National Science Foundation Convergence Accelerator, ReSpool prototyped a suite of groundbreaking technologies and processes that make it possible to turn discarded clothing into valuable textile products. The technologies include the Fiber Shredder, which breaks natural and synthetics fabrics down into reusable fibers, a new chemical process for recycling polyester fabric into fibers, and two machines that speed up the processing needed to recycle post-consumer materials. ReSpool also developed a set of manufacturing processes for creating woven and nonwoven textile products from recycled fibers. The team is now ready to scale these innovations for commercial application and test the systems and equipment at two recycling centers operated by Goodwill Industries.

Goodwill is a nonprofit leader in used clothing collection and resale, but the organization needs reliable markets for the 80 to 90% of donated garments that do not sell in its thrift stores. Currently, Goodwill sells these items to intermediaries who export them to countries in the Global South. Some clothing is reused, but too often it ends up in landfills. In Phase 2 of the Convergence Accelerator, ReSpool will divert up to 6 million pounds of unsold clothing from landfills in the U.S. and overseas and create 20 new, green jobs for underserved populations through Goodwill's training programs. With the potential to integrate ReSpool into 150 Goodwill organizations across the U.S. and Canada, ReSpool is positioned to transform fashion waste into a primary driver of regional economic development and environmental sustainability.

Differentiators

ReSpool takes a holistic approach to textile circularity. ReSpool works across regional partnerships to link social, economic, and environmental goals through the development of new technologies, advanced manufacturing capabilities, appropriate business models, circular design processes, lasting products, worker-centric training programs, and accessible educational modules.

ReSpool's proprietary technologies and processes alleviate key pain points that have discouraged investment in textile recycling. The Fiber Shredder, for instance, yields longer, higher quality fibers while using less labor and less energy than standard chemical and mechanical recycling methods. ReSpool's technologies and processes also reduce the energy needs for recycling polyester costs associated with recycling post-consumer waste, which requires materials identification, sorting, and pre-processing steps that are not needed for handling factory waste. Importantly, the team incorporates social science expertise to ensure that the processes for team-building, partnership-building, supply chain development, product development, skills training, and equitable economic development are transferable to regions with diverse waste streams, economic resources, and product needs.

Road Map

By the end of Year 1, ReSpool will deliver:

- Fiber Shredder, button remover, and zipper remover operating at commercial scale.

- Innovations in chemical recycling for discarded polyester fabrics.

- Complete materials evaluations of recycled natural and polyester fibers and fabrics.

- Set up and testing of all equipment and systems at two Goodwill recycling centers in Delaware and Minnesota.

- Create 10 new jobs at test sites.

- Testing of refined prototypes for recycled home goods, apparel, and geo-textile products (includes testing for microplastic release).

- Assessment of regional needs and additional opportunities for partnership-building.

- Data collection for Life Cycle Assessment (LCA) and social science evaluations of convergence process.

By the end of Year 2, ReSpool will deliver:

- Full-scale operations at Goodwill recycling centers in Delaware and Minnesota, diverting up to 6 million pounds of waste from landfills.

- Create 20 new jobs at test sites.

- Production runs and marketing of recycled textile products with industry partners.

- Results from LCA and social science evaluations disseminated to stakeholders.

- Dissemination of training modules for Goodwill employees nationwide.

- Targeted dissemination of ReSpool toolkits to promote and support ecosystem implementation in other regions.

- Dissemination of learning modules on textile circularity for undergraduate students.

Partnerships

In Phase 1, Goodwill of Delaware and Delaware County and Goodwill of Duluth, Minnesota provided discarded clothing and extensive data on operations and planning. For Phase 2, they have committed warehouse capacity, logistics support, and workforce recruitment and training. In Phase 1, ReSpool worked with textile and apparel brands and retailers Lobo Mau, Grant Blvd, FABSCRAP, and Shoreview Natives on prototype development and testing, and with textile manufacturers Tuft the World and LSC, Inc., on process and product innovation and testing. In Phase 2, ReSpool will expand the work with these partners to include yarn production, manufacturing, and marketing. ReSpool will work with the Industrial Sewing and Innovation Center to support ReSpool's skills training programs; Station1 to externally review ReSpool's LCA; and the Delaware Department of Natural Resources and Environmental Control to develop recycling policy recommendations. HBCU Delaware State University and Delaware Technical Community College will collaborate on development and testing of educational materials, workforce development, and diverse student cohort-building for research training.

Intellectual Property

In Phase 1, provisional patents were submitted for the Fiber Shredder #63/503,209 (Date: 2023 June 27) and for Novel Processes to Remanufacture End-of-Use Textiles into Second Generation Textiles #63/512,155 (Date: July 6, 2023). Fiber Shredder LLC was established (August 7, 2023) by Dr. Abigail Clarke-Sather and Paulo Alves at the University of Minnesota. ReSpool expects additional intellectual property (IP) will be developed in Phase 2 and have developed a Material Transfer Agreement and IP Management Plan to guide this process.

SOLAR

Securing Critical Material Supply Chains by Enabling PhOtovoltaic CircuLARity

Lead PI: Morgan Evans
volker@battelle.org

Eleftherios Iakovou
eiakovou@tamu.edu

Garvin Heath
Garvin.Heath@nrel.gov

Cara Libby
Clibby@epri.com

Overview

With the United States' commitment to a clean energy transition, the nation's solar capacity is growing at an impressive 21% annually, translating to tens of millions of additional panels in the coming years. However, this growth brings a challenge: between 2030 and 2060, an estimated 9.8 million metric tons of solar panel waste will accumulate. Securing critical material supply chains by enabling phOtovoltaic circuLARity (SOLAR) develops the technology needed to achieve sustainable solar panel recycling while helping to secure domestic supply chains of critical materials. SOLAR also enables broader circularity for end-of-life panels by developing decision making tools for panel owners and recyclers, reducing recycling costs to rival landfilling, and ensuring that valuable materials are repurposed and panels that are still functioning are reused.

Description

Managing solar panel waste is crucial, as currently, approximately 90% of end-of-life or defective solar panels are sent to landfills. This trend persists primarily because landfill disposal is more cost-effective than recycling. Similarly, by 2050, the value of raw materials recoverable from solar panels could exceed $15 billion. This provides not only an opportunity to circumvent waste but also provides a supply chain for critical materials required to achieve the nation's energy goals.

The SOLAR program will create impactful tools to improve solar panel circularity. "Solar panel circularity" refers to the concept of applying circular economy principles specifically to solar panels. In a circular economy, products and materials are reused, repurposed, refurbished, or recycled to keep them in the economic system for as long as possible, reducing waste and the need for new raw materials. In Phase 1, the team studied current literature and engaged stakeholders across the solar industry to identify the barriers to solar material circularity, and this feedback served as the foundation for forming the team's Phase 2 objectives. Phase 2 will leverage convergence research principles to collectively develop a comprehensive SOLAR toolkit to provide solutions to circularity barriers by innovating in three outcome areas. SOLAR will:

(1) Develop groundbreaking tools for full accounting of photovoltaic (PV) recycling impacts to both the supply chain and affected communities. These tools will be made publicly available as open source, to enhance the potential likelihood of widespread adoption.

(2) Develop silicon upcycling technology and establish key figures of merit for new silicon application markets to support the emerging PV recycling industry. This technology, available for licensing, can be utilized by recycling companies to enhance the recovery of critical materials, thereby improving their economic prospects.

(3) Build a profitable, equitable, and integrated modeling tool for whole PV module recycling to close the gap for a viable circular economy. This information will also be made publicly available as open source, to enhance the likelihood of widespread adoption and increase impacted community awareness.

Differentiators

SOLAR's convergence research approach brings together a broad group of industry, academic, and policymaker stakeholders encompassing the full solar supply chain and solar policy landscape. Only through gathering feedback and inputs from all stakeholders can the team develop an equitable and economical circular model for end-of-life solar materials. SOLAR's Phase 2 research aims are formed directly from stakeholder feedback, and the team's deliverables are expected to fill the key gaps to enable solar circularity.

Road Map

Year 1 deliverables:

- Prototype reverse logistics/supply chain modeling tool to show path to achieve equitable and economical solar panel material circularity.

- Prototype advanced panel damage detection toolkit.

- Decision making field guides for decommissioning solar panels.

- Feasibility assessment of process for silicon and critical mineral upcycling.

Year 2 deliverables:

- Full solar supply chain modeling software with easy-to-use graphical interface for all stakeholders.

- End-of-life decision-making toolkit for rapid and accurate assessment of panel state.

- Small scale processing technology for purifying and upcycling silicon and other critical minerals to specialty materials.

Partnerships

Battelle Memorial Institute–Prime, circular economy research, critical mineral extraction and material upcycling expertise.

National Renewable Energy Laboratory–Broad solar energy expertise, technoeconomic analyses, solar supply chain agent-based modeling.

Electric Power Research Institute–Circular economy, research focus for electric power sector to help end-users navigate end-of-use options.

Texas A&M University–Leading reverse logistics and circular supply chain modeling for solar power industry.

Intellectual Property

SOLAR's reverse logistics artificial intelligence-based modeling engine is covered by background intellectual property (IP), but the end software application for the solar industry is expected to be open source.

IP includes process patents to purify solar-derived silicon, composition of matter patents for specialty materials formed from solar derived silicon, and separation process patents to recover critical mineral contaminants in solar-derived silicon.

SpheriCity

Optimizing Circularity from Molecules to the Built Environment for Communities

Lead PI: Jenna Jambeck
jjambeck@uga.edu

Christina Fuller
Christina.Fuller@uga.edu

Melissa Bilec
mbilec@pitt.edu

Jason Locklin
jlocklin@uga.edu

Overview

While the concept and application of the circular economy continue to be discussed at the highest levels of government and global organizations, cities and communities are the front lines. Out of the struggle to define what a circular economy could look like for communities, the Circularity Assessment Protocol (CAP) model was born. In Phase 1, SpheriCity began integrating circularity in communities across multiple scales of molecules, plastics, organics, and the built environment, and in Phase 2, SpheriCity seeks to (1) create a dynamic SpheriCity portal that simultaneously provides data collection training, open-source data sharing, and intra- and inter-community collaboration and (2) further apply the SpheriCity converged CAP framework and construction & demolition (C&D) CAP.

Description

There is already a great demand for the CAP framework and data, as illustrated by the CAP deployment in 48 cities in 13 countries thus far. However, by creating an online portal with both automated training and integrated interactive data analysis and display, efficiency will be maximized, enabling even more rapid growth. A CAP currently costs an average of $40,000, yet it is anticipated that the implementation of the new SpheriCity Portal will lower the cost by 75% to $10,000–a significant cost-savings. Along with the training of community members as implementation partners, the SpheriCity CAPs also provide baseline data that the communities can use freely.

Differentiators

There are some other tools available to cities to assess waste management, and these are more limited than what SpheriCity does with the CAP, which is holistic, collaborates with Local Implementation Partners (LIPs), and encompasses input of materials into a community. Other circular economy city tools are more complex and require larger amounts of data than the city has

to provide directly, versus the sub-set of interviews required for CAP and the paid LIPs to collect any other data needed for CAP. In addition, CAP results are clear and relatively simple, making communication about them easier and facilitating the addition of diverse perspectives and contributions. Local and indigenous knowledge from the community is honored and is just as important as the data collected for CAP. In addition, the SpheriCity team is comprised of both quantitative and qualitative experts, which allows for a seamless mixed methods approach. SpheriCity welcomes community collaboration on scholarly work.

LIPs that have conducted CAP previously have been co-authors on journal articles. Bringing in underrepresented voices and people is a part of the mission of SpheriCity that the Principal Investigators (PIs) have been working on for years with success through partners, interns, students, staff, and science communication strategies (e.g., a podcast). Data is open and free through Debris Tracker (used to collect data) and the new SpheriCity portal. This work goes extensively beyond basic research–it is research translated into practice–SpheriCity works with communities to identify their needs and facilitates them finding solutions which they can then implement in the way that works best for them and their context.

Road Map

SpheriCity Phase 2 runs from December 2023 through December 2025 and consists of four main sections, 1) portal development, 2) training, 3) the CAP and 4) city discussions/ workshops. Each of these main sections can be broken down into components designed to engage all partners and facilitate convergence along the way. Although the U.S. National Science Foundation Phase 2 curriculum runs from January–Summer in 2024, the team plans to get started immediately on creating the data and education (training) portal. The team will have LIPs chosen and trained in Q2 of 2024, and CAPs will be completed over the next 7 months by the LIPs. The final stage of discussion and workshops

with the city partners will inform the final report section on "opportunities" to optimize circularity in that community. Deliverables include reports the city can use to apply for resources, grants and in sustainability reporting, and then the portal will have dynamic city data and metadata dashboards publicly available.

Partnerships

Phase 1 partners in Atlanta included the City of Atlanta, the Atlanta Center for Hard to Recycle Materials, Lifecycle Building Center, Truly Living Well, ReBuildATL, Shaw Industries, and Mars, Inc. Phase 1 Pittsburgh partners included the Green Building Alliance, Construction Junction, and Covestro. These partners across nonprofits, industry, and government in Atlanta and Pittsburgh provided key insights during the user research and low fidelity prototype interviews for Phase 1. The team will remain in contact with these partners as it moves into Phase 2 and will continue to receive feedback from them as the team builds out the data and education portal and the construction and demolition (C&D) CAP process. After developing the first prototype of the CAP portal, the team plans to test it and receive feedback by expanding and leveraging the networks. In Phase 2, the team will partner with the Resilient Cities Network, 2030 Districts Network, the Mississippi Rivers Cities and Towns Initiative, and the Upper Midwest Association for Campus Sustainability to expand the converged CAP to eleven more cities across the United States while harnessing these connections to use the CAP platform for training, data sharing, and community collaboration. The eleven cities chosen for Phase 2 represent a distribution of population sizes and geographic locations, and the partner organizations represent a wide variety of organizational types, stakeholders, and institutions.

Intellectual Property

The Sphericity team agreed in Phase 1 that the original intellectual property (IP) for the CAP is held at University of Georgia (UGA), by PI Jambeck. The C&D CAP, which uses the original CAP framework, but was led by University of Pittsburgh (UPitt) during the Phase 1 process, will be published by the Sphericity team with UPitt as first author. All publications stemming from Phase 1 research will include the active Sphericity team. During Phase 2, the same approach will be taken. UPitt will continue to lead the refinement of the C&D CAP. All CAP data and tools will continue to be housed in the

UGA Circularity Informatics Lab with acknowledgment to this project and the partners. All data will be housed in the open Debris Tracker database and the SpheriCity portal. All partners will have access to their own and publicly available data. Future access to the Sphericity IP and CAP tools and framework will be available for a small fee. UGA will provide the associated work needed for the plastics and organic materials CAPs; the fees for these CAPs will go to UGA. For any on-going work associated with the C&D CAPs, a fairly distributed fee will go to UPitt for their support. Each institution will engage their legal and technology commercialization offices as necessary to negotiate the details of any agreements and memorialize commitments in writing.

Topological Electric

Protected Toward More Power

Lead PI: Mingda Li
mingda@mit.edu

Liang Fu
liangfu@mit.edu

Qiong Ma
maqa@bc.edu

Tomas Palacios
tpalacios@mit.edu

Susanne Stemmer
stemmer@mrl.ucsb.edu

Overview

Topological quantum materials show great promise for next-generation energy and information applications, as recognized by the 2016 Nobel Prize in Physics. Topological Electric aims to build electronic and energy harvesting device prototypes based on environmental-friendly topological materials.

Description

The Topological Electric team aims to create three eco-friendly device prototypes with topological materials for advanced microelectronic and energy applications. These include the efficient terahertz (THz) rectification for 6G+ phones, future chip interconnects using topological metals' superior conductivity, and finally topological thermoelectric wearable devices to power headlight. The product could directly benefit all mankind with need on night reading and future cellphones.

Differentiators

The team contains world-class pioneers and leading researchers in topological materials, wireless energy transfer, and THz applications, and has been attracting very strong industrial interest. The team will partner with three leading industries for Phase 2. Beyond that, early topological materials research is largely driven by performance with little consideration given to sustainability, with some harmful materials like Mercury telluride (HgTe) and CdAs proposed, and Topological Electric's team pays significant attention to sustainability and environmental friendliness.

Road Map

For each of the three deliverables: THz detector, interconnects, and thermoelectric devices, the team will further decompose it into four phases of milestones, including Initialization, Execution, Iteration, and Finalization milestones. The related team members and industry partner for each deliverable will participate in the related meetings to initiate the process.

Partnerships

For each of the Thrusts, the team identified one partner to work together on Phase 2, including Raytheon Technologies, IBM, and Analog Devices. A professional consultant was recruited to form business plan and customer discovery for longer-future.

Intellectual Property

Currently, the Principal Investigators of this Project hold or co-hold seven patents, including the topological origin to demonstrate the THz rectification effect and the topological thermoelectric effect. More intellectual property (IP) is expected to be generated. To avoid conflict of interest, Massachusetts Institute of Technology's (MIT) Technology Licensing Office is partnered with Topological Electric's team, that has carefully drafted a comprehensive IP Management Plan, which outlines the collaborative efforts of research partners, including MIT, Boston College, Cornell University, University of California, Santa Barbara, Analog Devices, IBM, and Raytheon Technologies.

Additional Information

In Phase 1, Topological Electric has delivered the milestone report that contains the environmental impact evaluation for over 16,000 topological materials (see here: https://arxiv.org/abs/2308.09526 for a 300-page-long work). This milestone work builds a solid foundation for Topological Electric's Phase 2 competitions. The list of planned deliverables for Phase 2 include:

1. A more refined sustainable topological materials database containing the performance indicators.

2. A demonstrated THz wave detector that converts THz wave into direct current.

3. Wireless energy harvesting using topological materials at gigahertz range.

4. Conducting topological interconnects using topological material nano structures.

5. Recipes for topological nanowire conducting adhesives.

6. Wearable headlights using topological thermoelectric modules.

7. Thermoelectric prototype device that harvests waste heat from integrated chips.

8. Business plan to push topological materials toward broader societal impact.

9. Center of Sustainable Topological Energy Materials as part of MIT Energy Initiative.

urbanREmine

REmine, REfine, REuse

Lead PI: Ikenna C. Nlebedim
nlebedim@ameslab.gov

Hongyue Jin
hjin@arizona.edu

Marilu Perez
marilu@ameslab.gov

Long Qi
lqi@ameslab.gov

Fu Zhao
fzhao@purdue.edu

Overview

Rare earth elements (REEs) enable many industrial and personal device applications and are critical to clean energy technologies (e.g., electric vehicles and wind turbines) and national security (e.g., fighter jets and submarines). However, they are subject to a significant supply chain risk, and disruptions could limit the extent of ongoing effort towards a decarbonized economy. urbanREmine will establish a recycling innovation ecosystem for sustainable remining and refining of REEs from e-waste into metals for reuse in Nd-Fe-B permanent magnets, transforming e-waste into a national resource.

Description

urbanREmine converges multidisciplinary tools and expertise in artificial intelligence and machine learning (ML), computational chemistry, chemical engineering, metallurgy, magnetism, motor design, systems integration, techno-economic analysis, life cycle assessment, and business entrepreneurship, all focused on REEs. The research develops upon a novel acid-free dissolution recycling (ADR) technology that selectively recovers REEs from e-waste with minimal need for pre-treatment and without limiting subsequent value recovery from other e-waste components. urbanREmine will accelerate the deployment of the product from the ADR technology through advanced downstream REE separations and metals production technologies. For example, a new class of robust polymeric adsorbents diglycolamides (DGAs) is being developed with guidance from AI/ML, automated synthesis, and high throughput testing for effective separation of REEs. Preliminary life cycle analysis showed that urbanREmine's new DGA synthesis reduces the carbon footprint by 89% compared to the traditional method. Also, a new REE metal production pathway eliminates the use of hazardous hydrogen fluoride and targets improved economic and environmental benefits, relative to current processes

(e.g., reduce cost of production by ⅓ and carbon footprint by 50%).

Differentiators

urbanREmine provides a unique solution that will overcome the barriers to sustainable recycling of REEs. urbanREmine's ADR technology is designed to be a "drop-in" solution for maximizing value recovery through seamless integration into existing e-waste recycling business ecosystem. The ability to modularize the ADR infrastructure enables co-location with e-waste generation, eliminating transportation. REE separations and metal production technologies will be tailored to the rare earth products recovered from e-waste, creating a unique synergistic solution that is optimal for economic and environmental impacts. They can also be adapted for REEs from other recycled feedstocks, recycling approaches, and natural sources. Thus, the solution broadly enhances the supply of REEs and supports the high-tech applications that depend on REEs. In essence, the team is improving the process of recycling e-waste and recovering rare earths, which is a win-win for U.S. industry, national security, and people.

Road Map

The team will continuously engage with relevant stakeholders including e-waste recyclers and end-users through storytelling, interviews, and pitching to discover new customers and understand their needs to guide technology development. urbanREmine will first produce ADR feedstock with purity ≥99.5 wt.% from the 1st half of 2024. Two downstream-processing routes will be developed: (1) REE separation followed by individual REE metal production, which is compatible with the most prevalent REE supply chain and thus reduces the barriers to reinserting the recycled REEs into the market; and (2) one-step conversion of rare earth salt into rare earth fluoride, enabling the subsequent rare earth metal production for direct use in Nd-Fe-B permanent magnet manufacturing,

which will maximize the economic and environmental sustainability. They will test the produced REE metals in Nd-Fe-B permanent magnet manufacturing and evaluate the performance in electric vehicles and hard disk drives by mid-2025. Techno-economic analysis, environmental life cycle assessment, and end-user engagement will continue throughout the project for value proposition, business model, business plan, and sustainable strategy development.

Partnerships

The proposed research brings together over a dozen experts from industry, academia, and national labs. Four scientists from the Ames National Laboratory will lead the development of separation technology guided by AI/ML, metal production, permanent magnet production, and systems evaluation. Partners from University of Arizona and Purdue University will conduct techno-economic analysis and life cycle assessment to quantify and help improve the economic and environmental impacts of the proposed technologies and contribute to outreach, education and workforce development. TdVib LLC will supply products from the ADR technology for separation and subsequent metal and magnet production. Western Digital and Great Plains Partners will provide end-use inspired guidance and opportunity for partnership expansion in electronics, aerospace, defense, and manufacturing applications. urbanREmine will also collaborate with Noveon Magnetics to qualify the produced RE metals for commercial magnet production in Phase 2. The Director of the Critical Materials Institute will advise the team on the best path for leveraging the critical minerals ecosystem to maximize project impact.

Intellectual Property

urbanREmine's unique solution will generate multiple intellectual properties (IP). The ADR technology is patented, while the separation and metal production technologies are patent pending. urbanREmine anticipates creating additional IPs, hence they have developed a preliminary IP Management Plan (IPMP) and nondisclosure agreement (NDA), which entail background IP, title to subject inventions and project IP, and IP licensing. They will formally execute the IPMP and NDA as the first deliverable of the Phase 2 project to ensure the success of the multi-institutional project.

Additional Information

The project will help promote e-waste collection (currently estimated at 15% in the North America), mitigate the associated environmental pollutions (e.g., 10 tons of mercury and 18,000 tons of brominated flame retardants from improper disposal in the Americas per year), and reduce dependence on rapidly depleting virgin materials. It will create clean energy jobs for a net zero economy. Since improper e-waste disposal would most likely be in low-income communities, this work can help address threats to environmental and social justice and contribute to the Justice40 initiative.

TRACK J: FOOD & NUTRITION SECURITY

By 2050, the world's population is anticipated to increase to an estimated 9.7 billion people, with a corresponding growth in food demands by 60%, water demands by 55% and energy needs by 80%, according to the United Nations Department of Economic and Social Affairs and a U.S. National Science Foundation-funded workshop titled "Sustainable Systems Enabling Food Security in Extreme Environments and Food Deserts Employing a Convergence of Food, Energy, Water and Systems for Societal Impact Report". Changes in climate, land use, resource consumption, and population growth are constraining some regions to no longer be able to support regional food requirements, contributing to large-scale human migration in parts of the world.

U.S. National Science Foundation Convergence Accelerator's Track J: Food & Nutrition Security is accelerating convergence across food and nutrition sectors to combat challenges related to population health, climate change, and nutritional needs of vulnerable and disadvantaged communities. Track J envisions transforming food systems across the nation to ensure access to healthy and nutritious food is provided, as well as creating sustainable agricultural, forestry, and food practices that considers the climate, regeneration, and waste reduction.

Food & Nutrition Security funded Phase 1 teams include:

AI-FEED—Led by University of Houston, AI-FEED, an artificial intelligence-driven solution, connects the food charity ecosystem to feed the hungry equitably and minimize waste. AI-FEED empowers communities to support the health and well-being of food-insecure families by providing culturally appropriate and nutritious food resources. AI-FEED informs community leaders allowing them to allocate resources to ensure their community flourishes.

AquaSteady—Led by Pratt Institute, AquaSteady, a seaweed-based water absorbent, is solving the water scarcity challenge by helping farmers retain moisture in soil between irregular rainfalls and irrigations. AquaSteady absorbs water from soil when it is wet and gradually returns it when the soil dries. It can be formed into an antierosion net or other shape.

CropSmart—Led by George Mason University, CropSmart's digital twin provides on-demand, decision-ready solutions optimized to users' cropping goals without burdening them on data manipulation or instrument investments. The optimal solutions, up to field scale and CONUS coverage, are derived from near-real time remote observations of cropping systems with physics-and AI/machine learning-based modeling and simulations.

Cultivate IQ—Led by University of Arkansas, Cultivate IQ, an AI data transformation platform, integrates sales and production data from across the farm-to-market supply chain to help plan and manage regional food supply. Local food buyers, including aggregators and distributors, host their growers on the platform, extending access to market insights, production planning tools, and purchase orders.

Dairy NutriSols—Led by Boise State University, Dairy NutriSols, a research and innovation consortium, is enhancing nutrition security and quality across the dairy supply chain. NutriSols assembled to address industry challenges through sustainable solutions using chemometric software, pulse electric field, and extruder technologies. The hub will innovate processes that enhance consistent product quality, and improved production efficiency.

Earthstream—Led by Mesur.io, Earthstream is the dynamic on-demand intelligence platform that delivers real-time insights to decision makers regarding their food supply chains. With their source-to-consumer intelligence solutions, users can explore critical data and stay ahead of potential risks, ensuring optimized food and water security for their constituents and customers.

Eco-Aquafeed—Led by University of North Carolina Wilmington, Eco-Aquafeed is a sustainable fish feed for culturing high-value marine fish. Using novel alternative proteins Eco-Aquafeed reduces the use of unsustainable fishmeal in feed. Eco-Aquafeed is a high-quality, cost-effective alternative protein that will support and accelerate the production of fish in the U.S., while decreasing pressure on stressed ocean fish stocks.

EcoRICO—Led by George Washington University, EcoRICO is the first of its kind solution to help customers identify eco-friendly, nutritious items by combining the climate footprint and nutritional values for fresh and locally grown products into one easy-to-use, informational score. EcoRICO is hyper-local and includes locally grown and fresh, perishable imported products.

Food Forecast—Led by University of Maryland, Baltimore County, Food Forecast empowers government agencies and other organizations to bolster disaster food security in at-risk areas. The solution's interactive tool provides visualizations of disaster, food, and community data as well as what-if scenario simulations to proactively identify food security strategies customized to each community, allocating scarce resources to maximum effect.

Food Positive—Led by University of Arkansas, Pine Bluff, Food Positive empowers local communities to reduce food insecurity, promote health, and build confidence to make better nutritional choices. Using culturally sensitive solutions, Food Positive provides educational, governmental, and community-based organizations with support to enable healthy eating lifestyles.

FoodSight—Led by University of California, Santa Barbara, FoodSight, a co-produced multidimensional forecast tool, is enabling ranchers, pastoralists, and food aid agencies, to improve food production and food security. The solution provides improved management strategies and investment decisions to ensure vulnerable communities are supported.

NOURISH—Led by University of California, San Francisco, NOURISH (Network of User-engaged Researchers building Interdisciplinary Scientific infrastructures for Healthy food), an AI powered platform, addresses food insecurity by enabling small businesses in food deserts to provide convenient, affordable, and fresh food to people in their communities. Leveraging knowledge assimilation and geospatial technologies, NOURISH connects business owners with capital, supply chains, and knowledge resources from government, investors, and community organizations.

NourishNet—Many people do not have access to healthy food, yet too much food is wasted. Led by University of Maryland, College Park, NourishNet is changing this by providing connections between producers, donors, distributors, and those experiencing food insecurity. The NourishNet toolbox includes a food quality sensor and an app that allows for direct input from the food insecure.

Precision Produce—Led by Virginia Tech Applied Research Corporation, Precision Produce offers a secure web-based platform that forecasts crop issues and recommends cost-effective actions to family-owned farms for enhanced crop yield and quality. The solution's proprietary machine learning-based pipeline automates field data collection and analysis and streamlines crop management decision-making as growers face progressively erratic and extreme weather events.

SensD—Led by University of Missouri, SensD, a sensor-enabled decision support system, empowers multi-sectoral stakeholders to build safe, equitable, and resilient food systems. Through collaboration with the farm-to-fork supply chain, food banks, and educators, SensD leverages rapid pathogen sensors to provide data-driven solutions for mitigating food-borne pathogen risks with visualization, prediction, and optimization capabilities to create a safe food supply for all.

Stigma Out of Snap—Led by University of California, Los Angeles, Stigma Out of SNAP (SOS) aims to converge separate provisions of the federally-funded Supplemental Nutrition Assistance Program, which provides money to low-income households for food. SOS will create positive narratives to help SNAP facilitators maximize participation and promote encouraging experiences of nutrition and food benefits programs among college students.

Lead PI: Ioannis A. Kakadiaris
ikakadia@central.uh.edu

Junfeng Jiao
jjiao@austin.utexas.edu

Elizabeth Fletcher
efletcher@central.uh.edu

Norma Olvera
nolvera@central.uh.edu

Susie L. Gronseth
slgronse@central.uh.edu

Alison Reese
alison.reese@souperbowl.org

Overview

AI-FEED links the disconnected stakeholders in the food charity ecosystem, enabling them to serve the vulnerable populations in this country better. By providing insights into food insecurity challenges and introducing innovative solutions, AI-FEED decreases food waste, increases nutritional food consumption, and helps communities thrive.

Description

Each year, 12% of Americans experience food and nutrition insecurity, with $160 billion spent on related healthcare expenses. At the same time, 120 billion pounds of food are wasted. While ample food exists in America, a more robust solution to feeding the hungry is needed.

AI-FEED focuses on local food charities well-positioned to understand and cater to their communities' needs. Connecting these charities with food donors enables them to increase their impact. AI-FEED addresses nutritional literacy, supporting food charities in providing nutritional education and foods that are culturally sensitive and nutritious for their clients. AI-FEED also equips community leaders with tools that can be used to explore community data and develop strategies for expanding healthy food access in their communities.

Highly nutritious foods such as produce, dairy, and meat, often nearing their use-by date but still capable of being donated, are typically wasted rather than utilized. AI-FEED uses a blockchain-backed, artificial intelligence-optimized system to streamline linkages between those with excess food and local charities, preventing waste and increasing the amount of nutritious food provided to those in need.

Food may also be wasted when clients need to learn how to prepare it or if it is misaligned with their culture or medical needs. AI-FEED not only assists robust charities in providing appropriate food but also aids in educating clients about nutrition and cooking. Nutritional resources include customizable recipes that incorporate donated ingredients into meals suited to clients' available cooking appliances, their cultural food traditions, and their specific dietary needs.

AI-FEED empowers community leaders with data-driven insights, enabling them to tackle food insecurity more effectively. By identifying problem areas and projecting outcomes of potential initiatives, they will better coordinate resources across local food charities, grocery stores, and health institutions. Thus, AI-FEED is vital in transforming the local food security landscape.

Differentiators

AI-FEED sets itself apart by its commitment to enhancing the lives of food charity clients by providing food tailored to their specific needs and the necessary nutritional education for optimized use. This ethos has led the team to concentrate on local food charities; the entities best suited to accomplish these aims. AI-FEED enhances and forges new connections among food charities, clients, donors, and engaged community leaders.

While some projects focus on reducing food waste at the donor-to-charity level, AI-FEED focuses on the local level by employing a unique blockchain-backed system that improves transparency and accountability.

AI-FEED empowers charities to distribute relevant foods and instructional materials more readily to clients. While supporting greater nutritional intake of clients, food waste is simultaneously reduced. AI-FEED is the first initiative to harness smart technologies to support food charity activities at the local level.

AI-FEED offers innovative advances in community leader support through the Healthy Food Index tool features. The tool incorporates critical elements of nutritionally

communities. It illustrates how education and access to culturally appropriate, nutritious food can be optimized to support neighbors in need more meaningfully and practically.

Road Map

In the first year, the AI-FEED team will focus on developing an initial version of their web-based platform with specialized modules for community leaders, food charities, donors, and food clients. Tabletop exercises will be held over the first three quarters, each dedicated to one of the core functionalities: 'Learn,' 'Act,' and 'Educate.' Decisions concerning intellectual property and the platform's future structure post-project will be finalized during this timeframe. Onboarding sessions start in the fourth quarter, and the year will culminate with a platform launch throughout Texas. The second year centers on platform refinements, aiming to launch its second version nationwide by the end of the fourth quarter. Onboarding will continue throughout year 2, with the third quarter encompassing comprehensive tabletop exercises for each stakeholder group. Stakeholder interviews will ensure quality, complemented by internal reviews and quarterly U.S. National Science Foundation meetings.

Partnerships

This project is undertaken by University of Houston (UH), University of Texas (UT) at Austin, and the Souper Bowl of Caring. The team's (initial) other collaborators are a diverse set of organizations working at the core of the food insecurity crisis: Bivins Foundation, Brighter Bites, Catholic Charities Fort Worth/Wichita Falls, Christian Community Service Center, DairyMax, Hearts and Hands of Baytown, and St. Paul's Food Pantry Baytown. The team's project includes an outreach plan to city and state elected officials. These officials have provided initial support for developing the decision-making tool, viewing it as contributing to their constituents' and communities' health and economic robustness. Partners have been interviewed during Phase 1, evaluating the low-fidelity prototypes of the AI-FEED system and providing feedback for improvements. They have agreed to participate in Phase 2 tabletop exercises to test, evaluate, and provide input for AI-FEED as it progresses through its developmental phases.

Intellectual Property

The Principal Investigator (PI), co-PIs, and Senior Personnel have agreed that each lead will share patent rights equally, with a 1/6 share each. Upon funding for Phase 2, the team intends to engage UH Office of Technology Transfer & Innovation, alongside UT Austin and Souper Bowl of Caring, to draft a memorandum of understanding. Plans also include patent submission for the proposed inventions. Preliminary discussions are underway with directors at UH and UT's technology transfer offices.

AquaSteady

Balancing Soil Moisture

Lead PI: Cindie Kehlet
ckehlet@pratt.edu

Jon Chorover
chorover@arizona.edu

John Idowu
jidowu@nmsu.edu

George John
gjohn@ccny.cuny.edu

Karol Murlak
kmurlak@pratt.edu

Overview

The impact of climate change on agriculture is severe, as drought reduces crop yield, affecting food and nutrition security. To reduce these effects, a biodegradable hydrogel called AquaSteady has been developed. This hydrogel is made from alginate, extracted from brown seaweed, and increases the amount of water available to plants while improving soil health, resulting in increased crop yield and more nutritious food. AquaSteady comes in various shapes and forms, including powder, granules, strings, and patterned nets, used in different crops and soil types. AquaSteady is where aquaculture meets agriculture by utilizing the valuable and regenerative natural resource of brown seaweed. By sequestering carbon and removing excess nutrients like nitrogen and phosphorus from our oceans, the development of AquaSteady will create a new demand for sustainably grown seaweed. This will fulfill a critical element of building a circular economy, which involves regenerating natural systems and increasing food and nutrition security.

Description

Humanity is currently experiencing unprecedented challenges worldwide, ranging from escalating climate change and widespread food and nutrition insecurity to ever-increasing global populations. Agriculture is a crucial factor in these challenges, being essential for feeding our growing populations. However, it has also become one of the biggest drivers of global environmental change due to the overconsumption of natural resources and exceeding planetary boundaries. Paradoxically, as agriculture undermines human and planetary health, food production is becoming increasingly threatened by the impacts of climate change. Agriculture is the biggest water consumer globally, using up to 80% of freshwater resources for food production. Additionally, agriculture is accountable for significant soil degradation leading to the decline in soil quality caused by soil erosion, compaction, salinization, and loss of soil nutrients. Inappropriate water management practices contribute considerably to soil degradation, which can result in the loss of arable land, desertification, and ultimately, food production loss. The team has developed AquaSteady, a biocompatible and biodegradable hydrogel that enhances soil health by increasing plant-accessible water. AquaSteady is a hydrogel that can be made in different shapes and forms matching the needs of different crops and soil types. It can be made in powder, granules, or flakes and in large format as strings and patterned nets. Although hydrogels are not a novel idea, most hydrogels on the market are synthetic, petroleum-based materials that are not biocompatable. AquaSteady is produced from alginate, extracted from brown seaweed that enriches the soil as it decomposes. Soil health is often overlooked in its significance for food and nutrition security. Healthy soil, rich in diverse nutrients and organic material, fosters the growth of nutritionally dense food that provides people with a rich diet combating malnutrition.

Differentiators

At present, hydrogels for soil amendment (whether biocompatible or not) are usually available in powder or granule form. However, these forms have limitations when used in clay soil, as they struggle to expand properly. The research indicates that AquaSteady is effective in sandy soil, but they have gone further by creating a hydrogel that can take any shape and form, including one that performs well in clay soil. In a preliminary field test, the team evaluated the hydrogel by planting orange trees in clay soil, both with and without the hydrogel. After 45 days of drought following transplanting, the trees with the hydrogel remained healthy, while those without it were wilting.

Road Map

In Phase 2, the goals are to develop AquaSteady to be used for various crops and in different soils to balance water usage and to study its potential to improve soil health. Building on the lessons learned during Phase 1, the team will work with farmers to learn the needs of various crops and soil types. To this end, AquaSteady will be working intensively with two Agricultural Extensions and two farms. In these locations, AquaSteady will be interacting closely with personnel to understand and follow the progress of each crop over an extended period of time. In addition, they will implement a Small Farm Program to involve farmers who would participate in the project by testing AquaSteady. AquaSteady will initially meet the farmers to understand their needs, decide on the metrics, and ship AquaSteady Kits for each location. The preliminary interaction with farmers has already generated data that needs further research and development of the hydrogel. The strategy is to increase the data pool to further develop the material and come to a point where AquaSteady is ready for diverse crops and soils. To produce the hydrogel for testing AquaSteady will build a small production laboratory. In this laboratory, the team will test concepts for sustainable fabrication methods that include reclaiming water which is one of the heaviest-used substances in the production of AquaSteady. Finally, AquaSteady represents the convergence of aquaculture and agriculture. Seaweed is a crop that is very efficient in absorbing CO_2 and nitrogen contributing to carbon sequestration. In the spirit of circular economy, AquaSteady's plan is to investigate the complete use of cultivated seaweed. The road map will lead the team to a deeper understanding of AquaSteady and optimize its use for different crops and soils. At this point, the team will have the elements to develop a business plan to industrialize and commercialize AquaSteady.

Partnerships

AquaSteady has various participants, including academia and the farming industry. During Phase 1 they expanded the team and Phase 2 will allow them to expand even further. The multidisciplinary team has scientists, designers, and farmers working closely together to develop AquaSteady for optimal application in soil. Through the proposed Small Farm Program, the team will be able to include even more farms and learn more about AquaSteady's application in different soils and to different types of crops. The agronomists at University of Arizona, New Mexico State University, and University of Puerto Rico will connect with local farmers to do field tests in various climates challenged by climate change. They are developing educational material for elementary and middle schools and have partnerships to include AquaSteady in school gardens.

Intellectual Property

AquaSteady is filing for a U.S. Provisional Patent for the method to manufacture AquaSteady in different forms and shapes. After this filing, they will be investigating the possibility of filing a suit of patents for each of the different shapes that they can produce as there are variations on the original method. The filing of the provisional patent will allow them to disseminate the results of the team's work to a wider audience.

CropSmart

Making Wiser Cropping Decisions

Lead PI: Liping Di
ldi@gmu.edu

Fei Chen
feichen@ucar.edu

Qian Du
du@ece.msstate.edu

Juan Sesmero
jsesmero@purdue.edu

Haishun Yang
Hyang2@gmu.edu

Overview

CropSmart provides on-demand data-driven decision solutions optimized for the cropping goals of decision-makers, such as farmers, agro-business operators, government agricultural officials, without burdening them with data manipulation or instrument investments. The optimal solutions, up to field scale and coverage of the continental U.S., are derived from near-real time remote sensing of cropping systems with physics- and artificial intelligence/machine learning (AI/ML)-based modeling and simulations.

Description

The U.S. Department of Agriculture's (USDA) Agricultural Innovation Agenda calls for increasing U.S. agricultural production by 40% while cutting its environmental footprint in half by 2050. Sound crop management decision-making is key to reaching this ambitious goal. An example of such decision-making is "should I irrigate my cornfield today? If so, with how many inches of water?"

Traditionally, crop management decisions are made by individuals based on their empirical judgment, which is often subjective and less than optimal. Science-based, data-driven approaches for crop management decision-making rely on timely and accurate information on current and predicted future conditions of crop, soil, weather, and markets to make optimal decisions. Studies demonstrated that the data-driven approach can overcome the inherent deficiencies in the empirical approach and bring significant economic and environmental benefits. However, it remains a challenge for stakeholders to adopt the data-driven approach because they do not have full access to timely and accurate information and lack facilities or knowledge to process the information.

This project was created by a group of experts who are pioneers on data-driven decision making for crop management and have deep and trusted connections with farmers, agribusinesses, and government agricultural discission makers. The innovation designed in Phase 1, and to be built and deployed in Phase 2 by six funded institutions and 14 collaborative end-user organizations, will provide optimal data-driven cropping decision-making nationwide to stakeholders across the farming ecosystem by developing and operating CropSmart, an Earth system digital twin for decision making (ESDT-DM). CropSmart is a digital replica of real-world cropping systems over the Contiguous U.S. up to a 10-meter spatial resolution using advanced remote sensing, modeling, AI/ML, agro-geoinformatics, and ESDT-DM technologies (Figure 1): https://nassgeo.csiss.gmu.edu/CropSmart/PES_Image1_J137.png. It will not only accurately represent the current conditions, but also predict, with acceptable confidence levels, future conditions with hypothetical "what if" scenarios resulting in actionable predictions. CropSmart will provide three services to users for each kind of decision-making use cases: 1) user-specific decision ready information (DRI) for users to make data-driven decision; 2) "what if" tradeoff service that generates consequences (e.g., yield, economic return, or environmental footprint) when a user presents different decision options so that the user can find the optimal decision; and 3) decision advice service which will automatically generate optimal decision based on a user's decision goal.

CropSmart will significantly help reach the USDA Innovation goal and greatly enhance food and nutrition security of the U.S. and the world. It will bring hundred-million-dollar economic return and huge environmental benefits to U.S. economy and society each year. For example, if 50% of irrigation farms adopt the CropSmart scheduling, without impacting the yield, 1 billion cubic meters of water and $100 million fuel cost can be saved, and 1 million metric ton of CO_2 equivalent emission can be reduced annually in Nebraska alone. Other CropSmart-enabled use cases have similar scale of impacts.

Differentiators

While there are several commercial products available that support data-driven decision-making, each typically caters to one decision-making use case, and they often require large upfront investments for field sensors and processing of data collected by the sensors. For example, commercial irrigation scheduling requires farmers to spend over $50,000 on soil moisture sensors for each center pivot irrigation system. In contrast, CropSmart leverages freely available operational Earth observation data from the government, combined with advanced ESDT and modeling technologies. This allows users to bypass the initial investments and data processing burdens, while accessing multiple decision-making services either for free or at a highly competitive rate.

Road Map

At the end of Phase 2, a fully functional CropSmart V2.0 will be released. It will be deployed operationally to support at least six decision-making use cases, such as irrigation scheduling and when to plant and harvest, with at least 6,000 users. Its DRI service will assist end-users on decision making in many more use cases. A community-based nonprofit organization, CropSmart.org, will be set up to take responsibility of operating, maintaining, and further developing CropSmart. It will be funded by subscription fees for the "what if" trade-off and decision advice services, advertisement revenues on the CropSmart website, grants from funding agencies, industry, and foundations, and possible commercialization of CropSmart with partners such as Syngenta.

Partnerships

The CropSmart project has six funded partners, including George Mason University on digital twin development and operation, Mississippi State University on AI/ML and remote sensing, University Center for Atmospheric Research on land surface modeling and prediction; Kansas State University on climate-smart agriculture and extension; University of Nebraska-Lincoln on crop modeling and extension; Purdue University on cropping decision economy and extension, and 14 unfunded collaborative end-user organizations such as crop farms; seeds, crop insurance; farm loan, and crop advice service vendors;

and federal/state agricultural agencies. In Phase 1, the end-users actively participated in the end-user interviews, provided requirements and use cases, and verified the feasibility and applicability of CropSmart design. The 14 collaborators have firmly committed to fully participate in CropSmart development and operation in Phase 2.

Intellectual Property

The major intellectual properties (IP) of CropSmart are the data, algorithms and models, and software components and systems created before, during, and after CropSmart Phase 1 & 2. CropSmart.org will inherit all IPs created before and during the Phases 1 & 2 project and will create its own IPs through cultivating the CropSmart community ecosystem. CropSmart will manage IP access at three levels: 1) free, unrestricted use and reuse by everyone; 2) free, unrestricted use and reuses by CropSmart.org; 3) restricted use with access control and/or fee. The members of CropSmart.org will share IPs.

Additional Information

CropSmart prototype (Figure 2): cloud.csiss.gmu.edu/CropSmart.

Cultivate IQ
Empowering Regional Food Systems

Lead PI: Meredith Adkins
mmckee@uark.edu

Kristen Gibson
keg005@uark.edu

Thi Hoang Ngan Le
thile@uark.edu

Trey Malone
tmalone@uark.edu

Chase Rainwater
cer@uark.edu

Overview

Despite food shortages from global supply chain disruptions and growing consumer demand, there continues to be a void of local and sustainably grown food on retail shelves and community tables. Cultivate IQ is an Artificial Intelligence/Machine Learning (AI/ML) data transformation platform that will empower small to mid-sized farmers, ranchers, and local food buyers to optimize production and sales through accessible data insights and decision support tools. Cultivate IQ's vision is to strengthen the resiliency of regional food systems by enhancing supply efficiencies across America's agricultural food supply chain.

Description

While consumers are increasingly interested in purchasing local and sustainable options, small to mid-sized growers face barriers associated with economies of scale as they strive to integrate into the food distribution system. These producers are often limited in their access to comprehensive price, demand, and supply data. These constraints prevent local food purchasers from connecting with buyers via intermediaries.

The Cultivate IQ team has created the blueprint for a cloud-based software platform that delivers data insights to local food purchasers, such as food hubs, and producers. In Phase 2, the team will develop scalable technology that will be piloted initially in Northwest Arkansas, the Central Arkansas Delta, and Cherokee Nation, followed by broader geographic expansion.

The primary objectives are to 1) Prioritize the economic viability of small to mid-sized U.S. farms and local food buyers who support them; 2) Create data transparency and actionable insights across key decision points in the food supply chain, such as pricing, supply, demand, seasonality, and growing conditions; 3) Democratize access to data insights via AI/ML technological advances, ensuring useability by historically excluded communities; 4) Enhance U.S. food and nutrition security and surety of supply via demand-based market and production data, resulting in enhanced distribution through mainstream market channels, reduced food waste, and increased consumption of local, nutritious food.

Differentiators

Most farm technology software is focused on farm management or precision agriculture technologies. Few products offer functionality related to market channels, specifically to support price and consumer demand forecasting for non-commodity agricultural products such as fruits, vegetables, and regionally processed meat. Cultivate IQ addresses a significant market gap by leveraging advances in AI/ML decision science, as well as satellite imagery to identify cropland across a region so that regional food purchasers and growers can more efficiently plan production to meet existing demand.

Enhanced knowledge of consumer insights and market channels will reduce food losses and enhance crop diversification, supporting climate-smart resiliency in agricultural value chains. Furthermore, the approach is inclusive, prioritizing access to Cultivate IQ's technology by producers in underserved and disadvantaged communities, including Black, Indigenous, and Persons of Color. The AI/ML approach, its scalability, and its cost effectiveness mean that Cultivate IQ can address a significant market failure—supply and demand inefficiencies—within regional food systems.

Road Map

During Phase 2, the main deliverables are to build, test, and refine the Cultivate IQ platform. The product's design is informed by extensive investigation of user needs and low-fidelity prototype feedback during Phase 1 of the project, which will be expanded in Phase 2. By the end of year 1, the team will release Cultivate IQ's Minimal Viable Product. Year 1 milestones will include

co-creation of the product scope across the ecosystem and technology development work clusters, establishing requirements for data and computational models, and development of the technology infrastructure. By the second quarter, the web application will be developed, with initial user testing planned by the third quarter.

In year 2, the main deliverables are to continue to refine Cultivate IQ functionality through pilot launches and user testing. Cultivate IQ will engage their partner network, including local food purchasers and farm business educators, to gain user feedback and refine their implementation strategy, including identifying barriers to adoption. By the end of year 2, the team will finalize the strategy for market release and sustained platform operations.

Partnerships

Project partners include five majority land-grant academic institutions: University of Arkansas (UA), UA System Division of Agriculture, University of Arkansas at Pine Bluff, University of Florida, and University of Wisconsin-Madison, as well as two industry partners. The project is administered by the University of Arkansas Institute for Integrative and Innovative Research (I³R), a pioneering translational research institute that fosters convergence through collaboration to address grand challenges and deploy innovations to scale.

Junction AI is an AI/ML forecasting and consumer insights software startup that supports retailers and brands to adopt AI/ML in their day-to-day operations and supply chain. Cureate is a woman-owned business with a focus on the food and beverage industry. Through its educational curricula, local procurement platform, and strategic counsel, Cureate has become a tested model of supply and demand match-making— connecting big and small business supply chains that have been fragmented for too long.

Cultivate IQ current and future collaborators include food hubs, investors and funders, nonprofit organizations, and government agencies. Partners will offer feedback on technology design, pilot the solution, and consult on the long-term business model and sustainability plan.

The Cultivate IQ team offers deep expertise in technology development, deployment, and community engagement, including Tribal policy led by Indigenous Food and Agriculture Initiative. The faculty and industry partners have engaged at all levels of the food value chain, from farm to market, and developed solutions to connect farmers and food entrepreneurs to institutional markets.

Intellectual Property

Cultivate IQ's intellectual property (IP) is interinstitutional in scope. Background IP is owned by the originator and will be documented in the IP Agreement allowing all collaborators access to complete the work of the project. Data within the platform will include public and open-source datasets, as well as proprietary data. Ownership of Cultivate IQ jointly created IP will be assigned according to inventorship or authorship. UA will lead, in collaboration with joint owners, appropriate IP protection, licensing of existing and new IP, or commercialization of the Cultivate IQ product beyond the scope of the grant project.

Dairy NutriSols

Dairy Done Right

Lead PI: Owen McDougal
owenmcdougal@boisestate.edu

Tim Anderson
tandersen@boisestate.edu

Kumar Mallikarjunan
kumarpm@umn.edu

Prateek Sharma
prateek.sharma@usu.edu

Gulhan Unlu
gulhan@uidaho.edu

Overview

Dairy NutriSols is a Research and Innovation Consortium that provides sustainable process solutions for the production of nutrient-dense, safe, shelf-stable, healthy products to combat food and nutrition insecurity. Their convergent science team creates artificial intelligence-based chemometric software and facilitates industrial adoption of pulsed electric field and extruder technology to achieve 2050 climate goals and increase food production for a growing population.

Description

In response to global demand for nutrient-dense food, the United States dairy industry exported record levels of milk solids equivalents, at 2.4 million metric tons, equating to a volume that rose 25% in 2022, to nearly $10 billion U.S. dollars. At the same time that the U.S. is achieving record export levels of dairy products, fluid milk production is outpacing process capacity, thus limiting access to nutritious food products for food and nutrition-insecure populations. Food and nutrition insecurity threatens nearly 1 billion people around the world. In response, the Dairy NutriSols consortium of chemists, biologists, computer scientists, and dairy science engineers partnered with industry leaders to develop and deploy cutting-edge, innovative, and practical solutions to produce quality products, at higher volume and lower cost. Dairy NutriSols will catalyze the modernization of industrial practices to improve food processing efficiency, ensure consistent product quality, reduce waste, and upcycle byproducts by accelerating the adoption of cutting-edge technology that transforms the industry in emerging areas. Their pioneering approach integrates AI-based computational software with state-of-the-art technology to address industry-driven sustainability challenges critical to the competitiveness of U.S. dairy operations in a rapidly evolving global marketplace. Dairy NutriSols is fueled by students technically trained in convergent science disciplines, prepared to creatively generate process and technology solutions to provide all people

access to affordable nutritious foods at a scale that impacts growing domestic and global food and nutrition demand.

Differentiators

Dairy NutriSols draws on the capabilities of six existing regional dairy centers located across the U.S. to amplify their impact and provide timely solutions for industrially relevant challenges in combating global food and nutrition insecurity. Whereas the regional centers focus on traditional dairy science discovery and development, the Dairy NutriSols team offers a convergent approach that facilitates the adoption of unique, cutting-edge research processes and equipment to target industry-identified priorities that are critical to the dairy industry achieving carbon neutrality by 2050. Not only does the AI-based software and advanced manufacturing through pulsed electric field and extruder technology being prototyped by Dairy NutriSols provide innovative solutions to promote nutritious product production efficiency and affordability, but the next generation of career employees are provided essential technical training required to meet the growing demand for products.

Road Map

The low-fidelity prototypes developed by Dairy NutriSols include (1) chemometric software, (2) pulsed electric field application, (3) extruder technology, and (4) outreach programs for rural and underserved communities. Phase 2 milestones include: (1) beta testing of chemometric software for real-time monitoring of casein at Daisy Brand to address product quality and consistency, (2) integration of pulsed electric field technology at Agropur to improve protein spray drying efficiency, (3) enhanced ingredient functionality and new product development through extrusion technology with Glanbia Nutritionals, and (4) workforce technical skill training for young people to generate enthusiasm for food process careers,

and adults to develop expertise critical for upward mobility in industrial settings. Before the end of Phase 2, milestones will expand to include prototype adoption by additional dairy process stakeholders, leading to increased production capacity, efficiency, affordability, and sustainability to address growing domestic and global demand for food and nutrition security.

Partnerships

Dairy West, Daisy Brand, Agropur, Glanbia Nutritionals, Food Physics, and the National Dairy Council have been partners for initial prototype development. In Phase 2, six new industry partners and an economist will be added to assess the real-world impact of prototypes to make dairy products more accessible and affordable for domestic customers and export competitiveness in emerging markets.

Intellectual Property

Intellectual property (IP) will emerge from Dairy NutriSols' team activity. Co-Principal Investigator Mallikarjunan has a 2023 patent pending for technology to improve dairy protein functionality, and the potential for more patentable work is highly probable. Dairy NutriSols will manage Phase 2 IP in accordance with their IP management plan that was written to promote industry partnership.

Additional Information

The work conducted by the Dairy NutriSols consortium of chemists, microbiologists, computational experts, and dairy science engineers, directly involves three regional dairy centers, and partnership with more than a dozen dairy companies, to provide timely prototype solutions to challenges of greatest collective impact across the industry. The success of the Dairy NutriSols team will increase access to nutrient-dense, shelf-stable, affordable, and accessible products by vulnerable populations across the globe that reside in food deserts, food swamps, and climate crisis zones.

EarthStream

A Clear Path to Food Security

EARTHSTREAM

Lead PI: Michael Prorock
michael.prorock@mesur.io

J. Carl Ganter
jcarl@circleofblue.org

Thomas Chappell
thomas.chappell@ag.tamu.edu

Joseph LaForest
laforest@uga.edu

Overview

The Earthstream™ Food & Water (EFW) Platform empowers businesses, policymakers, researchers, and farmers with real-time insights into food and water security using automated machine learning and generative artificial intelligence. By automatically sourcing and analyzing relevant data, the platform not only identifies security risks specific to a user's region but also suggests actionable mitigation strategies. In an era of increasing environmental challenges, this tool is crucial for proactive risk management and sustainable decision-making.

Description

The global urgency of food and water security, magnified by climate change and population growth, is a significant concern in the U.S. The COVID pandemic highlighted the food supply chain's fragility, further stressed by erratic climate events. Droughts and extreme weather challenge the ability to meet growing food demands. Despite agricultural advancements, the need to maintain precision agriculture's gains is crucial. In response, Earthstream's partnership with the Food Bank of Central and Eastern North Carolina aims to improve sourcing nutritious foods for 80 million meals during the first year. As they expand beyond North Carolina, Earthstream's impact will grow. The solution, combining data science, AI, and supply chain analysis, ensures food and water access and strengthens community well-being. Through research and partnerships, the team is dedicated to enhancing U.S. food and water security, promoting global sustainability.Food production's complexities demand a holistic understanding. The EFW platform, utilizing advanced AI, offers system stability assessments, enabling early detection of potential issues. This innovation transforms traditional farming methods, facilitating efficient, green interventions. EFW's interface lets users input queries, delivering insights from diverse sources, including open-source intelligence. These insights address various threats, from weather to geopolitical factors. Prototypes are already operational with entities like Walmart and U.S. governmental agencies.

Phase 2 is crucial for EFW's growth. This phase will address industry research gaps, ensuring accurate user responses. The AI-driven EFW uses a research agent that selects the best tools for queries, guiding its research. If a query is beyond its scope, it identifies additional tools, directing areas for further development. For example, while climate change research is abundant, specific guidance for sustainable crops is limited. Early tests revealed this deficiency, influencing the research direction. The funding will also support platform development, user testing, and marketing, maximizing the platform's reach. This development phase will transition EFW to full market adoption. By establishing a sustainable business model, the team aims to offer free access to vital entities like food banks, farmers, and academic researchers, while commercial users ensure business sustainability. This isn't just about a tool; it's about future-proofing our food supply chain.

Differentiators

Capitalizing on recent generative AI breakthroughs, the EFW platform will set a new standard in scale and usability by introducing the first unified web-scale food and water database, complemented by a pioneering natural language interface trained to autonomously tackle diverse research and modeling tasks from factual data.Distinct from other platforms, EFW employs intelligent agents that not only plan, research, and engage with users but also prioritize data integrity. Every piece of information is linked to accompanying citations, ensuring users receive cutting-edge insights and verifiable sources.

Road Map

January 2024: Establish and work with key User Focus Groups on the farm, and in food sourcing, particularly with Food Banks.

June 2024: Release access to crop threat alerts and natural language interfaces for users of the platform; begin working with Commercial partners to understand enterprise needs.

December 2024: Release Crop suitability and planning capabilities that connect food sourcing, the farm, and changing climate conditions.

June 2025: Release pricing, economic impact, and forecasting capabilities to users.

December 2025: Full production release to commercial, NGO, and government users.

Partnerships

Phase 1's success was amplified by collaborations with diverse partners, a trend which continues into Phase 2. University of Tennessee provided deep insight into water usage and availability for crops. Feeding the Carolinas contributed with their expertise in alliance leadership and food networks. The Cognitive Security and Education Forum and University of Washington offered insights into intelligence fusion, while the National Defense University focused on food, water security, and international relations, especially in South and Central America.

Entering Phase 2, new partnerships will deepen the project's impact. Texas A&M University and University of Georgia will infuse academic and research strengths. The U.S. Department of Homeland Security will advise on technical standards and security. University of North Carolina's Gillings School joins as an Earthstream Advisory Board member, offering expertise in historical context and innovation. Additional experts will amplify outreach with marketing skills, emphasizing communication and branding. Collaborations with Walmart and Nestle are also in the pipeline based on their use of early prototypes during Phase 1.

Intellectual Property

mesur.io has developed exclusive models and algorithms that are currently undergoing testing with commercial clients. The company is engaged in partnerships with agricultural nongovernmental organizations as well as government entities, sharing their findings and supplying data at no cost to academic collaborators to enhance research publications.

Lead PI: Md Shah Alam   Patrick Carroll   MaryAnne Drake
              alamm@uncw.edu

              Christopher Dumas   Keerti Rathore

Overview

Eco-Aquafeed is fish feed formulated from a blend of alternative protein sources that fosters sustainable fish farming. Eco-Aquafeed curbs reliance on unsustainable fishmeal, offering quality and cost-effectiveness. This innovation accelerates U.S. seafood production, eases pressure on ocean fish stocks, cuts reliance on imports, reducing the seafood trade deficit and contributes to a healthy seafood supply for consumers.

Description

Due to its health benefits, seafood plays a crucial role in ensuring food security and nutrition. As the global population continues to increase, there is a significant need to expand seafood supply. In the United States, the demand for seafood surpasses domestic supply, leading to the importation of 70-85% of seafood (50% of which comes from aquaculture which cultivates under controlled or semi-natural conditions). Consequently, this results in a seafood trade deficit of $17 billion.

With capture fisheries nearing their limits, the future of seafood supply hinges on feed-based aquaculture. This project aims to address the priority of marine aquaculture technologies through both laboratory, semi-pilot and commercial-scale projects. The core objective is to develop sustainable fish feed from a blend of alternative protein sources. This approach will benefit high-value marine fish, such as black sea bass, striped bass, and Asian sea bass/Barramundi. The initiative also holds the potential to generate employment opportunities in coastal communities while producing nutrient-rich local seafood.

The project's scope includes evaluating various factors such as cost-benefit analysis, feed utilization, fish growth performance, and the quality of fish fillets. Additionally, the efficiency of waste and nutrient removal will be assessed through the utilization of an Integrated Multi-Trophic Aquaculture system (IMTA), the system used to house and grow the fish. This

integrated system manages aquaculture waste, utilizing it to cultivate the salt-tolerant plant Salicornia (Sea Beans), which has diverse applications, including its use as food.

By addressing the development of innovative techniques, this project benefits researchers, industries, fish farmers, and coastal communities involved in aquaculture production methods.

Differentiators

Previous domestic marine aquaculture commercialization efforts faced limitations due to market fit, demand constraints, and technological drawbacks. Undeveloped culture technologies, including fish feeds, led to high farm costs. Further, marine fish continue to lack sustainable feeds, a challenge recognized in the team's user-centered research.

Eco-Aquafeed's proposal focuses on a tailored diet for three U.S. marine aquaculture species. The team will assess alternative ingredients like single-cell protein, ultra-low gossypol cottonseed meal, Salicornia meal, and poultry by-product meal which offer low competition with human resources.

Eco-Aquafeed's development builds on recent marine fish nutritional advancements, incorporating Phase 1 lab findings. The project uniquely spans alternative protein feed design, encompassing juvenile and extensive growout phases, product testing, restaurant feedback, and waste management through IMTA. This approach lets fish growers observe real-world aquafeed application beyond labs.

Road Map

Eco-Aquafeed's key deliverable is to create sustainable fish feed using aquafeed formulated from a blend of alternative protein sources. This feed will be used for black sea bass, striped bass, and Asian sea bass/

Barramundi. The milestones for this project are to:

- **Q1, 2024:** Produce and stock fish fingerlings.

- **Q1-Q2, 2024:** Formulate and manufacture diets.

- **Q2, 2024-Q2, 2025:** Conduct growout trials and monitor IMTA.

- **Q2-Q3, 2025:** Taste profiling, restaurants, and consumer acceptance testing.

- **Q1-Q3, 2025:** Proximate and biochemical analysis of fish.

- **Q3-Q4, 2025:** Evaluate sustainability of feed against eco-certification criteria.

- **Q3, 2024–Q4, 2025:** Production economics analysis.

- **Q4, 2024 and Q4, 2025:** Dissemination through extension experts, intellectual property (IP), present at conference, and publication.

- **Q4, 2025:** Final report to U.S. National Science Foundation.

Partnerships

This proposed work is a collaboration of multidisciplinary experts and partners including fish nutritionists, aquaculturists, biotechnologist, economist, extension personnel, IP expert, restaurant chef and fish farmers. Eco-Aquafeed's academic partners are University of North Carolina Wilmington who conducted lab scale trials with alternative protein sources in Phase 1 for black sea bass and will evaluate sustainable methods of marine fish culture in phase 2 with Eco-Aquafeed, Texas A&M University who will produce ultra-low gossypol cottonseed meal, and North Carolina State University who will do taste test of fish fillet in Phase 2. The industry partners are the commercial striped bass farm Oak Grove Farm, North Carolina (NC), and the Asian sea bass/Barramundi farm Great Falls Aquaculture farm, Massachusetts (MA), who in Phase 2 will test Eco-Aquafeed diets and control diets. The feed manufacturer partner, Zeigler Brothers, Pennsylvania will produce the Eco-Aquafeed diets. The novel alternative protein producer, Knipbio Inc., MA, provided single-cell protein meal in Phase 1 and in Phase 2 will provide single-cell protein meal and technical support. The extension personnel from the NC Sea Grant will disseminate the results of the study

in Phase 2. Commercial end-users from fish farms and restaurants, and a university panel taste sensory evaluation team will evaluate the fish for flavor and consumer acceptability in Phase 2.

Intellectual Property

The Eco-Aquafeed formulations with alternative protein sources along with the IMTA system will be maintained as IP to promote entrepreneurship by enabling technology to be licensed to commercial scale farmers. Feed manufacturer Zeigler Brothers, Inc, PA, and single cell protein manufacturer, KnipBio Inc., MA, will also benefit from the exposure of their brands and services during this collaborative process. As such, any business construct will ensure each party benefits from the respective partnership, energizing continued growth and success for each party and the mariculture industries within the United States.

EcoRico

Transforming Your Local Food System for a Healthier Planet

Lead PI: Uriyoán Colón-Ramos
uriyoan@gwu.edu

Crystal Díaz
puertoricoproduce.com

Joel Gittelsohn
jgittel1@jhu.com

Oscar Meléndez
oscarm@taispr.com

Cesar Ostolaza
cjostolaza@inepr.com

Overview

Severe weather has dramatically impacted global food and nutrition security. Despite technological advances, many stakeholders in food production, or nutrition programs remain unengaged and disconnected from climate solutions, and vice versa. Globally harmonized solutions grounded in local insights are vitally needed to transform the broken systems of today. The EcoRico brand & Learning Platform (LP) is the first product to engage key stakeholders in a local food system to act under one cohesive mission: promoting foods that are good for their people, their environment, and their local economy.

Description

The EcoRico brand and Learning Platform (LP) is a user-friendly, interactive online platform that promotes systems thinking across different sectors. Through its brand and LP, EcoRico prioritizes foods that are nutritious (i.e. fresh fruits and vegetables), beneficial to the environment (i.e. farmed using ecological agriculture practices); and contribute to a vibrant local farming economy. EcoRico's solution targets audiences that are vital in any local food system: consumers, farmers, and decision makers.

- **EcoRico consumer-facing brand** and campaign informs consumers about the interconnections between nutrition, local farming economy, and climate. The EcoRico brand tags and offers foods that are nutritious, local, and climate-friendly.

- **Farmers' LP** module engages with local farmers to virtually test costs, inputs, and outputs for short and long-term consequences of yields, sales, and resources.

- **Decision-makers' LP** supports learning via visualization and gaming about: 1) how sectors are related to each other in a system; 2) how they interact and affect outcomes that decision-makers care about (i.e., health costs, disease prevalence,

food insecurity); or 3) unintended consequences of decisions.

Learning Platform

Differentiators

EcoRico delivers a locally-grounded, common language to discuss solutions that are globally aligned. It is the first platform to simulate how improving local nutrition and local economy may align with climate health. Data from EcoRico testing will provide valuable insights into behavior and decision making of diverse users in lower income settings, starting in Puerto Rico. Data from lower-income settings in America is limited but vital to understanding how various stakeholders react to the nexus of climate health and nutrition security. EcoRico is unique from the piecemeal solutions of today. It transforms unsustainable food systems by providing a tool to visualize cross-sector partnerships.

Road Map

Month 1-6, Y1: Establish EcoRico ecological farming practices and data integration architecture from farm to consumer apps. EcoRico brand campaign launch (based on Phase 1 work). Simulation model formulation (based on Phase 1 work).

Month 7-12, Y1: EcoRico brand testing using gamification. Simulation model testing and integration of climate change projections in LP. Sustainability plans for each deliverable.

Months 13-23, Y2: Design/test Farmers' and Decision-makers' LP. Data architecture and incorporation of global data.

Deliverables: 1. EcoRico Learning Platform Farmers' Module; 2. Consumer-facing EcoRico brand with summary of best strategies to promote EcoRico products (nutritious, local, ecological) to consumers; 3. EcoRico Learning Platform for decision-makers/stakeholders.

Sustainability: Funding streams beyond Phase 2 to be discussed with local advisory boards to ensure local co-ownership of decisions. Funding and transferability to other settings after Phase 2 is a measure of success and scalability.

Partnerships

EcoRico has a geographically, academically, institutionally, and culturally diverse team. The Phase 1 partnership with academic, commercial, and nonprofit partners is further diversified by adding Guarike and University of Puerto Rico. The team is already working to strengthen climate health, local food and farming economies, nutrition, and health.

Intellectual Property

The team is committed to openness and sharing of the simulation model and learning platforms, while EcoRico branding and consumer engagement may be licensed under more restrictive conditions.

Food Forecast

Actionable Insights for Post Disaster Food Security

Lead PI: Lauren Clay
lclay@umbc.edu

Chris Prentice
prenticecr@uncw.edu

Ashlea Milburn
ashlea@uark.edu

Julia Waity
waityj@uncw.edu

Overview

Food Forecast empowers community organizations and local, state, and federal agencies to bolster post-disaster food security, particularly for vulnerable communities. The interactive platform visualizes disaster, food, and community data. End-users can simulate what-if scenarios to facilitate planning and response. Food Forecast can be used to identify proactive food security strategies customized to each community and maximize allocation of scarce resources.

Description

Eleven to 15 percent of the U.S. population experience food insecurity from one year to the next, and these rates can increase threefold following disasters. Food Forecast provides actionable insights for proactive food security strategies and solutions customized to each community. Food Forecast can improve food system resilience and reduce household food insecurity in the aftermath of disasters by helping organizations and agencies better plan for, respond to, and restore food security following disasters. Dozens of interviews and two validation workshops with prospective end-users informed the development of the comprehensive Food Forecast decision support platform.

It features four tools: 1) a community food security measure, 2) an interactive map to integrate user-added information, 3) an interactive dashboard to simulate proactive interventions, and 4) a community scorecard with tailored insights. The complementary tools integrate data from dozens of sources identified as important by end-users and provide synthesized information in one place. Users can use these tools to identify vulnerabilities and facilitate collaboration with other stakeholders. In Phase 2, the team will scale their community- engaged model building approach to integrate the most hurricane impacted areas in the U.S. into the Food Forecast platform.

Food Forecast is built by an interdisciplinary, multisector team with expertise that includes disaster science, sociology, supply chain management, industrial engineering, physical oceanography, and nonprofit management, public administration, emergency management, nutrition assistance, and community development.

Differentiators

Food Forecast provides more detailed and up-to-date information on community level food insecurity within a disaster context than any other currently available source (e.g., Social Vulnerability Index) by: (1) modeling additional factors that contribute to community vulnerability, (2) improving upon existing community food security metrics (e.g., U.S. Department of Agriculture (USDA) food desert/Food Research Atlas) through integrating comprehensive indicators relevant to food security (i.e., dietary needs of the population, food assistance, etc.), (3) providing an interactive platform for viewing historical information and simulating what-if scenarios to support effective decision-making, and (4) improving the accuracy of currently used flood projections by incorporating the combined effects of rain, rivers, storm surge and tides. High resolution maps of potential flooding from each of these sources will be available for a wide range of storm scenarios and allow communities to proactively identify vulnerable areas.

Road Map

Phase 2 will deliver key innovations in measuring community food security and the impact of hurricanes on the social, built, and natural environment. These innovations will be integrated into the scale up of the Food Forecast platform to the coastal communities most impacted by hurricanes in the U.S., including the southeast U.S. from Virginia Beach to Miami, plus Louisiana and Texas. Partners from four coastal communities including a predominantly Hispanic community in Miami and a tribal community in

Louisiana will participate in Phase 2 to ensure that Food Forecast meaningfully addresses disaster food security disparities.

Year 1 (2024) Milestones: 1) four community-engaged modeling building workshops; 2) qualitative systems model developed throughhuman-centered design; 3) quantitative systems model developed resulting in community food security output measure; and 4) multi-system data acquisition.

Year 2 (2025) Milestones: 1) Food Forecast platform scale up; 2) four community workshops to test the Food Forecast Platform; 3) sustainable business plan; 4) validation analysis; 5) marketing and promotion.

Partnerships

The team's Phase 1 partners include community partners involved in disaster response in coastal North Carolina as well as governmental partners at USDA. In Phase 2, using a human-centered design approach, the team will engage community-based organizations and local government partners in three new demonstration site communities to validate the Food Forecast platform: Galveston, Texas, the Grand Caillou/Dulac band of Biloxi Chitimacha Choctaw tribal community in Terrebonne Parish, Louisiana, and a Hispanic community in Miami, Florida. Federal partners responsible for nutrition assistance and disaster management include USDA, Center of Disease Control, and U.S. Geological Survey will provide further platform feedback as potential end-users.

Intellectual Property

Intellectual property (IP) developed as part of this project will follow inventorship/authorship in accordance with U.S. law. Each party shall retain title to background IP. IP generated as part of this project will have shared ownership and use of IP will be governed by Inter-Institutional Agreement.

Food Positive

A Better Life One Bite at a Time

Lead PI: Zeeshan Habeeb
habeebz@uapb.edu

Tasnuva Enam
enamt@uapb.edu

Suzzette Goldmon
goldmons@uapb.edu

Michael Thomsen
MThomsen@uams.edu

Overview

Community Based Organizations (CBOs; e.g., nonprofits, food banks, local governments) provide much-needed training and support to socioeconomically disadvantaged populations to combat nutrition and food insecurity. Food Positive is a nonprofit research partner for CBOs, offering technical assistance to community-based organizations to culturally adapt and implement evidence-based food and nutrition security initiatives for greater impact. Food Positive provides landscape analyses, data maps of opportunities for food and nutrition initiatives, and evaluation plans to strategically apply for and attract competitive grant funding. Food Positive serves as a focal point for CBOs in the food and nutrition security space, fostering collaboration, reducing duplication of effort and promoting synergies.

Description

Many initiatives in food and nutrition security, such as educational materials with healthy food recipes or cooking demonstrations, have struggled to create behavior change, particularly in underserved communities, because they fail to address social, cultural, and other barriers preventing their audiences from adopting new behaviors. Additionally, clients fail to develop agency, defined as the capacity of individuals to have the power and resources to fulfill their potential.

Small and mid-size CBOs with city and state-sized footprints are typically understaffed, underfunded, and staffed by volunteers who lack research and technical expertise. The result: CBOs are unable to offer culturally adaptive, evidence-based, food and nutrition security initiatives.

Food Positive unites knowledge, resources, partners, and practitioners in the food and nutrition security space. As a nonprofit advisory service, Food Positive provides research support to CBOs so that they can adapt evidence-based initiatives to be culturally appropriate for their populations. Their work is guided by an extended framework to ensure that CBOs are using initiatives that influence behavior change, resulting in their populations making healthier choices in a sustainable way. Their framework (1) provides a snapshot of local resources, information on demographics, and opportunities for food and nutrition security initiatives in their communities, (2) grant and evaluation tools to help CBOs solicit grant funds for their food and nutrition security initiatives, and (3) aid in assessing the impact of programs in real time.

Differentiators

Food Positive assists CBOs to adapt initiatives to be culturally appropriate, anchored on evidence-based behavior change. Using AGENCY (Assess needs and Gather resources to Empower Neighborhoods and Communities to be healthY), Food Positive collaborates with CBOs to select evidence-based, behavioral interventions with the highest likelihood of generating sustainable adoption via client agency that will reduce food and nutrition insecurity in socioeconomically disadvantaged populations.

Road Map

Food Positive's deliverable for Phase 2 is building adaptation framework-centered processes for Food Positive's clients/partners and testing these frameworks with different population groups.

The milestones for these deliverables are:

Year 1: Pilot testing in central and southeast Arkansas. Food Positive will develop local resource and demographic profiles to assist collaborative organizations develop more culturally relevant programming, and develop formative and summative program assessment tools to evaluate the effectiveness of their programs. Food Positive will collect feedback from the Arkansas Department of Health, the CBO "Go

Forward Pine Bluff", and the University of Arkansas at Pine Bluff's (UAPB) 4-H and Cooperative Extension Programs to improve the process and enhance behavioral change frameworks.

Year 2: Food Positive will expand piloting in Year 2 to multiple states via partnerships in Mississippi, Louisiana, Virginia, Maryland, and California. Food Positive will develop local resource and demographic profiles to assist collaborative organizations develop more culturally relevant programming, and develop formative and summative program assessment tools to evaluate the effectiveness of their programs. Food Positive will collect feedback from collaborating programs to improve the process and enhance behavioral change frameworks. Food Positive will assist local and out-of-state partners to apply for grant funding based upon the results of Food Positive's analyses.

Partnerships

UAPB contributes a multidisciplinary team providing expertise in science communications, food preparation and safety, and development of adaptation frameworks. The team at UAPB is partnering with University of Arkansas for Medical Sciences, which brings a wealth of knowledge and experience in nutrition and food insecurity from a public health perspective. External partners include other Track J teams, for which Food Positive will serve as the implementation expert, the CBO "Go Forward Pine Bluff" working to reduce food insecurity in Pine Bluff and its surroundings, and UAPB's 4-H and Cooperative Extension Programs, which work with socioeconomically disadvantaged youth and individuals to improve health and nutrition outcomes and reduce food insecurity throughout southeastern Arkansas.

Intellectual Property

Food Positive's adaptation and implementation process is guided by an extended framework to ensure that clients are addressing all components needed for behaviors resulting in making healthier choices in a sustainable way. The process will be piloted in Phase 2, refined and then copyrighted and service marked for intellectual property protection.

Lead PI: Kathy Baylis
baylis@ucsb.edu

Kelly Caylor
caylor@ucsb.edu

Chris Funk
chrisfunk@ucsb.edu

Michael Hayes
mhayes2@unl.edu

Erin Lentz
erinclentz@utxeas.edu

Overview

FoodSight is an innovative platform that combines scientifically-informed statistical weather predictions to improve agricultural risk management and food security. Co-produced with community partners, this tool will provide actionable weather outlooks that empower food insecure and vulnerable populations to better cope with extreme weather events.

Description

Droughts and floods are the two most destructive weather events for global agriculture. Droughts cost the U.S. agriculture sector over $9 billion per year (National Oceanic and Atmospheric Administration 2023a) and reduced agricultural production in developing countries by over a third (Food and Agriculture Organization of the United Nations 2023). Floods cost low and lower-middle income countries $21 billion from 2008-2018 (ibid) and the U.S. economy over $32 billion per year, with a disproportionate share falling on communities of color (Wing et al. 2022). Extreme weather events increase agricultural production costs, decrease incomes (Reuters), and raise the price of food (USA Today 2023), making food less affordable, particularly for the poor. More accurate and accessible weather outlooks can help households mitigate the risk of extreme weather for agricultural production and food insecurity. In response, FoodSight will develop and deploy co-produced actionable weather outlooks that provide timely and location-specific forecasts of weather and its impacts on prices, production, and food insecurity (Figure 1). To ensure the outlooks are trusted and usable, FoodSight will co-produce these forecasting tools with community partners. The FoodSight team works with partners helping resource-constrained households in three settings: food banks along the U.S. Gulf Coast, ranchers in the Southwest US, meteorologists, and pastoralists in Kenya.

Figure 1: Long range forecasts and vulnerability combine to generate predicted weather impacts and co-produced actionable weather outlooks.

Differentiators

While weather forecasts are widely available, interviews found that vulnerable populations are currently underserved by available outlooks. Forecasts are not at the necessary scale, precision, or time frame, nor are they bundled with information needed for the decisions households can take. FoodSight brings together a team of climate scientists, economists, statisticians, eco-hydrologists, and sociologists to develop novel convergent methodological approaches that are already yielding improvements in spatially-detailed forecasts of drought, flooding, pasture, and prices. FoodSight outlooks will provide earlier prediction, with higher spatial resolution, and will achieve greater accuracy with reduced uncertainty. Development of this innovative FoodSight platform will incorporate critical information (productivity, prices) and forecast weather impacts directed at informing the specific decisions vulnerable households can make to mitigate their risk of weather extremes and food insecurity.

Road Map

6 months

1. Kick-off and scheduled meetings to ensure collaborative co-production with partners
2. Co-produce decision trees with partners
3. Develop data and model inputs including:
   - Improved flood maps for U.S. Gulf Coast
   - Analog-based weather forecasts for southwest (SW) U.S. and Kenya
   - Pasture productivity forecasts for SW U.S.
   - Price prediction models for SW

12 months

4. Develop additional elements of weather outlooks including:
   - Estimates of flood effects on economic outcomes
   - Food maps for Kenya
   - Price predictions for Kenya
5. Get feedback on initial models from partners

18 months

6. Prototypes of co-produced actionable weather outlooks including prices and impacts for three settings:
   - U.S. Gulf Coast food banks
   - U.S. Department of Agriculture (USDA) Climate Hubs in the SW U.S
   - Kenya county-level agro-meteorologists
7. Obtaining feedback from partners and revising the prototypes

24 months

8. Final actional weather outlook prototypes

Partnerships

The FoodSight team has established partnerships with organizations that are currently providing support to food insecure households and smallholder agricultural producers. These organizations include the Feeding America network of food banks in the U.S. Gulf Coast; ranchers in the SW U.S., including USDA Climate Hubs, the National Drought Mitigation Center, Santa Ana Pueblo rangeland managers, and consultant Livestock Wx; and Kenya agricultural extension and county-level agro-meteorologists, including the International Livestock Research Institute, a member organization of the Consultative Group on International Agriculture Research, and the Kenya Meteorological Department. These organizations face different combinations of data availability, hazard risk, modeling needs, and co-production experience. These partnerships will allow the FoodSight team to co-produce tools that will be usable and generalizable across a variety of settings.

Intellectual Property

FoodSight is committed to the principle of openness and accessibility. All products, algorithms, frameworks, interfaces, and software codes generated through this project are intended for open use. Commercial use of FoodSight's intellectual property and products will be subject to licensing under the Creative Commons Attribution license.

NOURISH

Fresh Food Where It's Needed

Lead PI: Laura Schmidt
laura.schmidt@ucsf.edu

Amarnath Gupta
a1gupta@ucsd.edu

Matthew Lange
matthew@ic-foods.org

Hans Taperia
ht29@stern.nyu.edu

Paul Watson
plwatson@theglobalarc.org

Overview

The Network of User-engaged Researchers building Interdisciplinary Scientific infrastructures for Healthy food (NOURISH) provides a user-centered web and mobile platform that will serve as a hub for small business owners and food entrepreneurs to connect with resources, capital, and support needed to launch or strengthen already existing fresh food businesses in food deserts. Food deserts are communities where ultra-processed "junk" food is widely available but fresh food is scarce. They are a consequence of market inefficiencies in the food system that advantage national food companies/chains and disadvantage small businesses. NOURISH uplifts small business food entrepreneurs, and collaborates with nonprofit small business mentoring organizations, to expand the capacity of small businesses to provide fresh food.

Description

NOURISH provides five key platform components that address the expressed needs of the end-users (aspiring and established small food business owners and their mentors), integrated using a multilingual chat-based (natural conversational language) interface:

1. Business Financing Center to match public and private funders with aspiring new small business entrepreneurs and established small business owners looking to expand,

2. Business Opportunities Map to provide local-level market data, insights, and suggestions regarding fresh food business opportunities,

3. Business Resource Center to provide start-up support services, including tools for idea generation and business plan development, to new and established businesses,

4. Fresh Food Marketplace to support and connect local fresh food suppliers and businesses in the local supply chain,

5. Regulatory Navigator to provide recommendations regarding zoning, planning, business licensing and permit requirements.

NOURISH will alleviate nutrition insecurity by empowering small businesses that serve food deserts to make fresh food more available, affordable, and convenient. This team will develop and extensively test the NOURISH platform during Phase 2 with two key use cases: 1) aspiring and established small business entrepreneurs (small farms, prepared food businesses) serving food deserts, and 2) small business mentors affiliated with the U.S. Small Business Administration who provide services to small business owners at low or no cost. Throughout, NOURISH will incorporate feedback from users and partners to improve the platform and ensure it meets community needs. The team will scale the NOURISH platform from a two-county use case in Phase 1 to the state of California, in collaboration with partners from California-based nonprofit sector, government agencies and private investors.

Differentiators

Ameliorating food deserts is a high priority for the U.S. Centers for Disease Control and Prevention, and U.S. Department of Agriculture. Yet current governmental efforts to incentivize grocery chains into food deserts and to increase produce purchases on food stamps are not adequate. These approaches do not address the foundational inequities in resources, capital, and access that give national food chains selling primarily ultra-processed foods a market advantage in food deserts. NOURISH seeks to address fundamental inequities in the food market by democratizing information, resources, and capital to help small businesses develop and expand in food deserts, and consolidating the information small food business owners and their mentors need into one convenient platform. NOURISH does so by leveraging existing, on-the-ground talent and assets in affected communities. With their small start-up costs and diverse forms (e.g., food

trucks, produce stands, rooftop farms), small businesses are an overlooked resource for putting a wider range of fresh, non-ultra-processed food offerings within easy and affordable reach of consumers in underserved communities.

Road Map

Key deliverables for Phase 2 are a comprehensive system of data and connection points (knowledge graph), a computer algorithm that customizes recommendations to optimize user success rates, and the NOURISH platform with mobile and personal computing interfaces. NOURISH's milestones for these deliverables are:

* **March 2025:** Comprehensive data and knowledge graph system,

* **September 2025:** Computer algorithm for recommending optimal market opportunities,

* **September 2025:** The NOURISH platform with user-appropriate interfaces (linguistically, culturally).

Partnerships

The NOURISH team expands upon an existing community-academic partnership, bringing together expertise in economic sociology, public health, nutrition science, food systems, business and management, community engagement, urban and regional planning, food psychology, sustainability science, data science/artificial intelligence, and geospatial modeling. NOURISH partners spanning private industry, government, the nonprofit sector, and academia will contribute: 1) assistance with platform testing and transitioning it into practical use, 2) data, 3) technological innovations, 4) assistance with leveraging private investments for small businesses, 5) contributors of knowledge to supplement the team's expertise, and 6) assistance with broadening participation to all who might benefit. Inclusion and diversity are prioritized in selecting participants, students, and partners to maximize the translational impact and relevance of the final product. Many of NOURISH's Phase 2 partners participated in the co-design process for the NOURISH prototype during Phase 1 and will continue during Phase 2 to facilitate continuity and bi-directional development and testing of the full NOURISH platform.

Intellectual Property

NOURISH'S convergence research context is a catalyst for invention and the NOURISH team expects that several of the innovations described in the above roadmap will be submitted as patents. In addition, the platform incorporates patented technologies from prior U.S. National Science Foundation funded projects.

NourishNet

A Food Recovery Toolbox

Lead PI: Stephanie Lansing
slansing@umd.edu

Vanessa Frias-Martinez
vfrias@umd.edu

Cheng Gong
cgongc@umd.edu

Oliver Schlake
oschlake@umd.edu

Hee-Jung Song
jhsong@umd.edu

Overview

NourishNet's integrated team offers a cutting-edge toolbox to enhance food security and reduce food waste. Their tools include 1) a real-time app, FoodLoops, that optimizes surplus food distribution among stakeholders; 2) an electronic sensor, Quantum Nose, to detect food spoilage at an early stage; and 3) app features that educate consumers and allow for data-driven decision making on climate-smart infrastructure to increase food system resiliency.

Description

In the U.S., 34 million people are food insecure. Yet a third of the food in the U.S. is wasted. NourishNet disrupts the linear, top-down approach and creates a connective ecosystem between producers, donors, distributors, and those experiencing food insecurity. The FoodLoops app allows for direct feedback from people experiencing food insecurity and expands real-time access to safe, healthy, and nutritious food. The FoodLoops app has three interfaces that allow for communication between 1) consumers, 2) donors and distributors, and 3) institutions. The Quantum Nose detects food spoilage using real-time gas measurements. In Phase 2, the team will optimize this portable sensor for sales and distribution. In addition to increased marketing and business development, the team will provide consumer education and develop curricula (in English and Spanish) on managing food resources, reducing food waste, and increasing digital literacy about the impact of wasted food on greenhouse gas (GHG) emissions and climate change. NourishNet's tools strengthen food system resiliency by increasing donations of nutritious food and converting unrecoverable food waste into renewable energy and fertilizer. Their real-time data collection and modeling will empower government agencies and institutions to strategically invest in food diversion and build climate-smart infrastructure for local food markets. The FoodLoops app will promote equitable social impact by connecting key food system stakeholders, increasing food access, reducing food waste, improving forecasting capabilities for decision-makers, and empowering underserved populations through nationwide deployment and education.

Differentiators

NourishNet will be the first software service to directly connect small and large donors, producers, and food distributors with donation sites in an integrated platform that includes the voices of people experiencing food insecurity. This level of engagement is lacking throughout the food donation and food waste reduction landscape. Connecting the Quantum Nose with the FoodLoops app brings an unprecedented level of real-time understanding of the quality of fresh foods within the food redistribution ecosystem. The data analytics and models created from the vast quantity of data collected from FoodLoops and the Quantum Nose will result in new insights and actionable recommendations for tackling food insecurity. Furthermore, NourishNet will fill a gap in consumer education programs on food waste reduction. By offering consumer education on food waste prevention and reduction through FoodLoops and nationwide Extension systems, there is immense potential to include hard-to-reach, food-insecure groups.

Road Map

In the first year, NourishNet will deploy the FoodLoops app and obtain yearly feedback on functionality from 50 food-insecure participants, 25 food donors, 20 food pantries, 20 food distributors, and 20 farmers. They will test the dashboard functionality and GHG analysis functions based on iterative modeling of transportation and waste disposal options. They will optimize the Quantum Nose sensor for accuracy in detecting food freshness at >95% selectivity. They will generate a set of business model approaches based on financial research and stakeholder and investor engagement. During the second year, the FoodLoops app will be bilingual (English and Spanish) with user feedback, incorporation

of artificial intelligence components, and formal evaluation of the level of engagement, alleviation of food insecurity, and reductions in discarded food. The FoodLoops platform will generate impact reports for municipalities and pantries to help in strategic decision-making. Together FoodLoops, the Quantum Nose, and NourishNet's digital literacy and food waste intervention materials will have nationwide impact providing the new connections needed to reduce food insecurity.

Partnerships

NourishNet's partners support the mission to alleviate hunger. NourishNet continues their partnership with Prince George's County Food Equity Council for engagement with diverse food pantries, food donors, and community stakeholders. NourishNet's nationwide expansion includes new partners: LindaBen Foundation, ChowMatch, Well Said Media, and SCS Engineers. ChowMatch, a food rescue developer, will support NourishNet's software development. SCS Engineers has nationwide food waste reduction and landfill diversion networks. With support from the Extension Foundation partners, the team will expand NourishNet's national scope and outreach with industry leaders in reducing food waste (LeanPath), researchers (RECIPES), NGOs (Natural Resource Defense Council), farmers (Florencia Farms), and municipalities as members of NourishNet's Advisory Board.

Intellectual Property

Quantum Nose has a patent application pending that will be combined with NourishNet's copyrighted software FoodLoops™ for Consumers, Donors & Distributors, and Institutions. Future intellectual properties include Quantum Nose Calibration Data for recovery scenarios and the FoodLoops™ proprietary database on pricing and logistics scenarios. Algorithms will converge to calculate a REAL VALUE™ for recovered food.
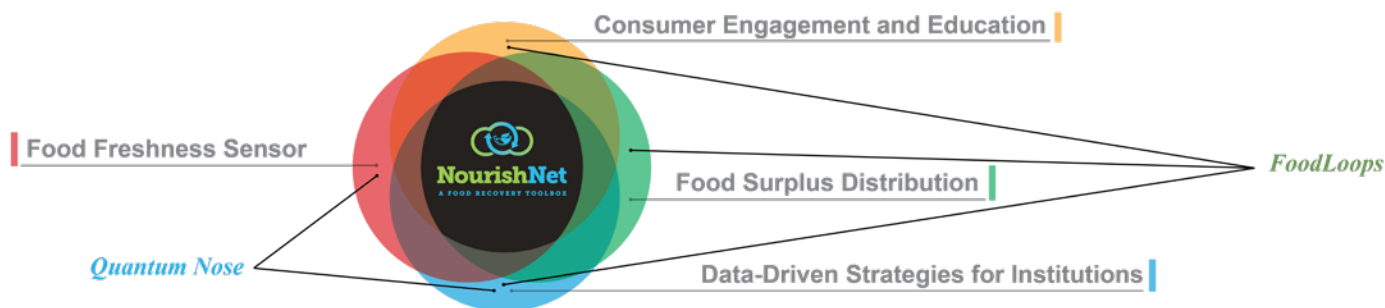

Figure 1: The tools that the NourishNet team will bring to the marketplace, including consumer engagement and education, the Quantum Nose sensor, and the FoodLoops app tailored to three sets of stakeholders/users.

Precision Produce

Grow More with Precision

Precision ⚲ Produce

Lead PI: Matt Wolfe
matt.wolfe@vt-arc.org

Abhilash Chandel
abhilashchandel@vt.edu

Kang Xia
kxia@vt.edu

Overview

The U.S. vegetable production system is in jeopardy due to climate change. And as weather becomes more extreme and unpredictable, vegetable growers are experiencing increasingly erratic threats from crop disease, pests, and weeds, resulting in lower crop yields and nutritional value. What's needed is an early crop threat detection and forecasting solution that enables rapid intervention, and a workforce capable of implementing it.

Description

Precision Produce is addressing climate change-induced increases in crop disease, pests, and weed pressure by developing precision agriculture technology to simplify crop health management and maximize production capacity. The team is also developing workforce development programs to create a new generation of tech-savvy growers and empower communities in the most vulnerable regions of the country. Their focus is on delivering these capabilities to the 94% of farms classified as small and midsized that generate approximately 40% of U.S. agricultural output. Small and midsized farms can be resource limited and have fewer technical education resources available as they are often located in socio-economically disadvantaged rural regions with high populations of underserved and under-represented groups.

More specifically, the team is developing an affordable web-based application that automates the collection and analysis of sensor and reference data using artificial intelligence and machine learning (AI/ML), transforming it into timely, site-specific, and actionable prescriptions for disease, pests, and weeds to manage crop health more efficiently. The team is also creating precision agriculture STEM and Career Technical Education programs for K-12 to educate and inspire the next generation of farmers, and establishing the first precision agriculture technician registered apprenticeship program in the U.S.
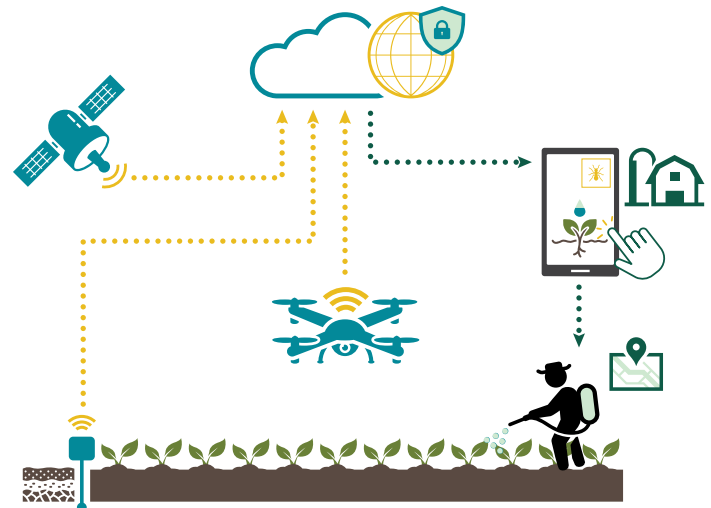
Data-driven solutions to guide crop protection decisions quickly and precisely.

Differentiators

The Precision Produce application derives its performance from the integration of innovative data collection, processing, modeling, and visualization techniques. What's unique about Precision Produce's approach is the integration and fusion of multiple datasets—plant physiological data, drone and satellite imagery, weather, microclimate, soil characteristics, and open-source data—to derive actionable insights for growers. In contrast, current AI/ML approaches to disease, pest, and weed forecasting and detection often utilize a single data type such as weather data. Precision Produce's application also employs a simple and intuitive user interface displaying information, not data, thereby reducing the analytic burden on the user. What's more, Precision Produce is making a strategic investment in workforce development and community engagement programs designed to ultimately transform the American family farm. This holistic convergence approach makes the project significantly different from traditional problems-focused projects.

Road Map

Phase 1 focused on performing field trials, establishing partnerships with the agriculture communities, and building relationships with leaders within underserved and underrepresented communities. The team developed a low fidelity prototype Precision Produce application and gathered feedback from growers and extension agents across Virginia. And the team developed the precision agriculture technician apprenticeship work plan. In Phase 2, Precision Produce will expand technology development and partnering efforts to scale up the team's impact. Phase 2 objectives include:

Objective 1: Develop the Precision Produce Application. The team will conduct vegetable field trials for data collection operations, develop and optimize the AI/ML processes, and develop the application user interface. Deliverables: a static functional prototype with data prepopulated (Q3, Y1) and a real-time data analysis functional prototype (Q3, Y2).

Objective 2: Implement a Workforce Development Program. The team will develop and execute programming to upskill/reskill the workforce and prepare the next generation of farmers. Deliverables: Communicating Science modules (Q4, Y1), STEM kits (Q1, Y2), and a pilot apprenticeship program (Q4, Y2).

Objective 3: Community Engagement. The team will grow Precision Produce's stakeholder community advocating for the adoption of precision agriculture and engage with users to evaluate the software and workforce development programs. Deliverables: user feedback on static (Q3, Y1) and real-time (Q3, Y2) prototype.

Objective 4: Achieving Impact, Scaling, and Sustainability. The team will initiate a marketing campaign, establish an external advisory board, formalize the intellectual property (IP) management plan, and pursue parallel funding opportunities. Deliverables: project website (Q2, Y1), Precision Produce business model (Q3, Y2), and project evaluation report (Q4, Y2).

Partnerships

Precision Produce's core convergence team consists of over seven academic, industry, and state government organizations providing exceptional expertise in support of Phase 2 objectives. In addition, they've established committed partnerships with national organizations 4-H and the Farmer Veteran Coalition that will assist with scaling the activities leveraging their nation-wide infrastructure. An External Advisory Board comprised of academic, industry, government, and nonprofit leaders will provide deep insight into the perspectives of the target groups and assist with growth and sustainability strategies.

Intellectual Property

No Intellectual property (IP) is associated with Phase 1 of the Precision Produce project. Precision Produce does anticipate background IP will be brought into the project including two proprietary data management platforms and a user interface architecture. They also anticipate developing project IP during Phase 2 that includes the final multiplatform integration, software code, algorithms, and course curricula. Per the team's IP Management Plan, background IP contributions may be made available to the Phase 2 team via a license, and they have protocols for identifying and reporting newly created project IP, establishing IP ownership, provisioning access to it, and transitioning the IP for further development, licensing, or commercialization.

Lead PI: Mahmoud Almasri
almasrim@missouri.edu

Haitao Li
lihait@umsl.edu

Amit Morey
azm0011@auburn.edu

Tim Safranski
safranskit@missouri.edu

Kate Trout
Kate.trout@health.missouri.edu

Overview

Salmonella is a leading cause of foodborne illness in the United States and around the world, disproportionately impacting vulnerable populations. It cost the U.S. economy $3.7 billion annually, with 1.35 million infections, 26,500 hospitalizations, and 420 deaths, with unchanged rates for three decades despite national goals. *Salmonella* has become a "One Health" issue requiring collaborative efforts across the animal-human-environment interface, recognizing that all are interconnected. To resolve this issue, the proposed project, through collaboration with the end-to-end supply chain, food banks, and educators, will create SENS-D, a sensor-enabled decision support system. SENS-D will incorporate multiple rapid sensing technologies along with visualization, prediction, and optimization capabilities to provide data-driven solutions to mitigate foodborne pathogen risks for a safe, equitable, efficient, and resilient food system.

Description

SENS-D's interdisciplinary team, consisting of 19 investigators encompassing expertise in Public Health, Poultry Science, Food Science, Animal Science, Supply Chain Analytics, Engineering, Analytics, and machine learning/artificial intelligence (ML/AI), is well-positioned to address this public health concern. This collaborative effort has allowed the team to work toward a common goal—a timely solution for a safe, equitable food system. The research team is working alongside multisectoral partners for broader and faster adoption to address the unique needs of disadvantaged populations in food nutrition, accessibility, and equity. SENS-D develops innovative sensing technologies and prototypes of the sensing systems for rapid detection and quantification of *Salmonella* serovars along the poultry supply chain. This technology enables detection within 10 to 60 minutes and is coupled with a data-driven decision-support system (DSS). This holistic approach deploys sensors across the supply chain and integrates real-time sensing results

into a centralized "One Health" data environment encompassing population health, poultry/food production, and environmental data, which empowers the DSS. By combining results from samples collected throughout the food supply chain, the project ensures a comprehensive understanding of contamination dynamics. The DSS features (1) optimization models for sensor placement in the food supply chain, (2) intelligent distribution of perishable foods in cold chain operations while considering the predicted *Salmonella* levels and shelf-life of products, (3) workforce planning and targeted outreach to vulnerable populations at high-risk for *Salmonella* infections, and (4) analytical toolkit for evaluating policies and interventions to reduce and prevent the spread of *Salmonella* infections. SENS-D's potential goes beyond poultry, with adaptability to detect pathogens in beef, pork, dairy, and produce, ultimately reducing the $152 billion economic burden of foodborne illness in the U.S. Implementing this technology ensures equitable food security for local and global consumers.

Differentiators

Salmonella detection for poultry uses either traditional culture techniques taking 5-7 days, or the more popular PCR technologies that have reduced the time to result to approximately 24 hours. Yet, this is not rapid enough to make effective food safety decisions in the fast-paced poultry industry. This project develops and employs three user-friendly sensors that reduce testing time to between 10 and 60 minutes. In addition, efforts to tackle *Salmonella* have been siloed, and there is a lack of data environments for the end-to-end supply chain to evaluate the efforts aimed at reducing *Salmonella* infections. The status quo has not connected the testing results to population health, poultry/food production, and environmental data either. This disconnect hinders informed timely decisions by stakeholders, impeding efforts to mitigate and prevent the spread of foodborne illnesses. SENS-D uses a holistic approach of integrating (1) sensor results from portable sensing systems, (2) data spanning social and population health to poultry

production as inputs for (3) a DSS that enables various stakeholders to make informed decisions through the SENS-D dashboard. This transformative technology aligns with the U.S. Department of Agriculture's (USDA) Roadmap for Reducing *Salmonella* and the 2023-26 Strategic Plan, highlighting the need for technology-enabled decision support systems and collaborative intelligence tools to address food security while ensuring a safe food supply.

Road Map

The main deliverables for the *Salmonella* sensing technologies are portable sensing systems capable of storing, transmitting, and analyzing sensor inputs for real-time data system integration. Key milestones:

- **May 2025:** Incorporate real-time sensing results into the cloud-based data environment.

- **June 2025:** Construct three sensors and sensing systems to detect *Salmonella* serovars.

- **December 2025:** Validate sensors using real-world poultry samples, to ensure compliance.

The major deliverable for the DSS is a high-fidelity prototype with data visualization, risk prediction, and optimization. Key milestones:

- **September 2025:** (1) Optimization of sensor placement along supply chain. (2) Intelligent distribution in cold chain operations with spatial and temporal prediction of *Salmonella* level and shelf-life. (3) The policy and intervention analytical tool kit. (4) Integrated workforce planning to implement the system for industry and targeted health outreach.

- **December 2025:** Refine user interface by deploying a dashboard in Missouri to target outreach for high-risk populations.

An advisory board will be formed with representation from poultry production, processing, population health, and vulnerable communities to address topics such as data sharing, research priorities, implementation, fast feedback loops for iterative technology development, and knowledge translation.

Partnerships

SENS-D has built partnerships with prominent companies across the food supply chain, including Cargill, Wayne-Sanderson Farms, LTI Distributors, and Save-a-Lot. These companies will provide commercial poultry samples and serve on the advisory board. Additionally, SENS-D has fostered collaborative relationships with food banks, the Missouri Extension educators, and a national public health agency to facilitate outreach initiatives with vulnerable populations. Phase 1 solidified ties with stakeholders across the poultry food supply chain. In Phase 2, focus will shift toward stronger partnership with policymakers (e.g., USDA Food Safety and Inspection), public health, and engineering firms to build prototype sensing systems and utilizing ESRI ArcGIS (Geographic Information Systems). The SENS-D will be piloted in an experimental setting for the end-to-end supply chain & Missouri in Phase 2.

SENS-D is in discussions with potential advisory board members and open to more partners.

Intellectual Property

The SENS-D system's intellectual property (IP) is in progress within the research team. SENS-D has received two patents, submitted two U.S. patent and three provisional patent applications. IP agreements for shared data, models, etc., are in development with Phase 2 partners. Phase 2 involves exploring licensing options, through forming a new company or partners, with an emphasis on speed to market and maximizing the scope of impact.

Stigma out of SNAP

Increasing SNAP Participation Through Positive Narratives

Lead PI: Sherry Wu
sherry.wu@anderson.ucla.edu

Eugene Caruso
eugene.caruso@anderson.ucla.edu

Stephanie Bianco
sbianco@csuchico.edu

Heather Caruso
heather.caruso@anderson.ucla.edu

Overview

The Supplemental Nutrition Assistance Program (SNAP), the nation's most successful anti-poverty policy, faces a significant disparity among eligible Americans, particularly college students. Over 80% of SNAP-eligible students don't receive food benefits, resulting in millions lacking access to healthy, sustainable food, negatively impacting the health, education, and innovation outcomes of future leaders. In addition to the SNAP food benefit program, complimentary federal SNAP programs such as nutrition education (SNAP-Ed) and local fruit and vegetable incentives (Gus Schumacher Nutrition Incentive Program) were created to encourage the use of these funds on a healthy fare. Similarly, these programs are underutilized due to separate funding agencies and implementation sites. The goal of Stigma Out of SNAP is to address the disparity of inequitable resource/food allocation to uniquely promote greater food security among the underserved.

Description

The team's work takes immediate action to reduce this disparity by 1) implementing a one-stop SNAP Resource Hub that will provide evidence-based solutions to improve participation in all food benefits programs in California and eventually across the nation; 2) designing bottom-up communication campaigns to reflect the authentic voice of SNAP participants and reduce stigma in social services; 3) creating a data-driven enterprise that converges ongoing behavioral research on food and nutrition insecurity. The team's deliverables will provide a vital bridge connecting resources, SNAP programs, and end-users in ways that increase returns on every dollar our country invests in food security.

Differentiators

Siloed federally funded programs address different aspects of the multifaceted problem, e.g., food access, nutrition education, and the purchase and consumption of fresh whole agricultural products, and none are sufficiently engaging enough of the eligible population to deliver the desired benefit. Stigma Out of SNAP's work not only tackles procedural inefficiencies in program coordination but also improves hunger and welfare narratives to address the fundamental stigma problem in the underutilization of food benefits and other social programs. By converging expertise in food security, public policy, nutrition, and behavioral science, the team tests and implements solutions that address critical barriers to efficient resource allocation.

Road Map

In Phase 2 Year 1, Stigma Out of SNAP plans to prototype three deliverables and implement an anti-stigma campaign on two college campuses. By Phase 2 Year 1.5, the team will roll out the beta version of the Resource Hub and launch an online behavioral science crowdsourcing platform. The team aims to finalize the platform, complete network-based anti-stigma campaigns, and secure sustainable funding by Phase 2 Year 2.

Partnerships

In partnership with 149 college campuses across California, Stigma Out of SNAP is well-positioned to put evidence-based resources into practice. The research team has the largest Higher Education SNAP Outreach in the nation with recognition from the California Department of Social Services, Food and Nutrition Services, and the USDA. In Phase 1, Center for Healthy Communities' largest prime contract, SNAP/CalFresh Outreach (CFO), provides training and technical assistance to 50 college campuses in the California State University, University of California, and California Community College systems and to five rural community-based organizations (CBOs). Stigma Out of SNAP expect to expand to all campuses in California—and beyond—in Phase 2. With the active participation of campus partners in Phase 1, the team has strengthened

the existing collaborations and will expand partnerships in Phase 2 to include nonprofits working in the social service domain.

Intellectual Property

This project aims to generate significant intellectual contributions with an open public-source intellectual property (IP) management plan. Chico State Enterprises' legal counsel and UCLA's General Counsel for IP are readily available to help develop and approve the IP management plan which will include language and guidance on information and data use as well as the need for a Provisional Patent Application.

Phase 1 Transition of Work to Practice

The team's dedication to combating this disparity has led Stigma Out of SNAP to start transitioning Convergence Accelerators Phase 1 work to practice. The team has been engaging in cooperative solutions through direct action and education with college campuses. For example, the Campus Engagement survey, which was executed on May 2023, gathers campus-level baseline data on CFO personnel's insights on SNAP Program Awareness and Implementation. Project Directors' or Coordinators' feedback has provided Stigma Out of SNAP with the most understanding of CFO programming on their own campus. The ongoing survey will refine prototypes based on-campus programming and community needs, incorporating CFO feedback in Phase 2 prototypes development. In addition, the team is in the process of conducting qualitative data gathering to identify and understand reasons why siloes exist in SNAP federally funded programs.