Addressing Climate Change in Kentucky through Robotics and AI: Environmental Sensing & Prediction, and Disaster Search & Rescue

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Summary

The proposed research is synergistic with the CHARGE program and brings together recognized leaders from our state who will make contributions to Robotics and Artificial Intelligence (AI) teaming research with applications in climate change research and disaster mitigation in Kentucky. **The main research theme of this effort is that embodied AI components (sensors and robots) will be deployed in the environment to collect and interpret climate and disaster data, use machine learning to perform assessment and prediction, and finally facilitate rescue missions during disaster events.** We will consider several use cases from CHARGE as a motivator for our research and incorporate AI components in different hardware and software embodiments. Our research will use sensors and robots deployed in the environment.

1. Environmental Monitoring by Multiscale Adaptive Sampling of Water Quality and Content

F1) Adaptive Spatio-Temporal Sampling of the Environment (D. Popa, X. Wang, O. Nasraoui).
F2) Optimal and Fair Human-AI Teaming Algorithms (X. Wang, O. Nasraoui, D. Popa).
F3) Edge-assisted Energy-Optimized Collaborative Sensing and Mapping (S. Baidya, A. Lauf, T. Roussel).
F4) Flying 5G Base Station for Connectivity and Crowd-sourced Data Acquisition (S. Baidya, O. Nasraoui).
P1) Optimization of Bio-platforms for Production of Novel Plant-based Materials for Environmental monitoring (M. Running, K. Kate).
P2) Environmentally Friendly Sensor and Robot Materials (K. Kate, T. Roussel, M. Running).

2. First Responder Autonomous UAVs with Flying Edge Computing and Collaborative Sensing Systems for Disaster Assistance

F5) Digital Twin based Collaborative target detection and Multi-target Path Planning
P3) Multi-UAV LiDAR Point Cloud Fusion for Low-Cost Distributed Search, Rescue, and Rapid Structural Integrity Assessment (A. Lauf)
P4) High Performance Control of Winged Electric Vertical Takeoff and Landing Unmanned Aerial Vehicles for High-Speed Landing Approaches (C. Richards, D. Popa).
P5) Autonomous Unmanned Aerial Vehicles for Extreme Weather Monitoring (C. Richards, D. Popa).

Search and Rescue Testbeds – ST	**Environmental Monitoring Testbeds – ET**
1) Search and Rescue UAV team 2) Telepresence search and rescue humanoid robot for indoor disaster environments. 3) Heavy-lift human extraction VTOL for outdoor disaster environments.	1) Mobile 5G/6G wireless infrastructure for monitoring climate change variables and disaster areas. 2) Intelligently coordinated robotic swarm team for climate monitoring and rescue. 3) Virtual and Augmented Reality platforms for simulation of environmental monitoring.

Table 2: Robotics and AI Core Faculty Expertise	**Institution/Department**	**Research**	**Testbeds**
Dan Popa (UofL Lead) – participant in KAMPERS Robotics, control, mobile sensor networks	UofL Electrical and Computer Engineering	F1, F2, P4, P5	ST2, ET2, ET3
Olfa Nasraoui (UofL) - participant in KAMPERS Fair AI, machine learning, and recommender systems	UofL Computer Science and Engineering	F1, F2, F4	ET2, ET3
Christopher Richards – new participant at UofL Control Systems, UAVs, Environmental Mapping for Climate	UofL Mechanical Engineering	P4, P5	ST1, ET2, ET3
Sabur Baidya – new hire at UofL through KAMPERS IoT, Wireless Communications, Drones	UofL Computer Science and Engineering	F3, F4, F5, P1, P3	ST1, ST3, ET1, ET3
Xiaomei Wang – new hire at UofL Human Factors, Human-AI Teaming	UofL Industrial Engineering	F1, F2	ET3
Thomas Roussel - participant in KAMPERS Environmental Sensing, MEMS	UofL Bio Engineering	F3, P2	ST3, ET2
Kunal Kate - participant in KAMPERS Additive Manufacturing, 3D Printed sensors	UofL Mechanical Engineering	P1,P2	ET2
Adrian Lauf – new participant at UofL Swarm Robotics, UAVs, Search and Rescue	UofL Computer Science and Engineering	F4, F5	ST1, ST3, ET1, ET2
Mark Running - participant in KAMPERS Biomaterials, Biofuels	UofL Biology	P1,P2	ET2

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- Research topics of interest and experience: ecosystem restoration (wetlands, streams, forests, prairies), ecosystem ecology (nutrient cycling soils/water/plants & greenhouse flux), invasive plants, green infrastructure, climate equity & resilience, science communication and public engagement with science
- Proposed Idea (abbreviated): With the threats to Kentucky from climate change and related hazards discussed in the CHARGE white paper, specific populations and communities will bear more impact and negative consequences than others. To build sustainable communities and climate resiliency for the Commonwealth of Kentucky, efforts must begin with the communities most vulnerable and it is imperative that residents are an integral part of the planning process. The need for increased transparency and participation in environmental planning has been recognized by many, including the US EPA. Through collaboration of scientists, policymakers and community members, local residents will actively engage and critically assess where and how interpretations of data should be utilized in local implementation strategies – leading to sustainable, resilient and environmentally just communities. A brief example has taken shape in the City of Cincinnati with its implementation of the Climate Safe Neighborhood Program after the culmination of extensive environmental and socioeconomic data in the Climate Safe Dashboard. The collaborative process to build neighborhood climate resiliency plans will increase environmental literacy, encourage behavior that improves the environment, prioritize environmental justice efforts and create a communal sense of ownership to community success. We propose to collate the successful methods used in other cities to create a model to implement in locations around Kentucky. Work would begin in northern Kentucky cities and be assessed, reviewed and reworked as the plan is employed in multiple locations around the state. Trained, regional leaders would oversee local efforts, while working collaboratively statewide, to change the trajectory towards economic prosperity, environmental sustainability and improved public health for all in the Commonwealth.
- Open to working on other's ideas where my expertise could be used