FRED LIVINGSTON, Ph.D.

RESEARCH STATEMENT

"I'm excited to bring my 20 years of experience in the autonomy industry and multiple patents and commercial products into academia."

My research focuses on multi-agent cyber-physical systems and algorithms that allow such systems to make smart decisions in active and uncertain environments. My research is motivated by real-world applications, such as environmental monitoring, maritime systems, precision agriculture, search and rescue, wearable sensors, and robots for patients with rare diseases. Multiple agents must cooperate in many of these environments to achieve a specific goal. For example, search and rescue missions often involve teams of people working together to find survivors. In such cases, the agents need to be able to share information to make effective decisions. However, communication can be a challenge in multi-agent environments, as the agents may be dispersed and have limited access to communication channels.

Additionally, the agents may be required to interact with other systems, such as sensor networks, which can further complicate communications. As a result, designing effective multi-agent communication systems is a complex task that requires a deep understanding of human-machine interaction. My research will investigate (1) open-system, **autonomous architectures**, (2) autonomous **control**, and (3) **human-machine** behavior modeling for real-world applications.

1. OPEN-SYSTEM ARCHITECTURES

Open-system architecture is a type of architecture that sets out guidelines for data, hardware, and software technology stack components. Open-system architectures aim to consolidate common resources, decrease risk, reuse software, enhance maintenance, and reduce cost. Open-system architectures are often used in enterprise systems where there is a need for future system modernization and sustainability. The main benefits of open-system architecture are that they can help to reduce duplication of effort and improve maintainability. Additionally, open-system architectures can provide a more flexible approach to system development, allowing for easier integration of new components.

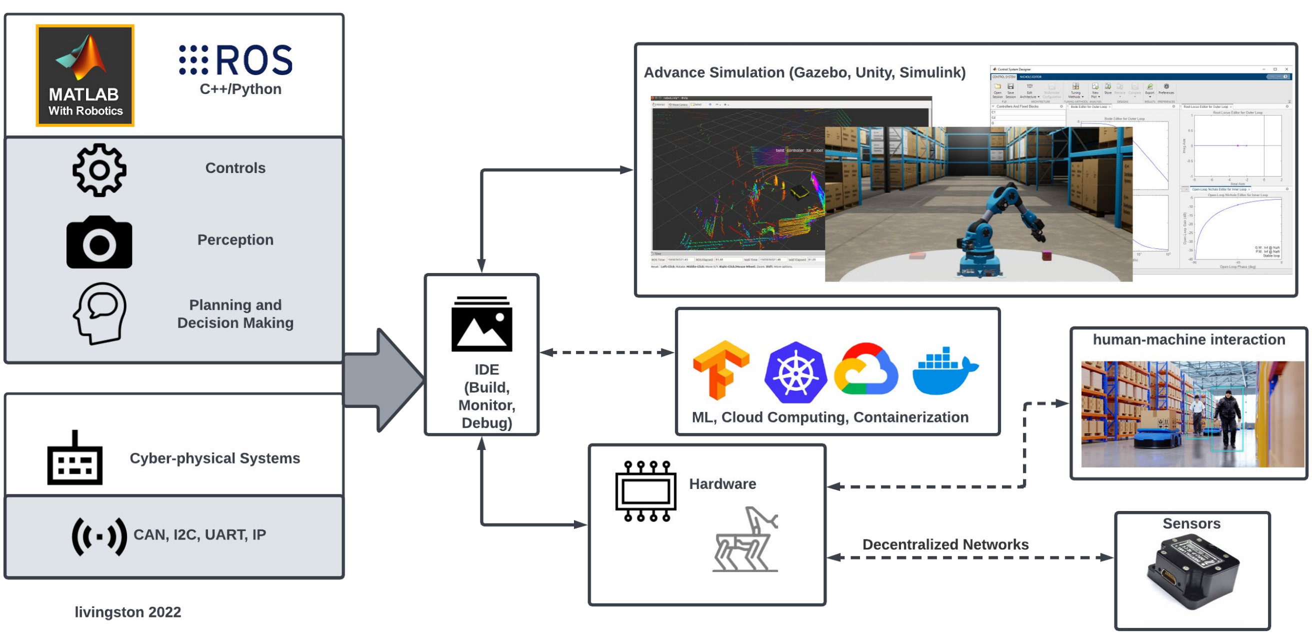

Figure 1 Architecture for collaborative cyber-physical systems

The Office of Naval Research provided a Phase 2 SBIR grant to develop a platform for the rapid design and development of secure, modular unmanned systems. The following technologies were employed in the system design for rapid integration and testing of trajectory and control algorithms in mobile robots:

- Decentralized Networks
- Hardware Security Modules
- Modular Algorithm Design and Simulation
- Real-Time Computing and Data Monitoring
- GPU Accelerated Algorithms
- Cloud Computing

The result of this research enabled rapid development and testing of control algorithms from various code bases (C++, Python 3, MATLAB) while providing data security.

2. AUTONOMOUS SENSE AND CONTROL ALGORITHMS

I would also like to utilize my research to include automating the mooring of two naval ships. The project I participated in was sponsored by the US Office of Naval Research (ONR), with the industry partners being Oceaneering, Cavotec, and Mechaspin. Mooring a naval ship is a challenging and dangerous task. The project I worked on developed a cyber-physical system to automate the docking of two vessels. The mooring process was automated by developing advanced algorithms, thereby replacing the need for human sailors to complete the task. This automated system reduced the hazards associated with mooring and reduced the time taken to complete the task. In addition, this automated system allowed for a more precise and consistent mooring process, which improved the safety of the ship and its crew. The technique considered the movement of both vessels and the surrounding wave motion. The automation algorithms calculated the command-and-control actions for robotic manipulators. Automating these tasks reduced the risk of accidents and injuries while increasing mooring efficiency.

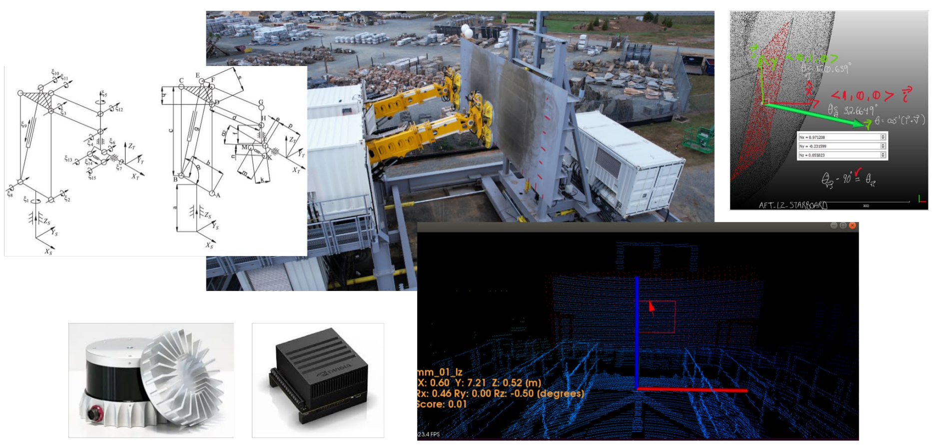

Figure 2 Autonomous Sense and Control in Dynamic Environments

Future research will expand on the following technologies of the Automated Mooring System including:

- Decentralized Networks
- Sensor Fusion
- Edge-Computing
- 3D Perception
- Real-Time Command and Control

The aim is to provide more intelligent and efficient systems that process and act on data in real-time. Decentralized networks hold great promise for enhancing the efficiency of data processing and communication. Sensor fusion is another vital area of my future research. This involves combining data from a suite of multiple, diverse, sensors to help create a complete picture of the environment. This is essential for applications such as autonomous driving, where it is vital to understand the surroundings clearly. Edge computing is another key technology that will be developed in my future research. This involves moving data processing and storage away from centralized servers to the edges of networks closer to where the data is being generated. This can help to reduce latency and improve response times. 3D perception is another critical area to be developed in my future research. This involves improving the ability of machines to interpret and understand three-dimensional data. This is essential for many applications, such as augmented reality and robotics. Finally, my future research will also focus on developing real-time command and control systems. These are essential for coordinating complex actions involving multiple agents, such as disaster response or military operations. By expanding on these technologies, future research will aim to provide more innovative and efficient systems that can better meet the challenges of our increasingly connected world.

3. HUMAN-MACHINE BEHAVIOR MODELING

Designing controllable autonomous agents is a challenging problem that has been studied extensively in artificial intelligence and robotics. One approach to this problem is to use human feedback to shape the agent's behavior. This is known as human-machine interaction or human-in-the-loop control. My graduate studies focused on developing a robot testbed that used human reaction monitoring and post-processing to capture human reactions to images of the robot for a collaborative activity. The validity of the approach was tested experimentally on a mobile robot with vision capability. Results showed that using human reactions to capture robot images provides a feasible architecture for designing mobile robot controllers. Future work in human-machine interaction includes utilizing cloud-based sensor analytics, haptics technology, and machine learning to develop autonomous control algorithms. My future research will focus on human-machine behavior modeling to optimize the interactions between humans and autonomous systems. My goal is to develop algorithms that can provide safe, efficient, and comfortable autonomous systems operation while minimizing operator burden. It is necessary to understand human behavior and preferences through data collection and analysis to achieve this goal. Once this understanding is achieved, it will be possible to develop models that can be used to generate predictions about human behavior. These predictions can then be used to design autonomously controlled systems that consider human preferences and limitations. Ultimately, this research will develop more effective and efficient human-machine interaction for various applications. One application of particular interest for my future research is developing smart wheelchairs for patients with rare diseases.

FUTURE FUNDING

The Office of Naval Research, Code 351 has a strong interest in unmanned system architectures for deploying rapid responses to adaptive control (i.e., VTOL transitions), multi-agent systems, and real-time trajectory planning with current funding opportunities that enable integrating MATLAB/Simulink C++ Python algorithms on edge computing devices. My industry experience has led to cooperative connections to companies such as NVIDIA Robotic Division, Ouster/Velodyne (3D LiDAR Manufactory), Ghost Robotics (UGV legged Robot), IAM Robotics (material handling robots), and many more. I plan to leverage my network to obtain additional research funding in addition to NSF, DARPA, and DOT.

FUTURE SCHOLARLY PROCEEDINGS

- IEEE Transactions on Robotics (TRO)
- IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
- IEEE International Conference on Robotics and Automation (ICRA)
- IEEE Robotics & Automation Letters
- Journal of Field Robotics