Undersea Object Detection

Applying Machine Learning Research for Undersea/Submerged Object Detection

ELECOMP Capstone Design Project 2020-2021

Sponsoring Company:

Rite-Solutions, Inc.
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Company Overview:

Rite-Solutions is an award-winning Veteran-Owned Small Business (VOSB) headquartered in Middletown, Rhode Island, established since April 2000. We have a stable and deep corporate history in Rhode Island, with over 250 employees with core competencies include systems engineering, software development, information technology, and cyber engineering. The stability of our business is demonstrated by both our longevity and our business backlog – well over $200M in recent contract awards that will be executed over the next 5 years. We have achieved both state and national recognition; one of our founders, Joe Marino, is an active member of the RI Science and Technology Advisory Council, along with other trusted Rhode Island business and academic leaders.

Rite-Solutions is known for innovation and dedication to the information and decision support needs of our government and commercial customers, a commitment we have coined as a company slogan, *The Information Advantage™.* We have significant US Navy prime contracts in both warfare systems and business systems development and sustainment, as well as in Information Technology infrastructure support and cyber protection. In our research and development efforts, we demonstrate a proclivity for our own inventive solutions but also for finding and working with non-traditional partners, including academia and small commercial businesses, whose technologies we adapt to national research objectives in practical, meaningful ways that lead to productization.

We take pride in our culture of Friends Enjoying Work (FEW) and work to create an open, creative, and stimulating environment for all members of our team. We have won numerous awards and received extensive media coverage and academic interest about our culture, including being the subject of case studies by Harvard University and Stanford University in employee motivation and idea generation techniques and have been mentioned in multiple books for our unique and innovative management approaches.

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Project Motivation

As part of an Innovation Voucher from the Rhode Island Commerce Corporation, the University of Rhode Island Computer Science Department (Dr. Noah Daniels) and his team in conjunction with Rite-Solutions is developing an approach using machine learning to better identify objects on the seabed This approach enhances the ability of ML architectures to identify objects using time-series data and has widespread applicability across multiple commercial and Navy systems and problem spaces. Specifically, this research is applicable for use in Navy Unmanned Undersea Vehicles (UUV) for hazard avoidance and object identification and would expand the opportunity to contribute to complex autonomous UUV operations.

As a result, Rite-Solutions is interested in developing a software prototype that can be evaluated under more complex operational conditions. Because this software will potentially be used in safety critical systems, existing Python/TensorFlow software developed as part of the proof of concept research will be translated into a new safety-oriented language called Rust. Simulated sensor data will be generated to better test the prototype software as well as analyze a wider range of environmental and operational conditions, objects, and sensors.

Anticipated Best Outcome

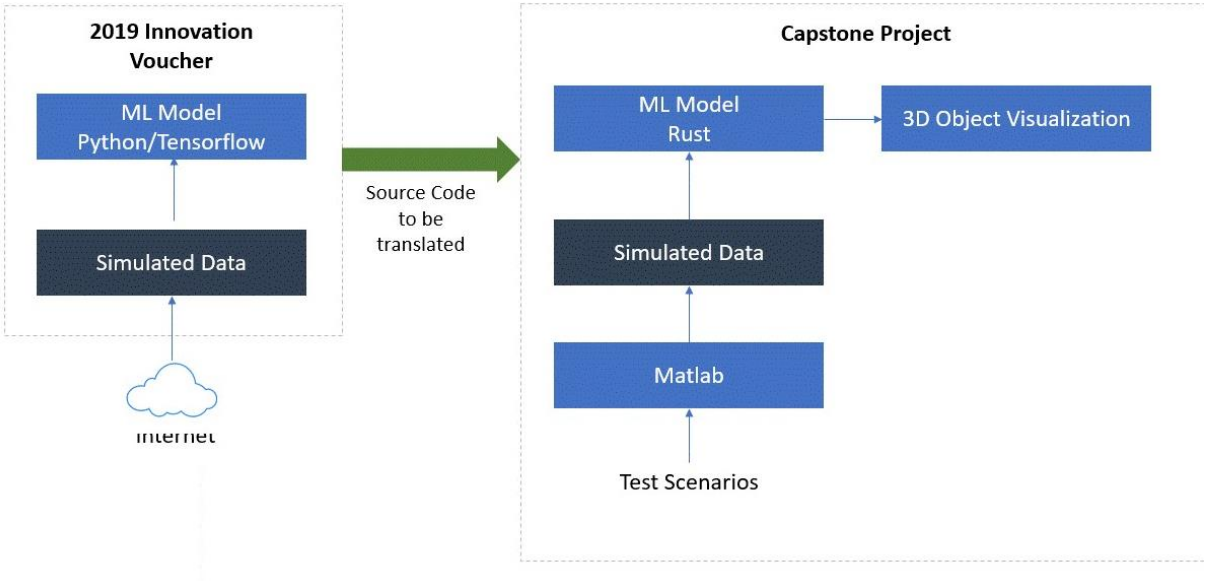
The primary goal of this effort is to design, implement, and demonstrate a prototype software solution based on research by Dr. Daniels and his team at URI that can be rapidly incorporated into commercial or Navy UUVs to enable quick and accurate identification of objects on the seabed. A complementary goal is the evaluation of new technologies and tools such as Rust and its supporting development infrastructure for use in safety critical production environments. Lastly, it would be desirable to develop a tool to support the generation of simulated data that can be used to support training and testing of the ML model.

Project Details

Marine sensor systems encompass a range of technologies: active and passive sonar, including side-scan sonar, magnetic detection, radio frequency, visible, and infrared sensors, encompassing surface-borne, underwater, airborne, and satellite-based systems. Integrating these disparate systems is a challenge; as is identifying anomalies or observations of interest in what amounts to a high-dimensional, noisy data set. Recent advances in computer science and applied mathematics have led to novel methodologies for analyzing and characterizing data in high-dimensional spaces. Ongoing work associated with the 2019 ML Innovation Voucher at URI focuses on developing and incorporating a new approach that couples machine learning, specifically Long Short-Term Memory (LSTM) recurrent neural network architectures with computational topology, to improve the identification of objects based on sensor data. Algorithm development and initial prototyping at URI uses Python/TensorFlow.

The capstone effort will extend and transition the work performed under the 2019 ML Innovation Voucher into a system that can be for use in a real-world environment. This effort would include rehosting software in a Linux environment, redesigning and recoding software using Rust, developing design, interface, and test documentation, generating simulated data to be more representative of real-world conditions for use in training and testing ML models, and identifying and using open source tools to display 3D objects.

The figure below shows the work done as part of the 2019 ML Innovation Voucher research will provide the foundation for the capstone activities.



Skills Required:

It is not expected that the students be familiar with Rust as it is a relatively new language. However, the student is expected to become proficient in its use and application during the capstone. Also, the ability to research and evaluate tools may be required throughout the project. In this case, we will work with student in the use of a Rite-Solutions methodology that aids in the evaluation of software tools and products.

All Members

- Gain an understanding of the ongoing research associated with 2019 Innovation Voucher performed by Dr. Noah Daniels and his team
- Support development of a draft and final report

Electrical Engineering Tasks

- Become familiar with the tests and results performed to date with the existing ML model
- Develop scenarios representative of additional new operational scenarios and/or sensors
- Using MATLAB or similar tool generate new simulated data to support training and test of ML model
- Perform training and testing using the existing Python/TensorFlow ML models with the new simulated data to establish a baseline
- Develop a user manual for the tool used
- Support training/testing of the Rust version of the ML model

Software Tasks

- Become familiar with Rust and its development environment
- Become familiar with the Python/TensorFlow implementation, tests, and results
- Develop and document software architecture; identify interfaces
- Translate the Python/TensorFlow code into Rust
- Test Rust version with the new simulated data
- Develop a user interface to visualize the identified 3D object

Composition of Team:

1 Electrical Engineer & 1 Computer Engineer

Skills Required:

Electrical Engineering Skills Required

- Use of MATLAB or similar tool
- Digital Signal Processing
- Acoustics sensors/systems
- Artificial Intelligence/Deep Learning/Machine Learning

Computer Engineering Skills Required

- Proficiency in Object Orient Programming (OOP)
- Computer Languages: Python/TensorFlow, Rust
- Artificial Intelligence/Deep Learning/Machine Learning
- Linux Operating Systems
- 3D visualization

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

This work aligns with Rite-Solutions' efforts with Navy Unmanned Undersea Vehicles (UUV) for hazard avoidance and object identification. As a contractor supporting NUWCDIVNPT's UUV Family of Systems, this research has direct applicability to ongoing development for the Large Displacement UUV prototype – Snakehead. The operational goal will be to incorporate a higher level of autonomous complexity relative to object identification in environments that are contested or where access to larger assets is denied. The best outcome for this effort is that the prototype system is designed so that it can ingest real world acoustic sensor data to rapidly and accurately identify 3D objects on the sea floor and, secondly, be easily deployable in production commercial and US Navy systems.

Broader Implications of the Best Outcome on the Company's Industry:

The importance of Artificial Intelligence (AI) continues to increase for our Department of Defense/Navy and commercial customers. In fact, "Artificial Intelligence is at the top of the Navy's list of new technologies to get more involved with. Rear Adm. David Hahn, the chief of naval research, said AI may be more important to great power competition than military power itself" [1]. Military leaders believe that AI is a disruptive technology that will significantly improve and speed up decision making thereby providing a critical advantage and agility in future conflicts. It is well recognized that the demand for AIinfused products is loud and clear throughout DoD as well as in the commercial marketplace.

The scope of this innovation can be expanded into other Navy, DoD, and commercial domains. Our goal is to continually improve the prototype and utilize the technologies/tools provided by this capstone effort and incorporate it into multiple DoD/Navy systems as well as in commercial systems. In the DoD/Navy domain, this innovation is addressing an ongoing Navy challenge to significantly improve automated or semi-automated systems' ability to better identify threats and navigational hazards as well reduce the cognitive load of operators and decision makers to make better decisions faster. Rather than being limited for use on a single Navy platform or type of platform, such as UUVs, we would anticipate improvements to the product to utilize data from multiple platforms such as submarines, surface ships, aircraft, as well as multiple unmanned systems (e.g., subsurface, surface, and air UxS).