AutoML Ship Classification in a Box

Utilizing AutoML for a standalone Ship Classification System

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 the F.E.W (Friends Enjoying Work) 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 noted in multiple books for our unique and innovative management approaches.

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Project Motivation:

As a proof of concept, Rite-Solutions has successfully demonstrated using weakly supervised learning to automatically generate labels for non-curated datasets to train ship recognition and classification ML models. This approach allowed us to label large, publicly available, un-curated datasets of ship images to train a Discriminative Classification ML model. Using a cloud-based system, namely Google Cloud AutoML, we trained our ship classification ML model with these labeled datasets to identify and categorize ship images. To demonstrate that this ship classification model could be used in an operational environment, we subsequently downloaded the ML model to run in a Google Coral AI Hardware Accelerator. This ML pipeline allowed us to rapidly incorporate and use new images to continually improve the classification process.

Although successful, this approach needs to be refined and improved to better address the operational needs of our customers. Specifically, cloud-based solutions are not a viable approach for our customers in those situations where network communications to a cloud do not exist or are bandwidth limited. Additionally, public cloud solutions present a security problem when the sensitivity and level of confidentiality of the data cannot be ensured and adequately protected. To address these concerns, an Automated Machine Learning (AutoML) solution that supports ML model training needs to be hosted on a standalone AI system/environment and operated in a protected, standalone environment. Once trained, the ML model should be automatically deployed to a device with a small footprint (e.g., power, footprint, etc.) that incorporates an AI Accelerator.

Anticipated Best Outcome

The primary goals of this effort are to (1) research, identify, deploy, configure, and test an open source AutoML implementation that can be used to support ship classification, (2) research and recommend a standalone AI system/environment that can support training of ML models in a standalone environment, and (3) design and develop a small footprint standalone device that incorporates an AI hardware accelerator for use in an edge computing environment to support ML model execution.

Project Details

This capstone project will improve and extend work previously performed by Rite-Solutions to provide a standalone ML training environment and an edge computing device that supports ML model execution in environments with limited or restricted communications.

Rite-Solutions has developed several machine learning demonstration systems including edge computing ship recognition systems developed and demonstrated on Google Coral Development boards and Raspberry PI with Google Coral Accelerators. These edge computing machine learning systems, demonstrated at SENEDIA (Southeastern New England Defense Industry Alliance) Defense Innovation Days in Newport RI in August 2019, prove that a fully trained model can operate with required performance totally independent from any outside input or communications, with inferences determined on targets in sub-second responses.

ML Model Development Environment

The ML Model Development Environment (see Figure below) consists of two major components: (1) an AI system/ environment tailored to support ML and the training of ML models, and (2) software environment that supports a ML pipeline which includes activities from data ingest to ML model architecture development and training.

AI Training Environment. Working with the Rite-Solutions team, a list of key criteria and properties will be generated and documented. Research of available hardware and vendors will be performed and evaluated using a Pugh Matrix methodology. Examine and evaluate both COTS (Commercial Off The Shelf) AI workstations with innovative solutions like clustered SBCs. The results of this evaluation will be used by Rite-Solutions to purchase a standalone AI system/environment for use in its computing facility.

AutoML. AutoML aids individuals with limited machine learning experience and expertise to identify and use ML models to address an organization's needs. Multiple open source AutoML solutions such as H2O AutoML, Auto-SKLearn, Auto-Keras, etc. exist and will be investigated for use as a replacement for Google Cloud AutoML. As we have done in previous similar technology assessments, a Pugh Matrix methodology will be used to evaluate alternative solutions.

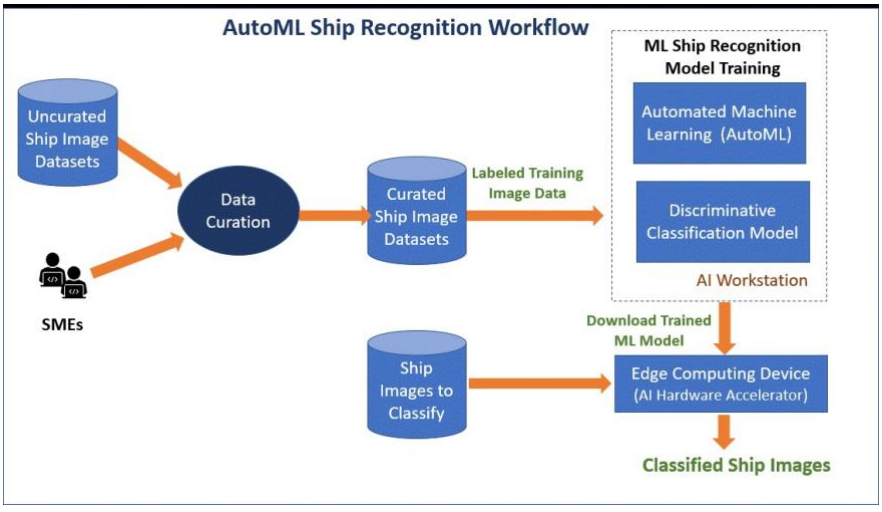
AutoML will aid in developing and training a ML model that performs ship recognition. Curated image ship data will be provided by Rite-Solutions to train the ML Ship Recognition model. The recommended AutoML open source solution will be downloaded, configured, and evaluated. Once trained, the results of selected AutoML model will be compared to the Rite-Solutions Google AutoML model (which will be provided to support the evaluation). It is expected that initial configuration, training, and testing will be performed using URI computing facilities. When it becomes available, the AI Workstation will be used.

ML Model Deployment.

Machine learning and the tools needed to train and deploy ML models are continually changing. In particular, the advent of low and ultralow (electrical) power devices such as Google's Coral TPU and Intel's Movidius VPU hardware accelerators provide the ability to deploy highly capable and state of the art deep neural networks with vision and audio recognition capabilities on small inexpensive, battery powered edge devices. This revolution makes these devices ideal for edge computing.

Researching off-the-shelf AI hardware accelerators and evaluating a variety of characteristics and properties such as cost, power usage, vendor support, machine learning model support, inference performance, size, and other criteria will provide objective recommendations for AI accelerator's use in an edge computing device. A Pugh Matrix methodology and supporting criteria will be developed to produce recommendations as well as a framework for future evaluations. The results of this evaluation will be used by Rite-Solutions to purchase an AI hardware accelerator for use in the proposed edge computing device.

A design incorporating the AI hardware accelerator along with a single board computer (e.g., Raspberry PI) and housed in a single small footprint enclosure will be developed and documented. The trained ML Model will be downloaded into the device and tested using curated ship images provide by Rite-Solutions. Metrics will be collected to evaluate the device's performance and resource utilization.



Hardware/Electrical Tasks:

- AI System/Environment
  - Working with Rite-Solutions, identify important hardware/software criteria needed for an AI workstation
  - Evaluate using Pugh Matrix recommend standalone AI workstation ○ Contact suppliers for availability and cost
  - Working with Rite-Solutions' IT group, setup and configure workstation; develop and perform installation tests
- AI Hardware Accelerator
  - Research available off-the-shelf AI Hardware Accelerators
  - Develop evaluation criteria and evaluate using Pugh Matrix, and recommend accelerator to use in the edge computing device d
- AI Edge Computing Device
  - Identify and recommend an SBC to use and integrate with the recommended AI Hardware Accelerator.
  - Research, evaluate and contrast image capture options including integrated still and video cameras and video and still image file ingestion. ○ Research, evaluate, and contrast power solutions for edge computing including battery energy density, recharging, costs, durability, and safety issues.
  - Develop and document the hardware design
  - Integrate, assemble, and test all hardware components; document test results

Software/Computer Tasks:

- Research and identify potential AutoML open source solutions for image recognition
- Evaluate, document, and recommend AutoML implementation using Pugh matrix; present recommendations to Rite-Solutions stakeholders
- Download, install, and configure recommended solution using URI's computing resources; document installation procedures and settings
- Train the ML model to identify and classify ships using curated ship images provided by Rite-Solutions. If available, train using the AI Workstation.
- Test the ML ship recognition model, collect metrics, and compare results to those previously obtained by Rite-Solutions using Google AutoML ship recognition model
- Develop test plan and approach to test the ML ship recognition model using the AI Edge Computing Device; perform tests, collect metrics, and document results.
- Develop demonstration of the AI edge computing device; document demonstration setup procedures

Composition of Team:

1 Electrical Engineer & 1 Computer Engineer

Skills Required:

The ability to research and evaluate tools, software, and hardware will be required throughout the project. In this case, we will work with students in the use of Pugh Matrix methodology that Rite-Solutions uses to aid in the evaluation of software tools and products.

Electrical Engineering Skills Required:

- Single Board Computers
- Vision/Image Recognition
- Artificial Intelligence/Deep Learning/Machine Learning
- Computer Languages: Python/TensorFlow
- Batteries and power for small systems

Computer Engineering Skills Required:

Artificial Intelligence/Deep Learning/Machine Learning

- Vision/Image Recognition
- Linux Operating System
- Computer Language: Python/TensorFlow

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) and submarine projects. 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 image data to rapidly and accurately identify threats and, secondly, be easily deployable in production commercial and US Navy systems.

In addition to vessel recognition for USVs and UUVs, recognition tools are extremely useful for both military and commercial manned surface vessels and aircraft. High-certainty recognition in any high-speed, quick-decision environment is a significant enhancement that would help our military keep and expand our target recognition advantage. Commercially, the application of this technology can be envisioned in numerous new dimensions, from the ability to recognize

undersea objects for oil and gas exploration, to accurately assessing forest density as part of wildfire prevention. Image classification is in the foreground of many industries and applications and frequently limited only by the scarcity of well curated datasets for training. With a demonstrable, proven solution, Rite-Solutions will find ready markets to provide and integrate ship recognition solutions into existing Navy and commercial platforms.

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 in. Rear Adm. David Hahn, the chief of naval research, said AI may be more important to great power competition than military power itself". 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 AI-infused products is loud and clear throughout DoD as well as in the commercial marketplace.

The scope of this capstone can be expanded into other Navy, DoD, and commercial domains. In the DoD/Navy domain, this means addressing ongoing Navy challenges to significantly improve automated or semi-automated systems' ability to better identify threats 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, we would anticipate improvements to the product to utilize image data from multiple platforms such as submarines, surface ships, aircraft, as well as multiple unmanned systems (e.g., subsurface, surface, and air UxS) to better identify new and emerging threats quickly. In the commercial domain, this capability would aid in the identification of commercial vessels underway or in port to enhance safety.