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Modeling High Power Microwave Engagements Versus Swarming Adversaries

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COTS AI/ML TECHNOLOGY FOR DATA FUSION AND TRACK MANAGEMENT

EXECUTIVE SUMMARY

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Project Summary

The Navy, and specifically Naval Information Forces, lacks the ability to fully employ artificial intelligence/machine learning (AI/ML) effectively to assist with data fusion and provide quick and timely analysis of the common operating picture/common tactical picture (COP/CTP). Other industries use this rising technology to enhance their analysis fusion. To help bring the Navy up to date, we examined multiple data streams such as geospatial intelligence (GEOINT) and radar data sets to fuse this information quickly and with greater accuracy of managing positive identification of tracks to provide the most current intelligence directly to the commanders for their decisions.

We performed an analysis of the ability to use AI/ML by using commercial off-the-shelf (COTS) software to automate filtering and demonstrate accuracy of multiple data streams into the Navy's COP/CTP for specific use by Naval Information Forces. Multiple data sets were integrated and filtered with automation to provide quick and timely analysis, while increasing speed and accuracy of managing positive identification of tracks, and developing the COP.

During our research, we created an ML pipeline that processes data from a simulation to train and test ML models that can be used in a Kalman filter (KF) system. We improved the KF by adding a learning component, called the ML-KF, which used sensor measurement errors to make more accurate predictions. The simulation system provided accurate data to train the learning component of our KF model, which means simulation can be a useful method for developing and testing ML models. These trained models may be able to be used in real-world situations in the future.

Keywords: *artificial intelligence, AI, machine learning, ML, intelligence fusion, data analysis, human-machine interaction, decision aids*

Background

The Navy, particularly the Naval Information Forces, is struggling to effectively utilize AI and ML to process and analyze data to assist with data fusion and provide analysis of the COP/CTP. Other industries have adopted these technologies to improve data fusion and analysis. To improve, the Navy has studied using various data sources, such as sensor track data, GEOINT, and radar data, to more efficiently and with greater accuracy, merge information and provide for the management of positive identification of tracks and furnish the most current intelligence to commanders for decision-making.

We set out to investigate whether ML models can improve the accuracy of state estimation (predict the position, velocity, and acceleration of an object based on its previous motion, and other factors) in a COP/CTP. We used a mathematical approach to study how adding a machine learning component to the KF algorithm can improve its performance.

Our research focused on the analysis of multiple sensor data streams for ingestion into AI/ML systems. Research also identified and analyzed relevant previous work on use of existing machine learning algorithms or techniques that could be usefully applied to the analysis of sensor data, searching for, and focusing on, those relevant and applicable to the COP/CTP and filtered for expedient track identification.

We consulted subject matter experts on background material and obtained feedback on appropriateness of proposed approaches and methodologies. We also identified principles and

tactics for integrating machine learning into operational scenarios. A thesis student analyzed proposed opportunities for ML and data flow applications and determined their value added in the context of surface warfare.

We have studied the Minotaur common operating picture and determined its suitability for the task. Examples of several COTS applications have been effective in providing promising results. We reviewed previously proposed solutions, identified potential future applications, and evaluated their utility for the Navy.

Findings and Conclusions
Our results showed that adding a machine learning component to the KF algorithm can increase the accuracy of state estimates by about 20%. In summary, our findings suggest that:

- We have developed a workable ML operations pipeline that ingests data from a simulation to train, validate, and test ML modules for subsequent deployment in a KF system. The methodology, dataset, and models generated are reproducible and replicable, as the code base and frameworks used for this development are open source.

- We added a learning component to a common algorithm called the Kalman filter. This improved the KF's ability to estimate the state of a system. Our modified version of the KF, called the ML-KF, was able to use a matrix of sensor measurement errors to improve the KF's predictions. As a result, the ML-KF provided more accurate estimates than the regular KF.

- We were able to train the learning component of our KF model because our simulation system provided accurate data that we could use to evaluate the model's performance. This shows that simulation can be a useful tool for developing and testing ML models. In the future, we may be able to use these trained models in real-world situations.

Based on the findings of this research, it is recommended that future study continue to explore this topic and build upon the knowledge gained here.

Recommendations for Further Research
We have conducted research on and evaluated the applicability of the Minotaur common operating picture for suitability for the task at hand.

During the execution of this research, we explored multiple interoperability architectures to determine the feasibility of passing our simulation data to a command-and-control (C2) system while the artificial intelligence/machine learning (AI/ML) track identification algorithm was operating. The simulation we used was Command Professional Edition, which has the capability of passing simulation data packets as defined by the Institute of Electrical and Electronics Engineers Standard for Distributed Interactive Simulation -- Communication Services and Profiles 1278.2-2015.1 Within this standard, we were seeking to utilize the data contained in the entity state protocol data unit (ESPDU) and map that to a tactical messaging format which can be processed for display on the C2 system. The System of Systems Technology Integration Tool Chain for Heterogeneous Electronic Systems (STITCHES) was the interoperability architecture we used for experimentation. It is currently under development and is managed under the Secretary of the Air Force – Acquisition, Technology and Logistics (SAF/AQ).

The Air Force developed STITCHES to support homogeneous, fixed-configuration weapons systems. When creating weapons systems for the Department of Defense (DoD), we need to consider that some of those systems will be operational for 30+ years. STITCHES has been designed to ensure system interoperability with emerging systems as the force modernizes.

Akin to STICHES, we have also created a similar contact report in the Over the Horizon - Gold (OTH-Gold) messaging format. Since the ESPDU and contact report contain similar data, our next research step is to map the latitude and longitude of each AI/ML algorithm-identified track into an OTH-Gold message for display on the Intelligence Carry-on Program (ICOP).

Both the STITCHES and OTH-Gold messaging format integration will provide valuable enhancements to the ICOP COP/CTP platform for potential implementation by the sponsor.

Future work may include further development of these methods and technologies.

Acronyms

AI	artificial intelligence
AQ	acquisition, technology and logistics
C2	command and control
COP	common operating picture
COTS	commercial off-the-shelf
CTP	common tactical picture
ESPDU	entity state protocol data unit
ICOP	Intelligence Carry-On Program
KF	Kalman filter
ML	machine learning
OTH	over the horizon
SAF	Secretary of the Air Force
STITCHES	System of Systems Technology Integration Tool Chain for Heterogeneous Electronic Systems