TRAINN

Track Real-time Artificial Intelligence Neural Network

ELECOMP Capstone Design Project 2020-2021

Sponsoring Company:

In-Depth Engineering, Inc.
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Company Overview:

In-Depth Engineering's core business is the development of Real-Time, Fault-Tolerant, High Availability, Mission Critical Software Systems for the United States Department of Defense.

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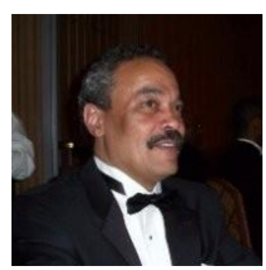

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Project Motivation:

Air traffic control and maritime traffic management are aided by platforms reporting their own position, speed and course. These self-reported tracks are used by control towers and nearby platforms for situation awareness, spatial separation and route planning. Air traffic uses a surveillance technology called ADS-B (Automatic Dependent Surveillance–Broadcast). Maritime traffic uses a system called AIS (Automatic Identification System). In both systems, vehicles broadcast positional data derived from Global Positioning System (GPS) satellites. The open air, self-reported nature of ADS-B and AIS data are subject to errors, spoofing, and inconsistencies. Spoofing attempts and irregular navigation are of great interest to law enforcement as they can be indicators of illicit behavior.

Machine Learning (ML), a subset of Artificial Intelligence (AI), has found broad engineering applications including classification, pattern recognition and anomaly detection. Machine Learning Neural Networks can be trained on typical AIS or ADS-B datasets and used to perform motion pattern analysis, behavior identification and spoofing detection on new data sets.

A significant challenge to developing Machine Learning algorithms is the availability of large data sets for training ML models. This project seeks to address this limitation by developing a system that gathers its own training data. This project will leverage two such sources. Source one, ADS-B will be received from nearby aircraft arriving and departing from TF Green airport. Source two, AIS will be received from nearby ships in Narragansett Bay. In both cases, the self-reporting data is broadcast on RF, and may be received using low-cost radio equipment. ADS-B and AIS data exchanges can be leveraged to create a robust data set in diverse locations for training AI/ML models.

The captured data will be stored in the cloud, where it will be accessed by software engineers and data scientists to develop machine learning models.

Anticipated Best Outcome:

The Anticipated Best Outcome of this project will include the development of two reusable data-collection units, cloud-based data storage and an Artificial Intelligence processing system to classify tracks and detect anomalies. The TRAINN system will consist of the following:

- ADS-B antenna and software-defined-radio receiver
- AIS radio antenna and software-defined-radio receiver
- GPS antenna and receiver
- Single board computer (SBC)
- ADS-B data exchange to obtain data from diverse locations

- AIS data exchange to obtain data from diverse locations
- Cloud data storage
- AI/ML (Artificial Intelligence / Machine Learning) models to characterize ADS-B and AIS tracks based on behavior.

In-Depth expects the data collection unit to be deployed on the URI Bay Campus, in an indoor space with a clear view of the bay to the east, and available power and an internet connection.

This mobile station, when complete, will perform the following functions:
- Configure the ADS-B receiver to receive & decode aircraft self-reporting messages.
- Configure the AIS SDR receiver to receive & decode ship self-reporting messages.
- Configure a GPS receiver to receive & decode position information for the data collection unit.
- Push the acquired data to a cloud data store.

If time allows, other data sources can be leveraged for platform identification and data labeling including video, images, and social media posts from platforms, ports, and airports.

Project Details:

Overall system concept:

The TRAINN system will receive and collect surveillance track information on aircraft and ships. The data will be used to train ML models to find hidden information in the datasets. The trained models with be optimized and then run on new data to classify features and detect anomalies.

The capstone team is free to choose their own hardware for the data collection unit. This discussion outlines hardware typically used for these applications.

ADS-B broadcast is a relatively new requirement for commercial aircraft, being mandatory in the United States as of January of 2020. ADS-B is broadcast at 1090 MHz and can be received using a simple vertical polarized antenna, and decoded using a software defined radio, typically in the form of a USB dongle, and decoded using open source software. Decoded information includes the position and altitude of the craft, as well as the speed and heading, and information identifying the aircraft model.

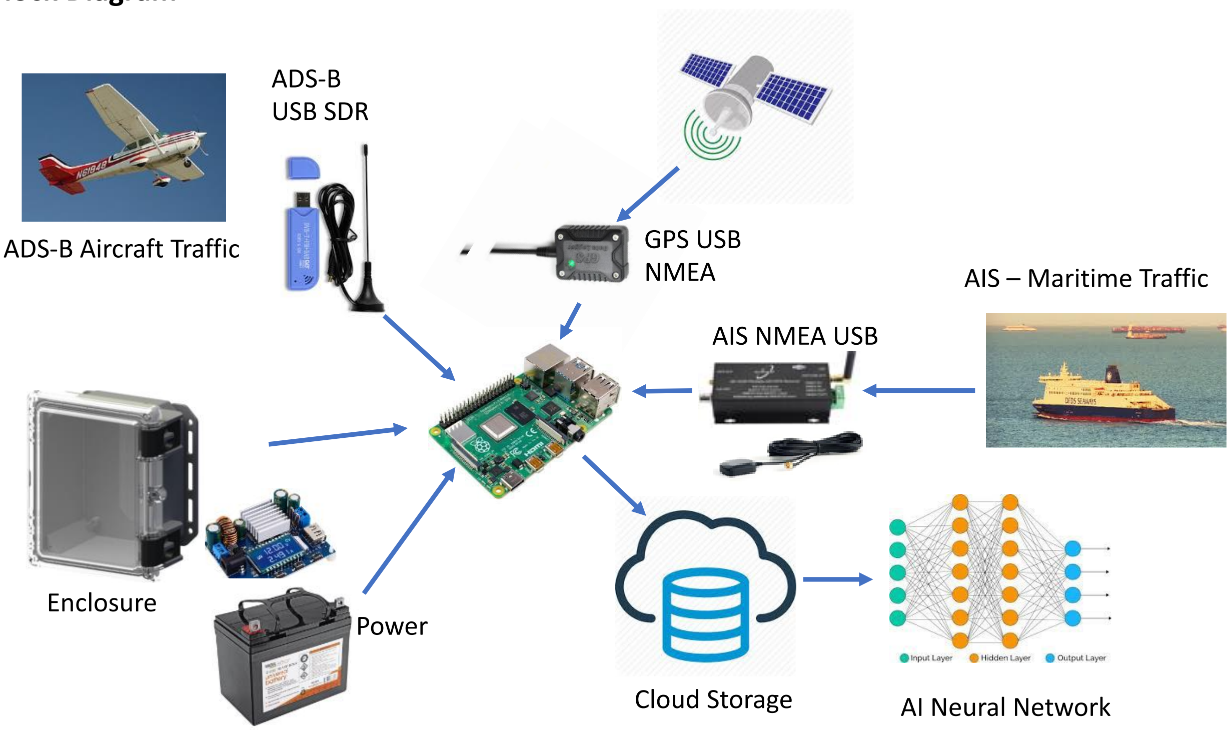
AIS broadcast has been a requirement for commercial shipping since roughly 2002. AIS is broadcast at approximately 162MHz and can be received using a simple vertical polarized antenna. AIS may be received and decoded using an SDR, and alternatively may be received and decoded using special purpose hardware that decodes to NMEA text data on a serial (RS-232) interface.

GPS dongles are inexpensive, and typically generate NMEA formatted text data as a virtual serial port over USB. Open source software is available to facilitate the decoding of ADS-B, AIS and GPS messages.

This data is input to the single board computer controlling the data collection unit. A prime consideration for the SBC is the availability of I/O ports to support the system inputs (radios) and system outputs (data for cloud storage).

The data collection unit should be portable, ideally the assembly can be powered using an inexpensive lead acid battery using buck converters to provide the required power supply. The physical mounting of the components should also be considered, a weather resistant enclosure should house the SBC, battery, SDR dongles, and interconnect wiring.

Block Diagram



Hardware/Electrical Tasks

- Design Data collection unit 1.
- Design Data collection unit 2.
- Assemble enclosure, power supply, ADS-B receiver, AIS receiver, GPS receiver and single board computer.
- Provide connection to cloud based storage.
- Test data collection units.

Firmware/Software/Computer Tasks

- Collect ADS-B Data.
- Train a Convolutional Neural Network (CNN) to predict aircraft type from the position/velocity time series of an ADS-B message, using labeling derived from the Icao field of the message. (pyTorch / Python).
- Tune hyperparameters, using a mixture of training, test, and validation data.
- Plot ADS-B tracks on 3D Globe (CesiumJS or similar).
- Analyze data to detect anomalies.
- Develop report on results.

- Collect AIS data.
- Train a Convolutional Neural Network (CNN) to predict ship type from the position/velocity time series of an AIS message, using labeling derived from the MMSI field of the message. (pyTorch / Python)
- Tune hyperparameters, using a mixture of training, test, and validation data.
- Plot AIS tracks on 3D Globe (CesiumJS or similar).
- Analyze data to detect anomalies.
- Develop report on results.

Composition of the Team:

1 Electrical (ELE) Engineer and 2 Computer Engineers; OR

2 Electrical Engineers and 1 Computer Engineer: Preference will be given to the ELE who can carry out the **Firmware/Software/Computer Tasks**, and possibly has a minor in Computer Science. (The project is more software focused)

Skills Required:

Electrical Engineering Skills Required:

- Basic RF Engineering, for VHF/UHF (Antennas, cabling, impedance, SWR).
- Systems Engineering, integrating open source hardware & software with bespoke work.
- Applied/Practical Machine Learning for classification and pattern recognition.

Joint Electrical Engineering and Computer Engineering Skills Required:

- Leverage open source tools and libraries.
- Decode ADS-B, AIS and GPS data into locations and identifying data.
- Cloud SDK interface to push data files to cloud data store.
- Configure cloud virtual server for image classification.
- Configure classification software.
- Develop AI/ML model with Tensor flow / Python.
- Train ML model and demonstrate performance using standard metrics.

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

If successful, this prototype concept can be ruggedized, replicated, and deployed to locations with high vessel traffic. The initial concept can also be expanded to include cameras, infrared imaging for night vision, video capture, VHF comms, acoustics, radar, and other sensors.

The resulting collected database can provide the basis for training and deploying ML models for a variety of naval ship and aircraft sensor systems.

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

Machine Learning is a hot topic in Electrical Engineering. While these are desirable skills, few people have practical experience implementing these technologies. This project will provide hands-on experience with ML, including the often-overlooked practical aspects.