JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

THESIS/RESEARCH PROJECT APPROVAL FORM
(Engineering for Professionals)

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Attach your research proposal. The proposal should be 2–3 pages in length and adhere to the requirements stated in the Thesis Guidelines for your program.
Available at: https://ep.jhu.edu/current-students/student-forms/

Approvals

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12/17/20

I Introduction

Radar electronic jammers are evolving from hostile nations thus becoming more complex and present serious issues when a radar system is trying to interrogate the actual targets of interest. Electronic jammers that present a serious challenge are in a class called Digital Radio Frequency Memory (DRFM). DRFM techniques work by generating coherent false targets to the radar receiver based on an intercepted pulse signal from the radar transmitter. This will position false targets either ahead or behind the actual radar target, thus masking the real target with false targets. The false targets can also be manipulated in amplitude, phase and frequency.

Traditional approaches to target detection and estimation for electronic jammers in general, rely on parametric modeling, that can fail because it violates the strict assumptions of classical signal processing algorithms. The result is substantial algorithm performance degradation. Furthermore parametric models to handle DRFM jammers are difficult to design and ineffective against an evolving DRFM technology. The key to identifying opportunities for improved electronic jammer protection and signal processing in radars is to use machine learning techniques to challenge the underlying assumptions of the standard parametric approach for the design and analysis of radar systems.

Convolutional Neural Networks (CNN) have gained popularity in the last few years with the advent of faster high performance computer systems which rely GPUs for the best computational performance. A CNN operates from a mathematical perspective and is used for non-trivial tasks such as image classification. CNN's have great performance while classifying images when they are very similar to the training dataset. However little work as been done in developing realistic radar models which are ignoring radar environmental and antenna effects thus providing inaccurate simulation training datasets and credibility. In addition, current public available research does not typically consider the five dimensions of a radar sensor, thus presenting an incomplete signal processing chain. From a first principles perspective the radar measures the following aspects of a signal target return: Range, azimuth, elevation, Doppler, and signal amplitude.

II Proposal

We propose to design a CNN that will use both temporal and spatial training datasets, where the radar signal processing with respect to DRFM jamming will be examined to identify and classify DRFM type jammers. The CNN will use raw uncompressed In-phase and Quadrature (IQ) time series data and range-doppler maps as inputs to classify if our ground based phased array radar system is being jammed by DRFM false targets. A suitable network architecture and values for hyperparameters are found by iterative experimental studies. The final classification accuracy objective will be 95 percent or better. This achieved accuracy suggests that CNNs can be used to detect radar DRFM jamming with good results and thus allowing a radar system to decide on any further actions to mitigate a DRFM jammer attack.

We propose the following Project Outline:

1. We will use applied mathematics to design and develop a ground based phased array radar testbed in MATLAB that will generate physics-based DRFM jamming signals or false targets into a real target scene while simulating the radar transmit and receiver operations to include the signal processing operations. This will generate the raw uncompressed IQ signals that we then can process into range-doppler maps. The time series IQ signals and spatial range-doppler maps will serve as the training datasets that are inputs into the CNN.
2. We will use our MATLAB radar testbed to baseline the standard parametric approach for electronic jammers. The signal processing operations will use conventional pulse processing and mathematical techniques, which will process in both fast and slow time. The signal processing outputs will provide a basis of comparison to our proposed machine learning approach.
3. We will design and train a CNN with Google Colab and utilize high performance GPUs (i.e. A100 which is NVIDIA's GPU latest technology) while implementing the CNN in Python using a hands-on

machine learning approach using production ready Python frameworks such as Scikit-Learn, Keras, and TensorFlow. To minimize the performance impact on learning speed we will implement a cross-entropy cost function.

4. We will develop metrics and evaluation criteria to support the claim that machine learning can be an effective technique for radar DRFM jammer classification and that it outperforms classical signal processing techniques against an evolving DRFM technology.

5. We will execute a series of iterative experiments that explore fast and slow time CNN inputs over the established hyperparameters. This will produce outputs that we then can examine for accuracy and precision in which to base our conclusions, thus highlighting that machine learning can be an effective technique for radar DRFM jammer classification.

In order to design and test the CNN we will apply mathematical rigor and original contributions. The desired outcome is to have new or add to the volume of knowledge and understanding in the areas of applied mathematics and modern computational methods. Opportunity exists in solving this problem to exploit several branches of mathematics and its concepts to advance the start of the art. This includes mathematical algebraic objects (i.e tensors), complex analysis, linear algebra, partial differential equations, computer vision, statistical analysis, and vector calculus. Furthermore the following areas of the project will be considered for mathematical exploration:

- Test data generation (Project Outline 1,2) - We will look for novel mathematical techniques to generate the training test data required to produce the desired classification outcome. We will explore statistical methods to reduce the size of the training test data thus reducing the overall time to generate sufficient test training data for this problem.
- Algorithm performance (Project Outline 3) - We will design original mathematical algorithms that demonstrate performance enhancements over existing techniques for a CNN.
- Metric and evaluation analysis (Project Outline 4,5) - We will explore and determine mathematical techniques that yield the most efficient, accurate, and precise classification results.