# Master’s Thesis Status Report: Convolutional Neural Network (CNN) for Digital Radio Frequency Memory (DRFM) Jammers

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**Background**

Traditional approaches to target detection and track estimation for electronic countermeasures (ECM) 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. ECM in general attempts to interfere or deceive the radar system with misleading electronic signals. We propose 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 Graphics Processing Unit (GPU) computers. Current research demonstrates CNN as a sound approach for radar signal classification with more work to be done.  We will show a Convolutional Neural Network (CNN) that will use spatial training datasets in the form of range-doppler images to perform radar signal classification.  The radar signal processing will then be examined to identify different ECM classes. The goal is to show that ECM can be mitigated and thus improve overall radar performance operation and target recognition. We focus on a particular type of active ECM called Digital Radio Frequency Memory (DRFM). DRFM has the capability to intercept a radar signal, then transmit misleading signals back to the radar which can appear as a time delay, phase shift or doppler shift, thus presenting a false target or intentional interference to the radar. We choose to focus on the DRFM jammer because it’s the most problematic ECM for radars to date.

Success is defined by the identification of an ECM, in this case a DRFM jammer and its type via the CNN model. The new CNN model is proposed to be part of the radar’s signal processing chain. The DRFM jammer will fail to effect radar detection and tracking operations in the radar. Identification is the first step in mitigating the effects of ECM.

The status quo is the high probability of failure to identify false targets or intentional interference since DRFM is problematic for typical radar signal processing. The failure effects are as follows:

* Promotes sub-optional radar signal processing operation
* Degrades detection performance
* Hides the real targets, thus deceiving the radar tracking algorithms

Diagram

Description automatically generated

**Challenges encountered**

1. As my neural network deepens, I think the step sizes or learning coefficients can either tend toward zero or infinity. Either way the algorithm fails to learn and does not converge, even though the direction is correct. For machine learning, we define the gradient descent as an optimization algorithm that is used to find the values of some multivariate function that minimizes in my case, a cross-entropy loss function generalized as for classes, where is the label for truth and is the probability for the class. Exploring the Levenberg-Marquardt algorithm, since we have a non-convex optimization and I understand it’s the standard for this type of problem.
2. Work is being done in the range-doppler space, but I would also like to consider the 1D time domain signal as well. The 1D time domain samples are complex numbers defined by , where is the amplitude of a sample, is the phase angle. This is the typical output of a matched filter radar receiver, after an Inverse Fourier Transform (IFFT). This would be beneficial because we would gain efficiency by identifying the false targets earlier in the signal processing chain. In addition, saving the computational cycles of doing range-doppler processing. This is a challenge since time series seems to be a hard problem with CNN. Exploring other alternatives such as but not exclusive to "Decision Tree", "SVM", "BP Neural Network", and "Generative Adversarial Networks".
3. Separating the real targets from the false targets is somewhat tangential to what I proposed. it’s a real challenge since real along with false targets are appearing in the mainlobe of the beam and thus should be considered. The mainlobe of a radar beam is like a sinc function where where The mainlobe is the prominent feature in the plot of a sinc function. The detection decision is typically done by hypothesis testing using a Bayes optimization which determines the optimal choice between our hypotheses. In this case, I’m considering a multi-hypothesis approach for TBD features. Also looking into a particle filter approach which is a recursive, Bayesian state estimator that uses discrete particles to approximate the posterior distribution of the estimated state.

**What needs to be done or try**

1. Expand the theory portions of the thesis, in particular the optimization “algorithms” approach and the justification for what will eventually be in the delivered thesis. Looking at other approaches besides CNN such as but not exclusive to "Decision Tree", "SVM", "BP Neural Network", and "Generative Adversarial Networks".
2. Design mathematical algorithms that demonstrate performance enhancements over existing techniques for a CNN. More research needs be done in this area to ensure we put forth the most optimal solution.
3. Need to examine my loss or objective function in more detail, since this is critical to minimize loss along with gradient descent. In other words, if the objective function does not correlate the task successfully then my neural network could have undesirable outcomes and do things that I don't want.
4. “Modeling” for the radar is about 90% complete, however there is much work left in designing the neural network. I do have a CNN prototype up and running with representative range-doppler images based on DRFM targets. Preliminary results of the CNN model accuracy are encouraging and provide a good foundation starting point for more work. I’m also running on the target “Hardware” which is exploiting parallel processing via NVIDIA GPUs.
5. The thesis outline is complete and starting to write the thesis chapters. Most of the focus in the 1st semester has been the “Science” part of the thesis. This includes the introduction, background, problem breakdown and what I’m trying to do, to improve the existing techniques. The methodology, mathematical techniques, data analysis and results, to include future work is the focus in the 2nd semester.
6. Research and review are continous and will occur up to the delivery of the final thesis. It’s of upmost importance to experiment with mathematical forms, processes, and techniques to align with the digital tools of today.
7. Need to baseline and show the comparison of the convential signal processing approach versus the CNN Model for DRFM.

**Comment**

An abstract based on this thesis topic was submitted to a Northrop Grumman symposium and was approved. I plan to present on this topic next month, Sep 30th. Hoping to gain more insights and ideas for this topic from the radar community.

I do have a plan and I’m on schedule. While I do have challenges, no major roadblocks at this point, so I’m confident in delivering my thesis in the 2nd semester. Note that my 2nd semester is Spring 2023, which is also my planned graduation. I’m taking my final class this Fall.