Course Title:
Deep Learning for Radar Automatic Target Recognition (ATR)

Needs Analysis:
Machine Learning (ML) algorithms have grown in popularity with advances in computation, data availability, and various applications. In particular, Deep Learning (DL) is altering big data analytics. Technology giants such as Google, Facebook and numerous start-ups are applying DL algorithms for object/face recognition (from video imagery) and real-time decision making. However, there is a need to understand the merits of DL as applied to radio frequency data (i.e., Radar data) for automatic target detection and classification. DL-based RF ATR will be beneficial both for military (target recognition) and civilian (self-driving car) applications. Furthermore, understanding the technical challenges and approaches to develop DL-based target classification on radio frequency (RF) data would determine approaches for leveraging ML for video imagery data for RF data.

Description:
The focus of this course will be recent research results, technical challenges, and directions of Deep Learning (DL) based object classification using radar data (i.e., Synthetic Aperture Radar / SAR data). First, we will present an overview RF ATR research in the past (i.e., template-based approach conducted under DARPA MSTAR (Moving and Stationary Target Acquisition and Recognition) program and limitations of this approach. Then will provide an overview of various machine learning (ML) theories. Finally, we will demonstrate implementations and performance analysis of DL-based ATR on SAR data.

It is evident that significant research efforts have been devoted to applying DL algorithms on video imagery. However, very limited literature can be found on technical challenges and approaches to execute DL algorithms on radio frequency (RF) data. We will present hands-on implementation of DL-based radar object classification using PyTorch and TensorFlow tools. Unlike passive sensing (i.e., video collections), Radar enables imaging ground objects at far greater standoff distances and all-weather conditions. Existing non-DL based RF object recognition algorithms are less accurate and require impractically large computing resources. With adequate training data, DL enables more accurate, near real-time, and low-power object recognition system development. We will highlight implementations of DL-based (i.e., Convolution Neural Networks (CNN)) SAR object recognition algorithms in graphical processing units (GPUs) and energy efficient computing systems. The examples presented will demonstrate acceptable classification accuracy on relevant SAR data. Further, we will discuss special topics of interest on DL-based RF object recognition as requested by the researchers, practitioners, and students.

Learning Outcomes:
1. The student will understand various machine learning algorithms
2. The student will be able to identify object features in radar imagery
3. The student will be able to construct a machine learning system to detect and classify targets from radar imagery
4. The student will be able to compare technical challenges involving radar and video image classification

5. The student can differentiate benefits of DL-based RF object classification as compared to existing algorithms (i.e., template-based approach)
6. The student would become aware of software tools and data applicable to their research interests

Intended Audience:
Engineer/Researcher interested in applying Deep Learning on radar or electro-optical data for developing object recognition/self-driving car/autonomous/expert systems.

Course Level:
The materials for this course will be intermediate; some understanding on machine learning will be useful but not a requirement.

Course Length:
The course could be made for Half-day (4 hours of instruction) or Full-Day (8 hours of instruction)

Course Materials: We have the public released slides (100 ppt slides), recent papers, and hands on algorithms implementation (on GPU-based Laptop) ready for students.

Other Course Materials: We are expecting to have our draft book (to be published by Artech House) on "Machine Learning for Radar ATR" ready around late March 2020.

Previous Offering: In RadarConf. 2019 (Boston), we presented this short course and we have the largest tutorial attendees (42 people) among all the tutorials. We also presented this tutorial at SPIE DCS 2018. The authors also presented a tutorial on "SAR Signal and Image Processing" at IEEE RadarConf 2010 (Washington D.C.).

Biography of the tutorial Authors/Presenters:

- **The authors have prepared the full tutorial and public released. Currently, we are working on writing a book to be published by Artech House (Fall 2019).**

Dr. Uttam K. Majumder is a senior electronics engineer at Air Force Research Laboratory (AFRL). His research interest includes Machine Learning for object recognition, High Performance Computing, Synthetic Aperture Radar (SAR) algorithms development for surveillance applications, Radar Waveforms Design and Digital Image Processing. From 2016 to present, he has been working with the Computing and Communications Division, AFRL Information Directorate, Rome, New York. From 2003-2015, he has worked with ATR Division, AFRL Sensors Directorate, Dayton, Ohio. He has earned Ph.D. degree (in Electrical Engineering) from Purdue University, West Lafayette, Indiana. He is technical lead for several DARPA programs including RFMLS (Radio Frequency Machine Learning Systems), TRACE (Target Recognition and Adaption for Contested Environments), and HIVE (Hierarchical Identify, Verify, and Exploit). He is leading several in-house machine learning research projects. He has presented a SAR ATR tutorial at the SPIE DSS 2018. He also presented a SAR Signal

and Image Processing tutorial at IEEE Radar conference 2010. He is a senior member of IEEE and recipient of many technical awards from AFRL.

Dr. Erik Blasch is a principal scientist at AFRL (AFOSR) researching information fusion evaluation, image fusion, and pattern recognition. He is a Fellow of IEEE and SPIE. He has supported multiple tutorials including SAR ATR.

Dr. David A Garren is an Associate Professor at Naval Post Graduate School. His research interests include SAR signal and image processing, Radar Systems Development. He teaches SIGINT Systems Engineering (in various DoD organization) among other courses at NPS.