ACTIVITY REFERENCE NUMBER	SET-ET-XXX	ACTIVITY TITLE Integrating Compressive Sensing and Machine Learning Techniques for Radar Applications.	APPROVAL (4)
TYPE	ET/RFT		START Jan 2019
LOCATION(S) AND DATES		Paris, CSO Office	END Dec 2019
COORDINATION WITH OTHER BODIES		NA	
NATO CLASSIFICATION OF ACTIVITY		NU	Non-NATO Invited Yes (AUS, FIN, SWE, CHE)
KEYWORDS	Adaptive Signal Processing, Compressive Sensing, Optimization, Machine Learning, Deep Learning, Radar, Target Classification, Sparse Signal Representation.		

I. BACKGROUND:

In the field of radar there is a growing need for higher resolutions to enable the detection of small targets in a complex background, to improve the tracking of multiple closely spaced targets, and to support automatic target recognition. Recently, Compressive Sensing (CS) emerged as a technique that enables to achieve higher resolution than conventional methods using a combination of random sampling and sparse signal reconstruction algorithms. In the past decade, a lot of theoretical progress has been made in CS and simulations have demonstrated the potential of CS to improve radar performance. However, the adoption of CS techniques in operational systems is still lagging behind the theoretical and algorithmic advances due to practical constraints such as latency, memory size, and power consumption dictated especially by the iterative nature of the algorithms used in CS.

In parallel, in recent years Machine Learning (ML) has achieved tremendous success in many commercial applications such as automatic face recognition, speech recognition, machine translation, self-driving cars, and robotics. An important element in the success of ML for these applications is the availability of large databases which are used for training. Machine Learning has the potential to provide computationally efficient approaches to improve target detection, tracking and classification in radar with enhanced resolution. However, Machine Learning techniques, and in particular deep neural networks, are often poorly understood from a theoretical perspective due to their black box nature.

An integration of Compressive Sensing and Machine Learning for radar applications offers the potential to combine the benefits of both worlds. For example, iterations of many CS algorithms for sparse signal recovery have the structure of neural network layers. Therefore, computationally efficient ML Models such as Deep Neural Networks can be used to replace the expensive iterations with fixed depth feedforward networks learned from the data. Furthermore, the learning process permits extraction of better dictionaries for sparse representation from training data. On the other hand, CS based generative models of target and clutter could possibly be used to produce vast training sets required for ML algorithms filling in the gaps in measured data by means of online predictions from a “compressed” database, improving the generalization. This CS assisted training strategy will significantly widen the scope of problems where ML could be successfully applied, as in the military domain the availability of a large measured radar data training sets cannot always be guaranteed.

II. MILITARY RELEVANCE:

Compressive sensing is a technique that can maintain or improve radar performance (e.g. in terms of target acquisition) whilst requiring substantially fewer radar measurements to be made. This can provide both operational benefits since the radar needs to spend less time on target (e.g. leading to more rapid targeting or freeing up the radar to perform other tasks) and cost benefits since a lower specification radar that exploits compressive sensing techniques can provide similar performance to a higher specification radar. A current disadvantage of compressive sensing based techniques is that they are extremely computationally expensive and they are sensitive to operational conditions and sensor parameters. This proposed activity will develop techniques based on machine learning which will provide computationally efficient implementations of compressive sensing processing adaptable to new operational conditions through learning thus facilitating the realisation of their benefits for operational systems.

III. SCIENTIFIC OBJECTIVE(S) AND EXPECTED ACHIEVEMENTS:

The main objectives of the ET are to define with the participating members the topics of interests for a possible TG, including:

- Identify application areas where integrated designs with CS and ML components outperform state-of-the-art techniques within power, size, latency constraints;
- Create big data repositories and algorithm libraries to enable learning techniques;
- Assess the performance and robustness of integrated architectures and algorithms for radar applications/scenarios;
- Identify and quantify generalization capability of integrated CS and ML systems across wide range of operational conditions.

IV. SCIENTIFIC TOPICS TO BE COVERED:

Themes of convergence in CS and ML techniques relevant to this NATO group include:

- Non-iterative signal reconstruction algorithms for radar imaging unrolling classical iterative CS algorithms and learning fixed depth architectures from data suitable for GPU implementation.
- Combining CS imaging algorithms with discriminative deep neural networks for learning imaging processes optimized for decision/classification tasks and robust to clutter variation and occlusions.
- CS framework considers measurements only in the form of linear projections, ML techniques could be used to learn nonlinear transformations of sensor data, with better information efficiency while maintaining universality.
- Unsupervised learning of novel sparsifying transforms and dictionaries that captures radar phenomenology resulting in higher quality reconstructions in under sampling regimes.

New system architectures might be devised as a result of the above analysis.

V. SYNERGIES AND COMPLEMENTARITIES:

During the ET possible synergies and complementarities amongst the participating members and other NATO RTGs will be explored.

VI. EXPLOITATION AND IMPACT:

The results that will be produced by this ET can lead to a new RTG whose results can be used by NATO and industry as an indication of the benefits of integrated CS-ML methods, and how to develop these into operational systems. Moreover, we expect unique aspects of radar phenomenology and resource constraints dictated by operational systems will spark new directions for CS-ML research applied to radar.

VII. TECHNICAL TEAM LEADER AND LEAD NATION:

Chair: Dr. Laura ANITORI, The Netherlands.

Lead Nation: The Netherlands

Co-chair: Prof. Emre Ertin, USA

VIII. NATIONS/NATO ORGANISATIONS WILLING/INVITED TO PARTICIPATE:

NATO Nations and Bodies that expressed their interest in this activity are Italy, The Netherlands, UK and United States.
Furthermore, this ET is open to the following non-NATO Nations: Australia, Finland, Sweden and Switzerland.

IX. NATIONAL AND/OR NATO RESOURCES NEEDED (Physical and non-physical Assets):

Participating Nations will be supported by their respective agency and provide the necessary resources for the duration of the TG.

X. CSO RESOURCES NEEDED (e.g. Consultant Funding):

Support from the CSO is requested to organize the 1st ET meeting at the CSO Office.