Neural Network Enhanced Radar Surveillance

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Signal Processing in Neural Networks (SPiNN)

Artificial Intelligence

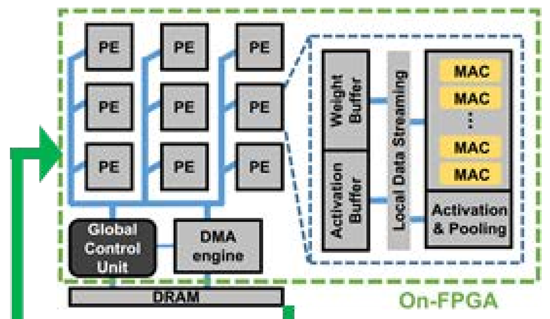
Background and Goals

Challenge Problem

- Persistent surveillance of small unmanned aerial systems in urban terrain from fixed-site radars

MIMO Radar

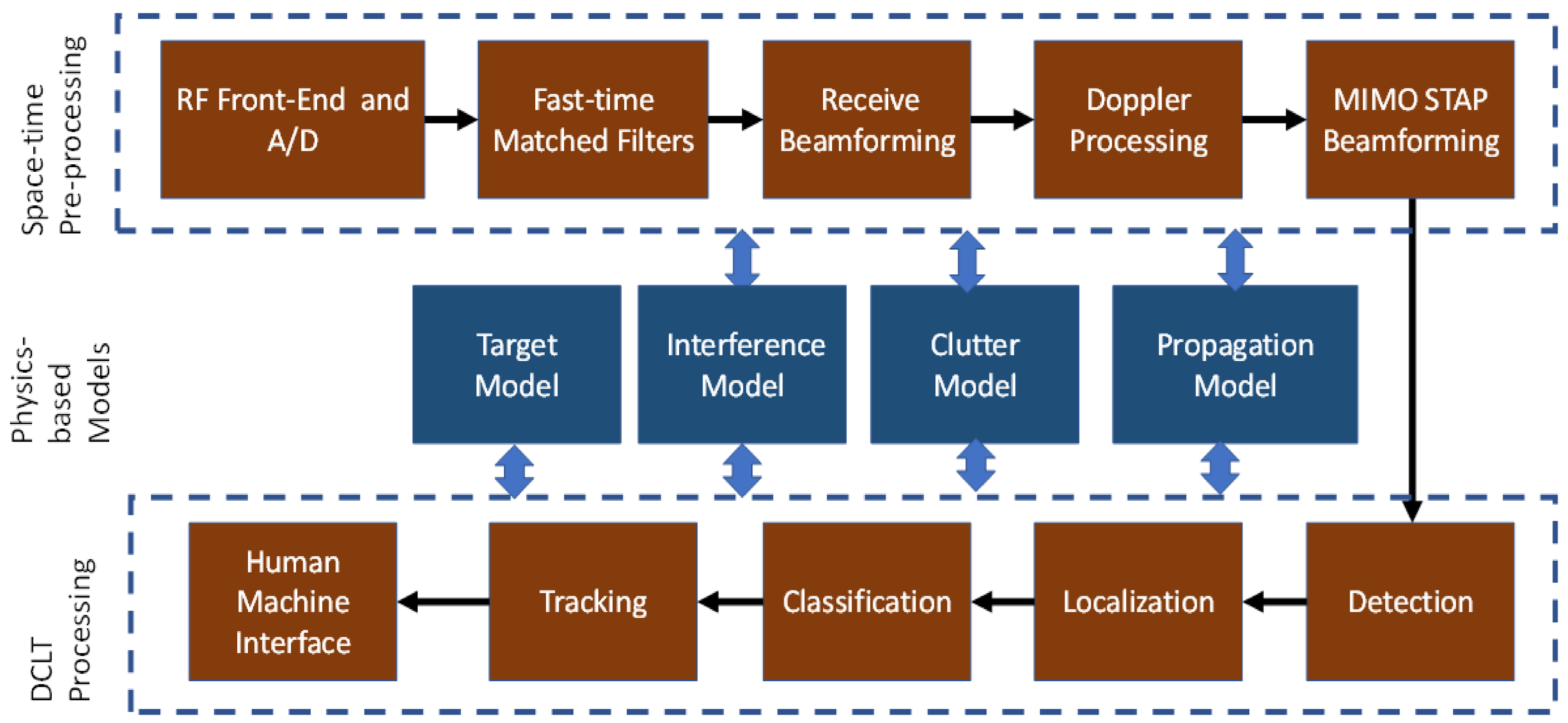
Urban surveillance radar which learns its operating environment



Geolocated Track

Background

- Moving target indicator (MTI) radars use idealized target, clutter, interference, and propagation models
- Real environments include strong discrete clutter/interference, non-target movers, multipath propagation, and sensor miscalibration
- In situ pre-detection data not used to learn the clutter, propagation, and noise environment with infrequent updates to target libraries
- Signal processing implemented using generic hardware which limits throughput and efficiency.



Conventional Multiple Input Multiple Output (MIMO) Radar Architecture

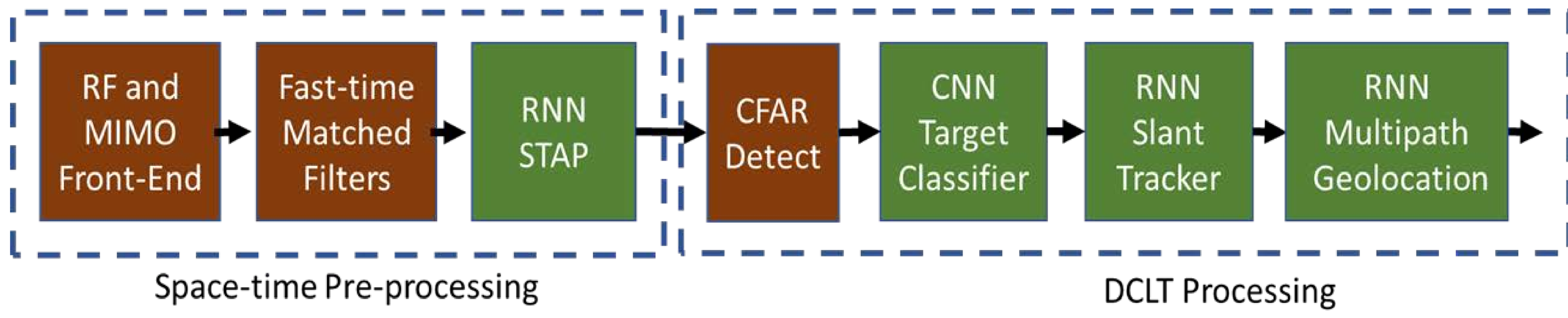
Goals

- Enhanced radar detection, classification, localization, and tracking (DCLT) in complex terrain using data-driven neural network (NN) elements which learn their operating environment
- Real-time signal processing with hardware adaptivity and cost efficiency

Approach

Neural-Network Enhanced Radar Surveillance (NNERS)

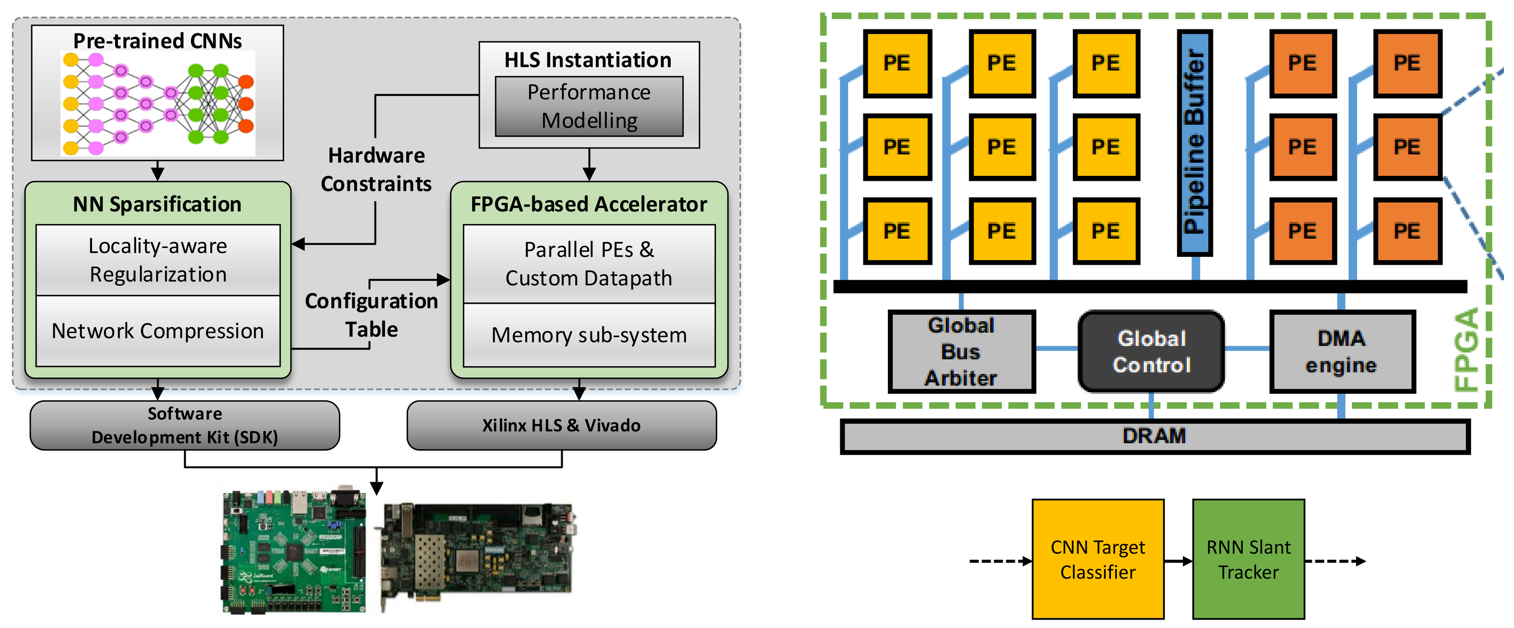
- Key ideas:
  - Use measured data to train four neural network elements (green boxes below)
  - Pipelined and modularized FPGA radar processing chain optimized to accelerate neural network elements
- Use “pattern-of-life” pre-detection data to train space-time adaptive processor for improving signal-to-clutter-plus-noise (SCNR) ratio
- Use generative adversarial networks (GANs) to extend libraries of UAS and non-UAS micro-Doppler spectrograms to train a convolutional NN (CNN) classifier
- Spiral development of signal processing, neural network architecture, and FPGA implementation



NNERS Multiple Input Multiple Output (MIMO) Radar Architecture

FPGA-based Acceleration for Neural Networks

- The design framework generate FPGA-based acceleration design for efficient DNN deployment
- The functional modules in FPGA are pipelined and built with distributed grids of modules, e.g., tree-based and systolic processing elements (PEs)
- PEs perform concurrent layer operations such as convolution, vector-matrix multiplication, max-pooling, ReLU, Sigmoid and Tanh

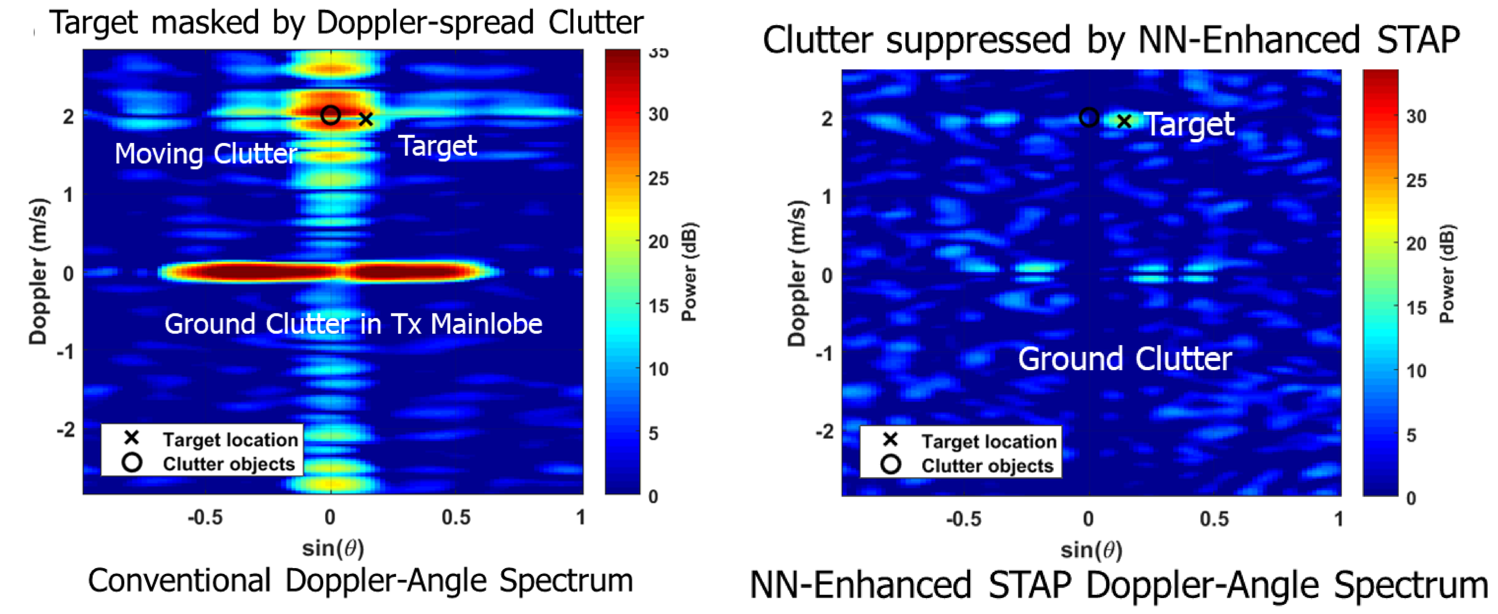


Software and Hardware Co-design Flow and Overall Architecture

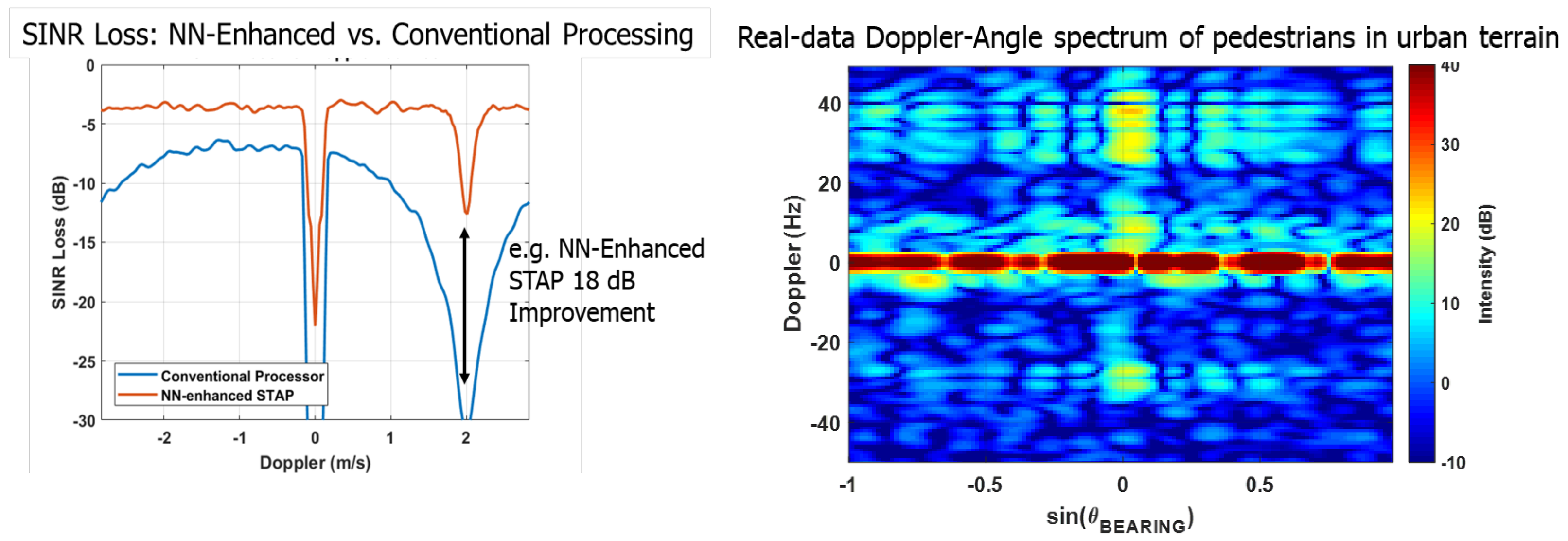
Results and Impact

Space-Time Adaptive Processing (STAP) in Urban Terrain

- Range-varying Doppler-angle clutter spectrum precludes conventional STAP
- Simulated urban Doppler-angle spread clutter masks target while NN-enhanced STAP classifies and removes strong clutter components

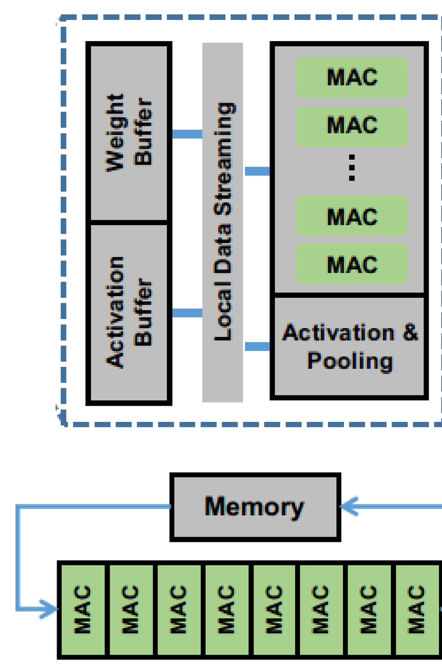


- NN-enhanced STAP improves SCNR at all target Dopplers



- Collection of real radar data in urban terrain currently underway

FPGA Processing Element (PE) Architectures



Measurement of AlexNet on ImageNet

Platform	NVIDIA Tesla K40c	Intel Xeon E5-2630 v3	Xilinx VC707
Technology	28nm	22nm	28nm
Optimization	cuSPARSE	MKL	HLS
# of Cores	2880	8	24*32
Mem. BW	288GB/s	59GB/s	12.8GB/s
Feq. (Hz)	745 M	2.4 G	150 M
Power (W)	235	85	13.5
Peak GOPs	4290	307.2	230.4

Impact

- Radar has potential for all-weather, day-night detection, classification, and tracking of low, slow, small unmanned aerial systems
- NNERS could implement stand-off “radar trip-wire fences” for target indications, warnings, and interdiction cueing
- Complementary to DARPA Aerial Dragnet, Mobile Force Protection programs, and DoD urgent operational needs

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