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Capabilities Statement for IARPA SCISRS BAA:

Riverside Research Capabilities to Support the IARPA Securing Compartmented Information with Smart Radio Systems (SCISRS) Research Program

Submitted by: Riverside Research

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1. Introduction

Riverside Research, a not-for-profit organization chartered to advance scientific research for the benefit of the U.S. government and in the public interest, is pleased to submit this Capabilities Statement that reviews our background, expertise, and experience to support the IARPA Securing Compartmented Information with Smart Radio Systems (SCISRS) Research Program.

Riverside Research's open innovation R&D model encourages internal and external collaboration to accelerate innovation, advance science, and expand market opportunities. It fosters creativity and synergy to encourage and drive innovative solutions to current and anticipated challenges while allowing us to more easily embrace emerging technologies. Our Open Innovation Center (OIC) operates a series of geographically-dispersed laboratories enabling company-funded research that complements our customer-focused services and provides reach back for our customers.

Particularly relevant to the SCISRS program is the work conducted by our Artificial Intelligence (AI) and Machine Learning (ML) Laboratory, Optics and Photonics Laboratory, and Trusted and Resilient Systems Laboratory. These laboratories support a diverse set of DoD and Intelligence Community customers, including the Defense Research Projects Agency (DARPA), National Air and Space Intelligence Center (NASIC), Air Force Research Laboratory (AFRL), U.S. Army Combat Capabilities Development Command (CCDC) Armaments Center, and National Reconnaissance Organization (NRO), working closely with numerous industry and academic partners.

2. Technical Competencies

Riverside has technical depth in several areas of machine learning, including signal and image recognition, adversarial AI, neuromorphic computing, and virtual and augmented reality. Our Optics and Photonics Lab has expertise in RF signal detection and characterization. We research and develop prototypes and integrate them into systems for land, sea, air, space, and cyber domain operations. Several examples of this work are briefly described below.

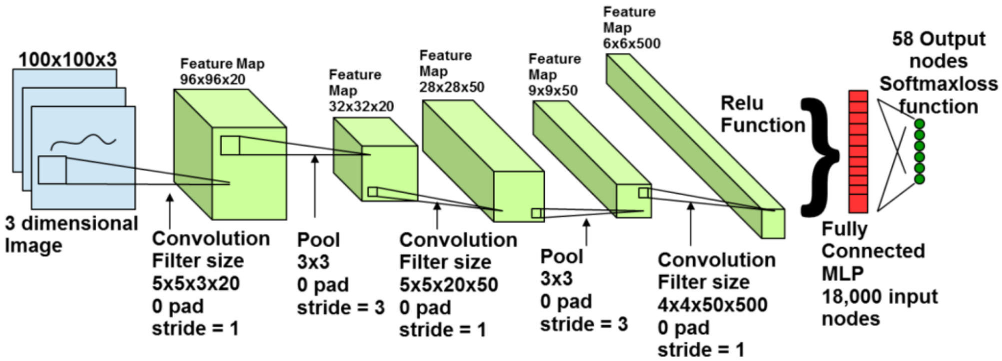
Machine Learning

Advanced image and signal detection, tracking, and classification

Riverside Research provided machine learning support for the classification of maritime radar emitters. In a recently published[1] effort we achieved a 98.7% classification accuracy across a testing set of 58 unique emitters. To achieve this, we performed data pre-processing to create input images that are ingested into a convolutional neural network (CNN), with the output of this CNN being input to a Multi-Layer Perceptron (MLP) to combine additional data obtained from the pulse descriptor words (PDWs). The figure below provides a visual representation of this network. Additional feature engineering work has allowed us to push towards a 99.8% classification accuracy with

[1] Cain, L., Clark, J., Pauls, E., Ausdenmoore, B., Clouse, R., & Josue, T. (2018, January). Convolutional neural networks for radar emitter classification. In *2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)* (pp. 79-83). IEEE.

traditional ML-based techniques. Application of neuromorphic techniques provided a means to explore an ability to de-interleave signals while also performing classification.



Cognitive and neuromorphic computing architectures, e.g., spiking neural networks

Riverside performs basic and applied research on neuromorphic computing, ranging from algorithm development to hardware implementation. For example, we use neuromorphic techniques to locate and classify moving objects. A neuromorphic camera captures movement in a sequence of “events” (activated pixels in an array). ML algorithms decompose the set of events into distinct objects, which we track and classify by type. A neuromorphic implementation of the RF anomaly detector would have very low size, weight, power and cost (SWaP-C), and offer an ideal solution for mobile applications in protecting staff members communicating in the field.

Adversarial AI and AI Protection

Attackers respond to machine learning detection tools by attempting to deceive them with disguised inputs. We are researching ways to counter such efforts using complex variables, the natural domain for signal processing. The effort involves training neural networks over complex numbers and creating adversarial examples for those networks. As ML-based anomaly detectors become operational, adversaries will attempt to defeat them, and adversarial AI can help protect the detector algorithms from these attacks.

RF Signals

RF signal Characterization

Riverside Research houses a wide array of RF probes and sensors for near-field and far-field characterization of RF signals. Our suite of commercial tools includes COTS systems such as Riscure, Beehive, Langer and custom-developed antennas for spread spectrum applications. We also use RF probe arrays to successfully acquire spatio-temporal RF images and holograms.

We created an RF signature library to correlate digital operations and instructions across various embedded, IOT and communication devices. We also developed an automated signal search and ID protocol to identify signals of interest in a congested/cluttered RF environment.

Riverside Research has established a framework[2] to implement cognitive radios using custom-developed and open source cognitive architectures. The framework employs a biophysically-inspired approach to allow the development of RF-based communication systems to process information in order to develop an agile platform to detect unknown or unexpected signals of interest and perform analysis for rapid feature extraction and identification.

Software Defined Radio

Riverside Research has two USRP-2945 radios with external clock synchronization that provide a total of 8 channels of input with a frequency range of 10 MHz to 6 GHz. The maximum instantaneous real-time bandwidth is 80 MHz, with a maximum I/Q sample rate of 100 MS/s. We used this hardware in a research project that involved capturing signals and computing their Angle of Arrival in a single, compact sensor. Although we are not authorized to publicly release the name of our customer for this effort, the hardware is available for use in the SCISRS program, if needed.

In addition, we are currently running another relevant project using low-cost Bluetooth sensors in an indoor environment to geolocate transmitters using RF signal characteristics. Our processing uses a mix of traditional techniques and machine learning, and we demonstrated high accuracy of locating transmitters in our laboratory.

Other

The AI/ML Lab also has other research focus areas that may be relevant to SCISRS:

- Deep Learning
    - Primarily applied to object detection, classification
- Over the Horizon Radar
    - Ability to segment specific layers of the ionogram for analysis
- Decision Aid/Support
- Next-Generation Sensor Algorithms
    - Integration of multiple sensor phenomenologies for enhanced data interrogation
- Genetic Algorithms for 3rd Generation Network Design
    - Designed to be platform agnostic (Loihi, TrueNorth, Akida, etc)
- Application of Virtual and Augmented Reality for AI/ML

3. Personnel

Our AI and ML Lab has a variety of scientists and engineers, including 19+ staff, consisting of 5 PhDs (+3 in Progress), 6 MS (+2 in Progress), 8 BS in facilities in OH, NY, MA, and DC; Our Optics and Photonics Lab has 15+ staff members, including 7 PhDs, 3 Masters, 5 BS in OH; and our Trusted and Resilient Systems Lab has 6 staff members, including 3 PhDs (+1 in progress), 2 MS, 1 BS in OH.

[2] Graham, J., & Fisher, A. (2018, December). Using Attention to Process RF for Cognitive Radio. In *2018 IEEE International Symposium on Signal Processing and Information Technology (ISSPIT)* (pp. 052-057). IEEE.

4. State-of-the-Art Equipment and Computing Systems

Machine Learning. Current hardware setup includes:

- NVidia DGX-1
  - 8x V100 GPUs
  - 20 core Intel Xeon E5-2698 @ 2.2 GHz
- 2x Lambda Workstations
  - 4x RTX 2080 GPUs per
  - 10 core Intel Core i9 @ 3.7 GHz per
- 1x Lambda Workstation
  - 4x Titan V GPUs
  - 10 core Intel Core i9 @ 3.7 GHz
- 30 TB of high bandwidth network attached storage (NAS)
- Additional Hardware
  - Acquiring Intel Loihi chip and Brainchip Akida processor
  - Multiple COTS edge devices, FPGAs, and small board computers (i.e.: Jetson Nano, Raspberry PI)

RF Signal Characterization. Our 800 square foot optics facility has laboratory instrumentation for prototype sensor fabrication, and testing and characterization of integrated, micro-, nano- and embedded systems, including data collection and signal processing capabilities. Three core capabilities are available to satisfy the needs of the IARPA SCISRS program: (1) Calibration of RF sources using a novel RF testbed consisting of commercial and custom developed RF and electro-optic RF probes (DC-20 GHz) providing broadband, high resolution noise and background characterization, (2) RF emission signature library for over 200+ IOT, embedded and other electronic devices and (3) an optical RF technology for adaptive spread-spectrum applications.

Equipment available to support this effort include broadband (DC-50 GHz) oscilloscopes, digitizers, network analyzers, waveform generators, COTS and GOTS RF single point probes as well as multi-sensor arrays.

5. Desired Teaming Expertise

Riverside Research has state-of-the-art capabilities in the key areas needed to support the IARPA SCISRS program, including advanced machine learning algorithms and techniques and RF signal classification. We seek to partner with other teammates that offer complementary capabilities, particularly experience and expertise in the various classes of RF signals germane to SCISRS program interests, including overt signals, anomalous signals and transmissions, and unintended RF emissions. Experience with these types of signals will complement our previous performance in this area. We anticipate using a variety of novel data collection and analysis techniques in the IARPA SCISRS program and especially welcome discussion of algorithms that can deal with non-stationary targets and domains.