Artificial Intelligence-Enhanced Radar Detection and Classification

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ABSTRACT

Recent work in autonomous vehicle navigation has driven research into artificial intelligence (Ai) processing for radar and lidar, primarily from moving platforms in relatively constrained environments. Building on computer vision research, Huntington Ingalls Industries (HII) created an Ai signal processing system for its Findr™ radar system to automate, accelerate, and augment entity detection and characterization. Findr is a human-portable, battery-powered Doppler radar system that can sense through foliage, walls, and other obstructions to detect and track targets. With Ai-generated classifications, users can more easily understand and control the behavior of the system— adding entity classification labels and allowing a user to specify which entities should be tracked and which can safely be ignored.

I. INTRODUCTION

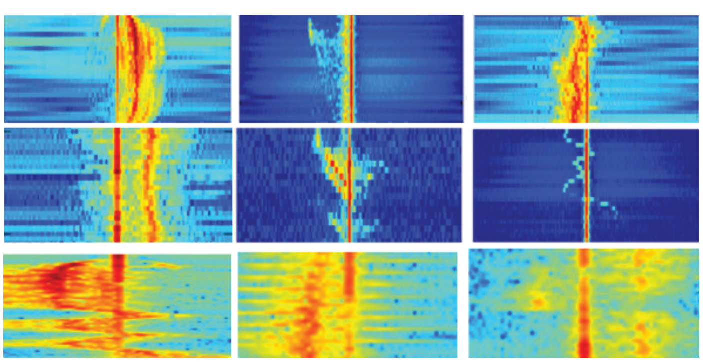
Since 2012, deep learning has come to dominate the field of computer vision. The availability of high-quality datasets of photographs and computer-generated visual images has facilitated this explosive growth; however, significantly less research has examined other forms of sensor post-processing.

Recent work in autonomous vehicle navigation has driven some research into Ai processing for radar and lidar, primarily from moving platforms in relatively constrained environments (e.g., roads). Systems that support situational awareness focus on discerning objects of concern in the field of view. Highly capable detectors can generate regions of interests in images and, at the same time, classify objects quickly. In radar applications, images can be generated in different forms and shapes to make Ai-based classification networks more robust.

II. PROBLEM OVERVIEW

Traditional radars pose two different, but equally limiting, challenges for users. The first is size. While powerful, traditional radars are large and require somewhat laborious processes to mount and disassemble, which can reduce both portability and speed of operation. Today's users need radars that optimize size, weight, and power (SWaP). The second challenge is that, as radars capture more data, users need to identify and accurately classify a variety of disparate, changing entities into useful and actionable information in line with their missions.

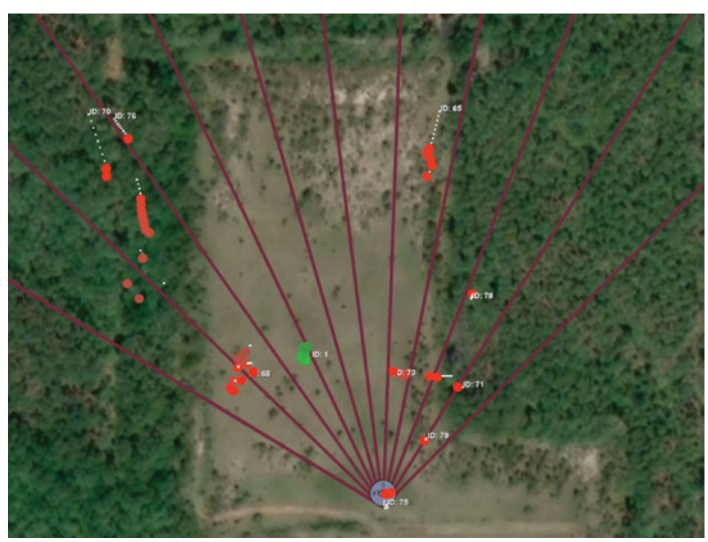
FIGURE 1: *Examples of Doppler representations for various classes, representing both human and non-human targets*



The features visible in Doppler radar data (Figure 1) reflect a combination of noise, ground clutter — present in every time bin — and backscatter from moving objects that is spread and distorted by multipathing from structures or other urban features. Typically, users are presented with track data (Figure 2) and have no way to identify which moving entities are which.

Traditional signal processors struggle to discern these signatures and apply the appropriate threshold to hide or suppress clutter or unwanted signals. Doing so in real time is especially difficult, since the data contain information both about the nature of the entity and about

FIGURE 2: *An example of output visualization as seen by the operator*



its activity during observation. Those indicators must be disentangled to make accurate identifications.

At the same time, traditional signal processing techniques struggle with the complexity of the data and entity signatures involved—particularly when operating in real-time. For instance, the contrast and scene complexity in radar imagery depend on many aspects, including the relative location of the radar and orientation of its face to a structure through which it is looking. Similarly, radar tracks for a given entity contain both instantaneous and temporal signatures. To understand what the entity is, the system needs information about both how it looks in a given scan and how it has moved over time.

Developing and testing traditional signal processing techniques to extract these signatures for each of the wide array of entities that may cross the radar's field of view would take significant effort—even assuming that the signatures were sufficiently distinguishable within the set of transformations produced by traditional techniques, which is far from guaranteed on problems in novel domains.

III. PROPOSED SOLUTION

Building on computer vision research, HII created an Ai signal processing system for its Findr™ radar to automate, accelerate, and augment entity detection and characterization. Findr is a human-portable, battery-powered Doppler radar system that can sense through foliage, walls, and other obstructions to detect and track animals, people, vehicles, or other moving objects.

HII engineers developed and tested a methodology for implementing Ai processing of Findr data to allow real-time, high-quality entity detection and categorization. The system builds on the state of the art in computer vision, adapting open source algorithms to the mathematical properties of radar data and enabling different approaches to be rapidly tested and trained to optimize performance across an array of use cases. While far from exhaustive, examples of those use cases are outlined in Figure 3.

PROBLEM	FINDR™ CAPABILITY
Human Safety & Security	The ability to detect and quickly classify human movement — even at night and behind obstructions — is critical to security of law enforcement personnel engaged in standoffs or negotiations. By extension, the system can also locate lost or missing persons as well as ensure the field is clear for outdoor ranges or other tactical exercises.
Wildlife Behavior Tracking	Findr's ability to see through foliage and (with Ai assistance) compensate for complex urban or suburban environments means it can be used for animal monitoring and control. Similarly, in rural or park environments, the ability to categorize detected animals enables automated, remote analysis of their activities and interactions.
UAV Traffic Management	As increasing numbers of remotely-piloted and autonomous aircraft take to the air in and around populated places, Findr can help track their activities in support of deconfliction. The ability to individually carry and rapidly deploy a cost-effective system like Findr provides a level of flexibility appropriate to the urban airspaces of the future.

FIGURE 3: *Examples of use cases for which Findr's Ai-enabled classification, obstruction penetration, and lightweight portability are ideal*

The system leverages traditional Doppler radar tracking to detect targets, then enhances their classification via Ai post-processing. Like the systems used in most deep learning computer vision research, Findr includes convolutional layers in its neural network, to take advantage of their ability to find entities' signatures regardless of the signatures' location in the sensor image. Detected entities are tracked in real time and classified within seconds, with data sent to the controlling computer via a wired or wireless link.

The temporal evolution of a given track is a useful factor in its classification. For instance, the speed of an entity's motion (Doppler) is helpful in identifying it. The neural networks used to process Findr data expand seamlessly to include temporal factors via a recurrent network architecture — a network that remembers the evolution of the data and uses that evolution to support its predictions.

User requirements drove key design decisions for Findr. For example, while HII engineers determined that Ai models can detect entity tracks in the data, traditional tracking methods are effective and more directly explainable — and, therefore, more easily trusted — than state-of-the-art Ai techniques. At the same time, the traditional tracker helps create the datasets on which HII engineers train the Ai techniques, decreasing the human effort required to produce a labeled dataset appropriate for training.

As a consequence, users can more easily understand the situation by adding Ai-generated entity classification labels (e.g., human, dog, bat). They can also better control the behavior of the system by specifying which entities should be tracked and which can safely be ignored. With this ability, users can move from data to decisions faster than with traditional techniques.

IV. PATH FORWARD

Successful tests of the system have demonstrated its efficacy on an array of use cases. Depending on user requirements, additional enhancements may be of interest:

- In cases where classification speed is critical and latency of a few seconds is too slow, the Ai could be paired with another Ai system to predict Doppler returns in advance, reducing time to insight while increasing accuracy.

- Experiments with training a neural network to distinguish between areas of the sensor image that contain moving entities — and areas that do not — showed that step can be integrated into an all-Ai system, with the trade-off that such a detection and tracking system is less straightforwardly understood by users than traditional methods.

- To further optimize SWaP, along with latency, specialized applications of Findr could employ field-programmable gate arrays (FPGAs) rather than GPUs for the neural networks — using HII's extensive experience with FPGAs to deploy the systems effectively.

Additional training data in a broader variety of field conditions can improve the robustness and precision of the Ai classifier, particularly in specialized use cases such as distinguishing the species of animal or physical characteristics of a person being observed by the system.

V. SUMMARY

Through extensive expertise in traditional engineering as well as new capabilities in Ai, HII has created a novel way to process and classify information from radars more accurately while easing the burdens on humans in the field. This technology will continue to evolve and expand, as new use cases are identified and additional classes are taught to the Ai system.

HII is applying Ai to help the DoD and other government agencies augment human performance and realize massive efficiencies in developing and operating current and future systems. Using Ai tools and techniques, our teams help clients develop more effectively, build more robustly, manage more precisely, make decisions more quickly, and sustain more efficiently. We envision seamless human-Ai teams as the standard in future operations, and we are helping build the foundations to make that possible.

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Learn more at tsd.huntingtoningalls.com/ai