SAND2024-09207C

Sandia National Laboratories

ARTIFICIAL INTELLIGENCE APPLIED TO RADAR

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Overview: Artificial Intelligence (AI) and in particular Machine Learning (ML) has been applied across virtually all scientific disciplines, in some cases with extraordinary results. My assignment this summer was to investigate the relationship between radar sensing and AI and provide a resource to managers and radar specialists. I wrote an in-depth report including an annotated bibliography surveying the field. I learned *where ML techniques have solved problems* in radar, *where there is promise* that more research could prove beneficial, and *where substantial barriers stand in the way* of further application.

Manager: Laura McNamara
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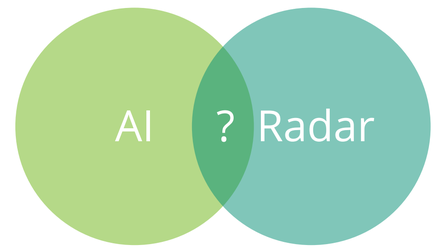


Key Questions:

- *How* are ML techniques being used throughout the radar lifecycle?
- *What* ML techniques are being used?
- What are the *strengths* and *weaknesses* of the ML techniques?
- *What is required* to make effective use of ML methods?
- *What are the risks* and how can they be managed?

Summary of Findings:

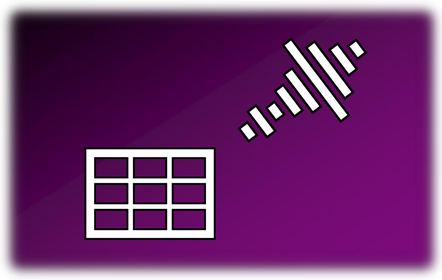
- AI/ML is being adopted in many new areas of radar, including but not limited to the three areas below.
- Significant issues:
  - Lack of training data
  - Interference and noise
  - Interpretability and robustness

Types of AI Algorithms:

- **Neural Networks (NN):** Input is passed through layers of "Neurons", parametrized by weights, ending with an output layer. Often weights are determined by optimization over a training dataset.
  - **Convolutional (CNN):** NN with layers that scan or "convolve" over images, used for 2D data.
  - **Recurrent (RNN):** NN with layers that have "memory" of previous output. Used for variable length inputs like speech or handwriting.
- **Reinforcement Learning (RL):** Methods used to train an agent to take actions based on rewards.
- **Genetic Algorithms (GA):** Methods based on natural selection to optimize solutions over a search space.

Antenna Optimization:

Designing antennas requires fine tuning many different parameters to fit the design specifications. ML algorithms have made strides in finding optimal parameters from large configuration spaces, often reducing the need for expensive simulations. **Neural Networks** and **Genetic Algorithms** are among the most common algorithms used.

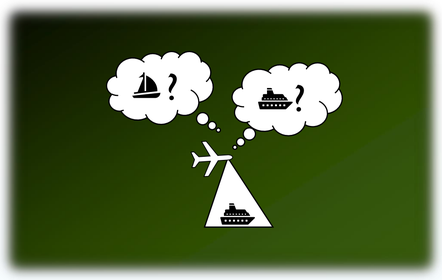


Waveform Design:

Choosing a waveform to transmit is an important design choice for any radar system. Particularly when communication systems and radar systems must share the same spectrum band, interference and noise become problematic. **Recurrent Neural Networks** and **Reinforcement Learning** show promise in this area.

Automatic Target Recognition (ATR):

ATR uses Synthetic Aperture Radar (SAR) images to identify targets of interest. **Convolutional Neural Networks** have shown to be useful for object identification in natural images, and can be similarly applied to SAR Images. However lack of large datasets, noisy images, and identification of previously unseen targets remain difficulties unique to this area and are active fields of research.



Joe Geisz has a B.S. and M.S. in Applied Mathematics from the University of Colorado. He worked 3 years for the U.S. Geological Survey applying ML to questions in aquatic ecology. He is currently a PhD student at Colorado State University studying Mathematics.

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