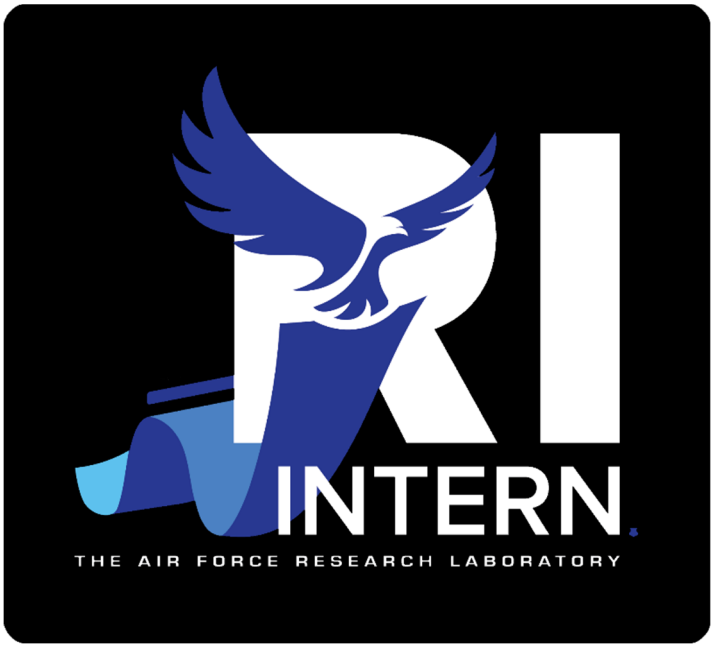

2024 RI Summer Internship Program

Research Topics

2024 RI Summer Internship Program Research Project Topics

The mission of the RI Intern Program is:

- *Cultivate and develop future research scientists and engineers in Command, Control, Communications, Computers, Intelligence (C4I) and Cyber Technologies.*
- *Provide mentor-led projects to assist the mentor and empower the intern to discover, develop, and expand their professional talents.*
- *Recruitment of talented and motivated students for summer internships and co-op positions.*
- *Expand the Interns skillset through Enrichment Sessions, advocate graduating interns as potential hires, and facilitate a buddy system to stay connected with the interns.*

The projects on the following pages detail potential opportunities for internship at the AFRL Information Directorate for summer 2024. Please review the projects and preferred skills of each project, and feel free to email any questions to intern@griffissinstitute.org. Please reference the name of the project when asking questions.

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2024 RI Summer Internship Program- Research Project Topics

Intelligence Systems Division (RIE)

Dark Saber - Air Force Web Development Platform

Dark Saber is a Software Engineering Ecosystem across the USAF that brings together innovators and developers to create next-generation software capabilities to modernize the USAF. Our mission is to create an ecosystem of airmen that are equipped to develop and deploy operational capabilities for the intelligence community at a rapid pace. To date, our group has 8 web applications developed and deployed that airmen across the Air Force are using daily to manage their information. We support over 500 users across our platforms and span across the globe for our user-base.

Tasks:

As part of the team, you'll be integrated into our team of web-developers to learn full-stack web-development. Following an initial training for the first 2-3 weeks, you'll be given a task working on one of our application ideas that will be supporting a group of airmen somewhere across the globe.

Skills Preferred Include:

This task requires some background knowledge in Javascript and web development. You'll be using ReactJS to perform development tied to an ExpressJS API to connect to a database. Please be comfortable with programming concepts and fundamentals along with web technologies.

Dataset Quality Metric for Object Detection Tasks

Investigating simulated data as a solution to the data limitation problem is valuable to the Air Force due to its potential to save time, be cost efficient, and generate more robust data. Despite the growing trend to dedicate money and resources to produce synthetic data via simulated environments, it remains undetermined if training algorithms on simulated data is an operational advantage to the Air Force. This research topic will develop a dataset quality metric such that a high-scoring dataset correlates to a high likelihood of obtaining high performing object detection model trained on it. This topic is particularly interested in exploring and evaluating the quality of simulated data, the effect of photorealism on model performance, the diversity and representativeness of the dataset needed to improve model reliability and resiliency, the transfer learning algorithms on simulated data, algorithms for determining the ideal composition of simulated and real-world data for a user case, and algorithms for guiding edge case development for improving model robustness.

Tasks:

- Literature review.
- Object detection model training and evaluation.
- Dataset quality metric development and evaluation.

Skills Preferred Include:

Familiarity with Python, machine learning/deep learning, and object detection techniques.

Feature Extractor for Overhead Images

ResNet, VGG, Inception, and AlexNet are some of the popular models that researchers used as image feature extractors. However, these models are usually pre-trained on ImageNet, which is not in an overhead perspective. Some researchers have fine-tuned these models on overhead imagery. Nevertheless, the attributes such as: Scale, rotation, and viewpoint invariance; Spatial invariance; Scene/background/context information understanding; Adaptability and transferability; Computation resource efficiency need to be thoroughly studied and further improved. This research topic focuses on developing a state-of-the-art feature extractor for overhead images with these attributes. Some research areas of interest include but are not limited to unsupervised and self-supervised representation learning, such as contrastive learning models, deep clustering, CLIP model, manifold learning techniques, and zero-shot learners.

Tasks:

- Literature review on object detection and feature extractors.
- Compare and contrast the existing feature extractors.
- Implement the proposal feature extractor for our dataset quality metric.

Skills Preferred Include:

- Working knowledge of computer programming, optimization, and mathematics.
- Familiarity with Python, machine learning/deep learning, and object detection techniques.
- A background in unsupervised and self-supervised representation learning, such as contrastive learning models.

Satellite Light Curve Analysis Data Extraction

Light curves are a graph that shows an object's brightness over time. It has been shown that a space object's attitude, shape, material, and other surface parameters are observable via the object's light curve. It is advantageous to know this information about spacecraft to gain Space Domain Awareness giving indications of an advisory's spacecraft mission, as well as giving indications and warnings left of an event. There have been several techniques implemented on light curves for feature detection including Kalman filtering, wavelet analysis, FFTs, and change point detection. Our goal is to utilize in-house light curve simulation fused with real light curve data to identify new and innovative ways for extracting features out of these light curves. This could include using machine learning techniques, such as Neural networks or physical informed neural networks, or it could involve other mathematical analysis, such as wavelet analysis, for feature detection.

Tasks:

- Utilize in-house BRDF simulation tool to simulate light curve models.
- Learn how to ingest EOSSA files and plot light curve data.
- Perform wavelet and FFT analysis on light curves for feature extraction.
- Research other techniques for feature detection and attempt to implement machine learning or other techniques on light curves.

Skills Preferred Include:

- Knowledge in Matlab, python or other scripting language

Desired Background:

- Aerospace Engineering
- Computer Science
- Physics
- Mathematics
- Astronomy

CAD Modeling and Development of Space Surveillance Telescopes

To maintain a complete knowledge of the population of objects in space, each object must be routinely observed to allow their orbits to be determined and updated. Observation and tracking rely primarily on ground-based sensors, including radar and electro-optical sensors such as telescopes. The most common method by which Geostationary satellites are tracked is optically – i.e., through telescopes. The objective of this topic is to utilize a previously developed library of CAD models as well as an onside 3D printer to develop function physical models of observation sides and various commercial-off-the-shelf telescopes 3D printed. An Arduino controller as well as other mechanical components will be utilized to automate various aspects of the models, including but not limited to having the telescope tilt and rotate to a desired azimuth and elevation. A raspberry pi will be implemented to control the Arduino. Software and hardware integration will be a primary part of this project.

Tasks:

- Go through the CAD library and identify a set of objects to be printed.
- Modify models for printability and for modularity.
- Print model using on side 3D printer.
- Identify appropriate scales so components fit appropriately.
- Design support equipment for motor mounts.
- Program Arduino for model control
- Design GUI

Skills Preferred Include:

Knowledge of CAD modeling

Multiple Criteria Recommender System for High-Value Targets

The Tactics, Techniques, and Procedures (TTPs) guiding the use of Intelligence Surveillance Reconnaissance (ISR) sensors by the Air Force (USAF) are insufficient to achieve moving-target engagement at scale in highly contested environments (HCEs). A challenge preventing the realization of moving target engagement at scale is that Moving Target Indicator (MTI) trackers do not have the ability to automatically orchestrate sensors to focus solely on high-value targets (HVT). In a HCE, HVT priority will not be static because of changes in sensor availability/integrity and will require target reprioritization. Due to shortened timelines, this is not feasible manually. The focus of this topic is to help implement a novel multi-criteria recommender system that can suggest HVTs and learn user ranking preferences in the face of dynamic and adaptive data sources using sources within (IMINT, radar, ELINT) and outside the sensing grid.

Tasks:

- Familiarizing with reinforcement learning, modeling and simulation tools, and ISR data sources
- Development of techniques, methodologies, or algorithms to support a multi-criteria recommender system for HVTs.
- Evaluation of algorithms and machine learning models against simulation data

Skills Preferred Include:

The project will require proficiency in Python and familiarity with Machine learning concepts. Knowledge of modeling and simulation is preferred but not required.

Implementation of an Intuitive Augmented Reality User Interface for Data Interaction

The Three-Dimensional LiDAR Information Visualization and Exploitation (3DLIVE) project aims to create a new system of interaction with 3D point cloud data (primarily LiDAR collects). A major component of the 3DLIVE project is an Augmented Reality (AR) interaction system that would allow to select precise points and measure distances on point cloud data within an intuitive three-dimensional space projected onto the real world. Such a system requires an easy to use and intuitive user interface (UI) that allows the user to select options to switch interaction modes as well as control the way the data and metadata is displayed. An intuitive AR UI would be displayed in front of the user in the augmented world, following either the user's gaze or hand. There would be a main menu with buttons that can be pushed with a finger to lead to submenus for interaction modes, metadata, measurement info, and point display options. Every button, input box, and radial/slider would be easily visible and interactable by the user and would include easily interpretable visuals alongside text descriptions. The 3DLIVE project is made using the Unity game engine, so the UI would also be designed within this engine (likely utilizing the Mixed Reality Toolkit Unity Plugin).

Tasks:

- Brainstorming an idea for an Augmented Reality User Interface meeting the 3DLIVE project's requirements for interaction with point cloud data.
- Implementing the proposed design within the project using the Unity game engine.
- Developing a user interface for data visualization and interaction.
- Developing a use case to test the model.

Skills Preferred Include:

- Knowledge of UI design and the C# programming language.
- Knowledge of Unity and modeling engine as Blender.
- These topics can be learned during the internship.

Phantom Arrow War Game

Phantom Arrow is an AFRL Information Directorate volunteer wargaming team that seeks to improve scientists and engineers' ability to reason about their technologies in an operational/warfighting context. We do this by using a commercial off the shelf board game, Persian Incursion, with AFRL/RI tech concepts integrated into the gameplay. Ongoing intern software development efforts aim to digitize the game. The objective of this is two-fold: First, we want to move the game away from the current Iran versus Israel scenario of Persian Incursion to a more generic blue versus red peer competition scenario. Second, we want to make tech concept integration easier and more objective by adding more non-kinetic facets to the scenario on top of the existing airstrike focused and political components of the original game. Currently the team is focused on work with the Air Strike Process and Networking Development.

Tasks:

- Getting familiar with the Phantom Arrow War Game, Unity Game Engine, C# programming, and Git.
- Continuing the current work with the Air Strike Process, which includes designing and implementing the process to allow for autonomous adjudication, as well as working to get this process on the game's current server.

- Continuing current work with Network/Backend Development. This includes implementing more of the base game mechanics into the current digitized game server and implementing a database in SQL to save data of the game while it's being played.
- Documenting work done.

Skills Preferred Include:

Basic knowledge/experience with C# or object-oriented programming, SQL, Unity, and Git. These skills are preferred, but not necessary.

Advanced Analytics and Exploitation of Space Situational Awareness Data

Space Situational Awareness requires always maintaining knowledge of all activities in the space domain. As space becomes more congested, it is necessary to collect more data for space object tracking and characterization. This results in large volumes of disparate data from a variety of sources. As such, automated tools are needed to process this data. Specifically, we seek to develop methods to autonomously identify and characterize space-based threats. These may be physics-based algorithms such as maneuver detection methods and conjunction prediction and assessment methods, as well as machine learning methods to identify complex patterns-of-life for space objects. The focus of this topic is to develop or improve methodologies to detect, track, and identify space objects, identify and assess threats, characterize and assess the impact of events, and evaluate courses of action for response.

Tasks:

- Familiarize the intern with satellite motion, orbital dynamics, and space data sources.
- Development of techniques, methodologies, or algorithms to support Space Situational Awareness goals to be determined by candidate experience, background, and research interests.
- Application of work to and evaluation against real-world data and scenarios

Skills Preferred Include:

- Working knowledge of physics, familiarity with satellite motion
- Programming experience in relevant language (e.g., MATLAB, Python) or proficiency in tool such as STK or AFSIM

Cislunar Space Situational Awareness

Cislunar space is the region of space that expands pass the Geosynchronous Orbit (GEO) region to a region within the moon orbit. In this region of space Keplerian orbital mechanics start to break apart and three body effects account for the earth and moon’s gravity need to be considered. Normal orbital propagations start to break down in this region and it is advantageous to have orbit propagators that can be utilized in this region of space. The purpose of this internship is to investigate problems in the Cislunar region of space including developing tools for cislunar orbital propagation. Including orbits in lunar orbit (LLO), frozen orbits, near-rectilinear halos orbit (NRHO), distant retrograde orbit (DRO) and other types of cislunar orbits. The focus of this topic is to develop or improve methodologies to detect, track, and identify space objects in Cislunar space, identify and assess threats, characterize and assess the impact of events, and evaluate courses of action for response.

Tasks:

- Familiarize the intern with satellite motion, orbital dynamics, and space data sources.
- Development of techniques, methodologies, or algorithms to support Space Situational Awareness goals to be determined by candidate experience, background, and research interests.
- Application of work to and evaluation against real-world data and scenarios

Skills Preferred Include:

- Working knowledge of physics, familiarity with satellite motion
- Programming experience in relevant language (e.g., MATLAB, Python) or proficiency in tool such as STK or AFSIM Desired Background: Aerospace Engineering, Computer Science, Physics, Mathematics, Astronomy

Large Language Models for Generating Nation State Propaganda

Question Answering (QA) has become a real capability due to recent advancements and availability of Large Language Models (LLMs) such as OpenAI's GPT4, Meta's LLaMa, Google's Bard, and others. Typically, QA is evaluated on passages with clear and concise factoid answers covering the Who, What, Where, and When. Conversely, few resources exist for getting at argumentative types of passages that cover the Why and the How. Processing argumentative passages is important for detecting misinformation related to COVID, nation state propaganda, and other areas. There are various persuasion techniques that can be utilized when making an argument. For example, SemEval 2023 Task 3 "Detecting the Genre, the Framing, and the Persuasion Techniques in Online News in a Multi-lingual Setup" covers 23 separate techniques. However, there is class-imbalance and poor inter-annotator agreement for many techniques.

Tasks:

Explore prompt engineering and fine tuning of recent LLMs for generating argumentative types of passages related to nation state propaganda. Given a nation state, a persuasion technique, and corresponding Diplomatic, Information, Military, and Economic (DIME) dimension the LLM is supposed to generate examples and reasoning with humans in the loop review. We aim to generate at least a couple dozen examples for each DIME dimension and each persuasion technique.

Skills Preferred Include:

Proficiency in Python and access and familiarity with LLMs

Short-Arc Initial Orbit Determination for Low Earth Orbit Targets

When new objects are discovered or lost objects rediscovered in Low Earth Orbit (LEO), very short arcs are obtained due to limited pass durations and geometrical constraints. This results in a wide range of feasible orbit solutions that may well-approximate the measurements. Addition of a second tracklet obtained a short time later – about a quarter of the orbit period or more – leads to substantially improved orbit estimates. However, the orbit estimates obtained from performing traditional Initial Orbit Determination (IOD) methods on these tracklets are often insufficient to reacquire the object from a different sensor a short time later, resulting in an inability to gain custody of the object. Existing research in this area has applied admissible regions and multi-hypothesis tracking to constrain the solutions and evaluate candidate orbits. These methods have been primarily applied to Medium Earth Orbit and Geostationary Orbit and have aimed to decrease the total uncertainty in the orbit states. The objective of this topic is to research and develop methods to minimize propagated measurement uncertainty for LEO objects at future times, as opposed to minimizing the orbit state uncertainty over the observed tracklet. This will improve the ability to reacquire the object over the course of the following orbit or orbits to form another tracklet, which will result in substantially better orbit solutions. Sensor tasking approaches which maximize the likelihood of re-acquisition are also of interest.

Tasks:

- Familiarizing with classical orbit determination methods
- Simulating satellite orbits, maneuvers, and ground observations

- Formulation and testing of propagation models and sensor tasking to optimize probability of re-acquisition.

Skills Preferred Include:

Knowledge of orbital dynamics, familiarity with optimization and programming experience in relevant language (e.g., MATLAB, Python).

Automated Characterization of Satellite Rendezvous and Proximity Operations

Space Situational Awareness requires always maintaining knowledge of all activities in the space domain. As space becomes increasingly congested, automated methods to characterize and identify satellite motion are needed. One area of interest is that of satellites engaging in proximity operations, where one or more satellites are moving relative to a target. This effort seeks to develop methods to automatically process spacecraft orbit data and categorize relative motion based on pre-defined classes. Criteria will be sought by which motion classes can be distinctly identified, and an algorithm will be implemented to classify motion. Different algorithms may be developed and tested, including but not limited to decision trees, multiple-hypothesis methods, and conceptual spaces.

Tasks:

- Familiarizing with satellite proximity operations modeling, including Hill Frame coordinates and Clohessy-Wiltshire equations.
- Simulating satellite proximity operations and maneuvers.
- Definition of unique criteria that define different motion classes.
- Development of an algorithm or algorithms that categorize proximity operations based on said criteria.

Skills Preferred Include:

- Knowledge of orbital dynamics
- Programming experience in relevant language (e.g., MATLAB, Python)

Multi-source Analytics for Conversational Intelligence (MACI)

The Multi-source Analytics for Conversational Intelligence (MACI) program aims to deliver an AF Conversational Artificial Intelligence (CAI) baseline that improves the state-of-the-art for multi-domain natural language understanding and multi-task dialogue state-tracking. AF CAI can be leveraged to measurably reduce analyst workflow and increase the speed and efficiency it takes analysts of any skill level to solve common Requests for Information (RFIs). In recent months, Large Language Models (LLMs) have become increasingly popular across the AI community. MACI explores using LLMs as the primary conversational agent to connect to disparate data service and APIs across the AF enterprise.

Tasks:

As part of the team, you'll be integrated into our mixed government in-house and contractor team working on enhancing our existing LLMs, creating user-interfaces for end-users, and supporting the design of experiments with Air Force analysts interacting with our conversational system.

Skills Preferred Include:

This task requires some background knowledge in Natural Language Processing and Machine Learning. Knowing Python is a must. In addition, familiarity with API development and database design is important for system integration.

Information Exploitation and Operations (RIG)

Counter Small Unmanned Aircraft Systems (C-sUAS) and UAS Traffic Management (UTM)

The AFRL/RI C-sUAS team is comprised of a unique combination of program managers, cybersecurity specialists, hardware/software engineers, UAS flight testing operators, and UAS Traffic Management (UTM) subject matter experts. This combination of individuals allows them to tackle a wide spectrum of topics including: Basic and applied research involving Commercial Off-the-shelf (COTS) Small Unmanned Aircraft System (sUAS), Radio Frequency (RF) Command and Control (C2) link exploitation (i.e., RF Cyber), sUAS detection/tracking/identification and defeat capability development, UTM capability development for ensuring the safe operation of UAS within the National Airspace System (NAS), Application of Artificial Intelligence (AI) and Human-Machine Teaming (HMT) to speed up decision making to assist C-sUAS and UTM Operators in executing their missions, Machine learning (ML) and AI to support sensor fusion, target validation, and false alarm suppression, Multi-vehicle coordination, control, and exploitation (i.e., swarm and counter-swarm), High speed vehicle tracking and maneuvering for sUAS interceptor technologies.

Tasks:

Typical summer tasks may include: C2 protocol analysis, C-sUAS capability development, wireless and RF analysis, AI/ML/HMT programming and algorithm development, sUAS design and configuration, and UTM capability development. Tasks will involve working with various sUAS and counter-sUAS technologies including RF sensors, cameras, radars, etc.

Skills Preferred Include:

Proficiency in AI/ML algorithm development, protocol analysis, experience with software defined radios (SDRs), C-sUAS and UTM knowledge, commercial sUAS autopilot knowledge (i.e., PX4/ArduPilot), embedded systems experience (i.e., Raspberry PI, nVidia Jetson, Arduino, etc.), cybersecurity, software/hardware engineering. Relevant programming languages include Python and C++.

ORION (Open-architecture Resilient IoT for Operational Networks)

AFRL/RI is leading ORION, an Internet of Things (IoT) focused effort, located in the Innovare Advancement Center (IAC). ORION will host a device and infrastructure test and evaluation environment that will provide security, interoperability, resilience, and data governance opportunities for AFRL/RI and other stakeholders with IoT interest. The objective of this project is to equip the next generation of IoT cyber systems engineers with the fundamental skills required to reason effectively about the design, security, and the resiliency of IoT systems. The focus is on understanding foundational architectural concepts, and in developing proficiency with the technology stacks that underly IoT devices and dependent systems.

Tasks:

The goal of the summer project is to design and implement a robust prototype solution for a specific IoT system. Tasks include: 1. Construct the (Device) Hardware. 2. Develop the code (called the driver) that runs locally on the RPi to manage the electronic components that implement the functionality of the device. 3. Develop a serverless code function and deploy to the Azure Cloud as a FaaS (function-as-a-service) to monitor and process temperature and humidity conditions remotely and initiate automated actions/ 4. Provide real-time visualizations using an Azure Cloud-host (PaaS) web application, and a custom Power Bi dashboard.

Skills Preferred Include:

- Experience (proficiency) with programming languages such as C++, C#, .Net, Java, and Python. Basic familiarity using and developing on both Linux and Windows systems.
- Foundational understanding of wireless networking communication/connectivity protocols used for IoT including basic TCP/IP, MQTT, LoRaWAN etc.
- Basic understanding of Cloud service models is helpful (IaaS, PaaS, SaaS models) for Microsoft Azure and/or Amazon AWS clouds.
- Familiarity with existing IoT/Smart device/sensors (i.e., cameras, weather stations) and a good understanding of how to access sensors contained in a smart phone are also desired.

Resilient and Secure Computing on Untrusted Clouds (RESCU Clouds)

The AFRL/RI Resilient & Secure Computing on Untrusted Clouds (RESCU Clouds) program keeps close collaboration ties with highly skilled students, professors, engineers, and researchers from academia and industry to conduct different basic and applied research projects. The peculiar diversity of talents working with and cooperating under RESCU Clouds investigate, design, and implement novel methodologies to securely and efficiently outsource data and distribute computations across heterogeneous hostile computing environments and untrusted Cloud Service Providers (CSPs).

Tasks:

The research topics of interest focus on zero trust security and include, but are not limited to, (1) decentralized identity and access control mechanisms and protocols, including those that support anonymity. (2) Novel application of existing cryptographic primitives and protocols to zero-trust computing paradigms. (3) Design cross-cloud, CSP-independent, privacy-aware protocols and frameworks that operate in the presence of emerging zero-trust security mechanisms. (4) Enable secure and transparent migration of application and data across heterogeneous CSPs and facilitate multi-objective optimization in the security-mission trade space. (5) End-to-end data protection, concurrency and consistency for multi-user multi-cloud environments.

Skills Preferred Include:

Skills Preferred Include: Proficiency in one or more programming languages. Knowledge of one or more of the following topics: Machine Learning (ML), data analytics, cryptography, cloud computing, and blockchain.

Investigations into Tools for the Probability Distribution Divergence Landscape

Establish a clear understanding and benefits of the alpha-beta divergence as compared to standard divergence method(s) (e.g., Kullback-Leibler). Develop a robust and extensible. (2) Acquire analysis tools (Python implementations) of relevant probability comparison tools. (3) Assessment of probability divergence methods in controlled and real-world scenarios. (4) Dissemination of Knowledge gained and advanced in this field.

Tasks:

Approach: (1) Perform literature and research journal reviews on the alpha-beta divergence. (2) Develop a robust and extensible Python implementation of each. (3) Perform comparison study of the two methods: a. against simulation data of known, controllable distribution types. b. against real world data sets. These are to be determined but will be either audio data or infrared imagery data. (4) Periodic reporting of progress and results. (5) Presentation of work at for RIG Colleagues

Skills Preferred Include:

Senior or graduate student level in computer science, mathematics, physics, and/or engineering is required. The selected student must have skills in computer science, mathematics, and programming.

Secure Containers

Containers and container orchestration technology are becoming more popular due to the performance benefits, portability, and the ability to leverage them in many different environments/architectures. However, security remains the barrier to widespread adoption in operational environments. The container threat model is headlined with the lack of high assurance and weak security isolation properties. As cloud and microservice architecture expansion continues, the assurance of container security has become a requirement.

Tasks:

Intern will be involved with answering research questions, developing proof of concept architectures, tools, and environments as well as examining the use of container technology in various use-cases and environments such as the cloud, microservices, and embedded devices. One specific task will involve analyzing the bare minimum kernel services required to deploy and run a container.

Skills Preferred Include:

Adept understanding of computer science concepts. Any experience using popular container engines and management systems such as Docker and Kubernetes are a plus. Experience with kernel and microkernel development is also a plus.

Information Systems (RIS)

Compositional Optimization

Optimization problems are ubiquitous in DoD applications. Each problem has a collection of choices to make and some criteria which express which choices are best. In this work we consider various theoretical mechanisms by which optimization problems may be made "open", meaning that certain choices are exposed as an interface to the rest of the world, allowing for the composition of optimization problems by interaction of their interfaces. The applications of open optimization problems include routing problems, optimal control, machine learning, and more. As an example, a swarm of quadcopters may naturally have a single optimization problem per quadcopter, perhaps to reach some destination subject to constraints. These problems compose by way of the quadcopters' positions in a global coordinate system, which make a larger optimization problem that has, for example, non-trivial safety constraints induced by the shared space in which the quadcopters operate.

Tasks:

Students will be asked to read and digest research papers, consider motivating applications, and synthesize understanding of problems and techniques into formalisms which allow for rigorous

characterization of open optimization problems and their compositions. They may also be asked to build implementations in cutting edge software libraries.

Skills Preferred Include:

Strong foundation in both analysis (particularly convex) as well as algebra (particularly linear) AND/OR a background in combinatorics, and ideally a passing familiarity with category theory. Previous experience with the Julia metaprogramming is also desirable.

Resilient Distributed Optimization and Learning

In many military applications, large volumes of heterogeneous streaming data are needed to be collected by a team of autonomous agents which then collaboratively explore a complex and cluttered environment to accomplish various types of missions, including decision making, optimization and learning. In order to successfully and reliably perform these operations in uncertain and unfriendly environments, novel concepts and methodologies are needed to 1) analyze the resiliency of algorithms, and 2) maintain the capability to reliably deliver information and perform desired operations. This research topic will develop resilient distributed optimization and learning algorithms in the presence of • Abrupt changes in the inter-agent communication network, • Asynchronous communications and computations, • Adversarial cyber-attacks capable of introducing untrustworthy information into the communication network. Some distributed methods of interest in this topic include, but are not limited to weighted-averaging, push-sum, push-pull, stochastic gradient descent, and multi-armed bandits.

Tasks:

- Familiarizing with distributed algorithms for optimization and learning.
- Development of techniques, methodologies, or algorithms to analyze the resilience of distributed algorithms.
- Development of resilient distributed optimization and learning algorithms in the presence of abrupt changes in the inter-agent communication network, and asynchronous communications and computations.

Skills Preferred Include:

Strong background in mathematics. Proficiency in one or more programming languages. Familiarity with reinforcement learning and multi-agent systems.

Multi-Agent Planning Algorithms for Airlift Operations

Planning the delivery of cargo as part of an airlift operation is a notoriously complex problem. We recently held a public competition asking researchers to develop algorithms which can plan such operations while at the same time coping with disruptions (see https://airliftchallenge.com/ for more details). As part of this competition, we developed a Python simulator (with Open AI Gym or Petting Zoo interfaces) that provides a simulation of the airlift. We now seek to build on these efforts by developing new machine learning and reinforcement learning algorithms which can exceed the performance of existing state-of-the-practice algorithms.

Tasks:

Students will develop multi-agent planning algorithms using techniques from machine learning (e.g., deep neural networks or graph neural networks). These solutions will be tested against our simulation environment and hold potential to improve future Air Force operations.

Skills Preferred Include:

Python, Deep Learning / Machine Learning / Reinforcement Learning, Linux, git

Explainable RI

RL represents a groundbreaking technology with the ability to perform long-term decision-making in complex and dynamic domains at a level surpassing human capability [1]. Leveraging this capability holds immense strategic significance for the United States Department of Defense (DoD), given that RL-enabled systems have the potential to outperform even the most exceptional human minds in a wide range of tasks [2]. Its adoption in high-risk real-world domains like military applications has been limited due to the challenges associated with explaining RL agent decisions and establishing user trust in these agents, despite remarkable improvements. For instance, while the AI AlphaStar competes against highly skilled StarCraft 2 players, comprehending its inner workings necessitates extensive and impractical empirical investigations [3]. This substantial and inhibitory constraint arises because current Explainable Reinforcement Learning (XRL) methods inadequately address the fact that autonomous decision-making agents can alter future data observations through their actions and effectively reason about long-term objectives aligned with the agent's mission. Therefore, it is imperative to develop effective XRL approaches that overcome these limitations to unlock the widespread utilization of RL's capabilities. Therefore, we seek to have proposals that would adhere to effective and efficient models for XRL, which will be used for the US Air Force’s direct operational use.

References:

[1] V. Mnih, K. Kavukcuoglu, D. Silver, A. A. Rusu, J. Veness, M. G. Bellemare, A. Graves, M. Riedmiller, A. K. Fidjeland, G. Ostrovski and S. Petersen, "Human-level control through deep reinforcement learning," Nature, vol. 518, pp. 529-533, 2015, February

[2] "THE NATIONAL ARTIFICIAL INTELLIGENCE RESEARCH AND DEVELOPMENT STRATEGIC PLAN: 2019 UPDATE https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf," A Report by the SELECT COMMITTEE ON ARTIFICIAL INTELLIGENCE of the NATIONAL SCIENCE & TECHNOLOGY COUNCIL, 2019, JUNE.

Tasks:

Need someone very knowledgeable with Reinforcement learning, Machine learning, and Data Science

Skills Preferred Include:

Proficient at Pytorch, Python, C++

Small Unmanned Aircraft Systems – UAS NEXT

Under the umbrella of the AFRL/RI Assured Base Operations team, the UAS Next project leverages cutting edge, consumer based, small UAS technology to revolutionize base defense. The team is comprised of a unique combination of program managers, cybersecurity specialists, hardware/software engineers, UAS flight testing operators, and AI/ML application experts. This combination of individuals allows them to tackle a wide spectrum of topics including:

- Applied research such as Commercial Off-the-shelf (COTS) electronics.
- Small Unmanned Aircraft System (sUAS)
- Command and Control (C2) link development and integration
- Computer vision applications – object detection, recognition, tracking
- Personal computer application development – Team Awareness Kit, app plugin development and testing

Summer interns would be attached to a small team focusing in one or several of these areas. They would be immersed in an iterative testing environment with the various opportunities for hands on engineering, troubleshooting, coding, and testing. Their involvement in these areas would promote brainstorming and development of real-world technical skills, allowing the student to implement guided solutions to operational problems.

Tasks:

Typical summer tasks may include: C2 protocol analysis, sUAS test pilot, AI/ML

programming and algorithm development for computer vision, RF analysis for sUAS C2 links, and application development.

Skills Preferred Include:

AI/ML/Computer Vision experience, Android app development, familiarity with electromagnetic spectrum concepts, hand-eye coordination

CBRN (Chemical, Biological, Radiological, Nuclear) Integration & Networking

CBRN (Chemical, Biological, Radiological, Nuclear) is a sector of research which serves both the military and law enforcements communities around the world. CBRN is primarily used for chemical, biological, radiological, and nuclear detection, but it is also utilized by the EOD (Explosives Ordinance Detection) units. Coordination of CBERN response efforts across different agencies and jurisdictions may need to be considered. The primary objective of CBRN research is to provide prompt response times and near-real time sensor data to provide situational awareness to end users. Data fusion from multiple sources must be effectively sanitized to a centralized location. In recent years, there has been a growing interest in integrating many of these tools into networks to ensure accurate situational awareness. The overall goal is to provide the best sensor readings in real time to ensure that CBRN team members have the capabilities to respond and protect their communities.

Typical summer project will include working on developing and improving CBRN systems; integrating sensors into a larger application; testing development and obtaining end user feedback; attending meetings with CBRN communities to grow and obtain a larger knowledge base. Machine learning techniques may be used to improve accuracy and run time of current systems. Other ML use cases may include developing models for CBRN detection from sensor data, predicting the spread of CBRN hazards, or identifying patterns in CBRN attacks.

Tasks:

- Analyze and evaluate current CBRN systems.
- Collect and interpret end user feedback.
- Conduct current sensor efficiency tests and propose improvements.
- Integrate CBRN sensors into larger applications.

Skills Preferred Include:

- Strong programming skills in Python or Java
- Experience with sensor data processing
- Good problem-solving and analytical skills
- Excellent communication and teamwork skills
- Additional skills that may be useful but not necessary:
- App development background
- Knowledge of CBRN materials and sensor measurements
- Experience conducting field testing.

Indoor Geolocation

Development of GPS began in the 1950s and was originally developed for military purposes, but it was eventually made available for civilian use. GPS is used in a wide variety of applications, including

navigation, mapping, tracking, and surveying. In recent years, there has been a growing interest in indoor geolocation. Indoor geolocation is the ability to determine the location of a device or person indoors. This is a more challenging problem than outdoor geolocation, as there are fewer signals available to use. However, there are several technologies that can be used for indoor geolocation, including Wi-Fi, Bluetooth, and RFID.

Indoor geolocation has a wide range of potential applications. It can be used to track the movement of people and objects in buildings, to provide wayfinding assistance, and numerous others. It is also being used in healthcare, retail, and manufacturing.

A typical summer project will include working on developing and improving indoor geolocation systems. This may include using machine learning techniques to extract location information from sensor data, such as WiFi signals, Bluetooth beacons, and RFID tags. Extension of work may include developing algorithms to track the movement of people and objects indoors. ML techniques may be implemented to improve accuracy and robustness. Additional areas of research and development may include work on designing and implementing the data collection and processing pipelines and analyzing and evaluating the performance of the system.

Tasks:

- Develop and improve machine learning algorithms for indoor geolocation.
- Design and implement data collection and processing pipelines.
- Analyze and evaluate the performance of indoor geolocation systems.
- Work with other engineers to integrate indoor geolocation systems into larger applications.

Skills Preferred Include:
:

- Strong programming skills in Python or Java
- Experience with machine learning
- Experience with data mining and statistical analysis
- Experience with sensor data processing
- Good problem-solving and analytical skills
- Excellent communication and teamwork skills
- Additional skills that may be useful but not necessary:
- App development background
- Mobile optimization
- Knowledge of wireless networking
- Experience with computer vision
- Experience with 3D modeling and visualization
- Familiarity with cloud computing platforms.

Automated Site Defense

The development of automated military site defense systems has been a topic of research for many years. Early systems were based on simple rule-based algorithms, but recent advances in machine learning have made it possible to develop more sophisticated systems that can learn to detect and identify threats in real time. One of the earliest automated military site defense systems was the Semi-Automatic Ground Environment (SAGE) system, which was developed in the United States in the 1950s. The SAGE system used radar and computers to track and identify aircraft, and it could automatically direct interceptor aircraft to intercept hostile aircraft. In the 1980s, the United States developed the Patriot missile system, which is an automated air defense system that can detect, track, and intercept incoming missiles. In recent years, there has been a growing interest in using ML techniques for automated military

site defense. ML algorithms can be trained to learn the patterns of different types of threats, and they can be used to detect and identify threats more accurately than traditional rule-based algorithms.

There are numerous research and development areas that need to be addressed in order to develop effective automated military site defense systems. One challenge is the need to collect and label large amounts of data for training the ML algorithms. Another challenge is the need to develop machine learning algorithms that can operate in real time and that are robust to false positives. ML algorithms can be used to develop systems that are more accurate, reliable, and efficient than traditional systems. A summer project will encapsulate a reasonable area to tackle in the given timeframe. The end goal of the internship will be to develop a basis for automated systems for defending military sites against potentially a variety of threats. The design of a scalable and modular solution will be explored to easily enable adaptation to different types of sites and threats. The solution will also be designed to be robust and reliable, so that it can operate in a variety of environments and conditions.

Tasks:

- Researching and developing machine learning algorithms for detecting and identifying threats
- Designing and implementing a system for integrating the machine learning algorithms into a real-time system
- Testing and evaluating the system's performance
- Documenting the system's design and implementation
- Integration of developed systems using existing TAK APIs

Skills Preferred Include:

- Strong programming skills in Python, Java, R, or other programming languages
- Experience with machine learning, and frameworks, such as, TensorFlow or PyTorch
- Experience with data science tools, such as NumPy and Pandas
- Experience with data mining and statistical analysis
- Experience with sensor data processing
- Good problem-solving and analytical skills
- Excellent communication and teamwork skills

Explainable Reinforcement Learning (XRL) for Command and Control (C2)

RL represents a groundbreaking technology with the ability to perform long-term decision-making in complex and dynamic domains at a level surpassing human capability [1]. Leveraging this capability holds immense strategic significance for the United States Department of Defense (DoD), given that RL-enabled systems have the potential to outperform even the most exceptional human minds in a wide range of tasks [2]. Its adoption in high-risk real-world domains like military applications has been limited due to the challenges associated with explaining RL agent decisions and establishing user trust in these agents, despite remarkable improvements. For instance, while the AI AlphaStar competes against highly skilled StarCraft 2 players, comprehending its inner workings necessitates extensive and impractical empirical investigations [3]. This substantial and inhibitory constraint arises because current Explainable Reinforcement Learning (XRL) methods inadequately address the fact that autonomous decision-making agents can alter future data observations through their actions and effectively reason about long-term objectives aligned with the agent's mission. Therefore, it is imperative to develop effective XRL approaches that overcome these limitations to unlock the widespread utilization of RL's capabilities. Therefore, we seek talented interns to work to make an effective and efficient model for XRL, which will be used for the US Air Force’s direct operational use.

Tasks:

- Design, develop and test code/software for explainable deep reinforcement learning (XDRL) in OpenAI/Gym environment.
- Work extensively and communicate effectively with the team about the problem to debug any issues.
- Perform frequent iterations of design, development, integration of software components, testing and getting feedback from advisor about the results and improve upon them.

Skills Preferred Include:

- Must have a good level of expertise in pytorch, python, C++ to pick up tasks quickly.
- Preferably, the ideal candidate should have some work experience with machine learning algorithms and possibly, a publication in the subject area.
- Excellent attention to detail.

References:

[1] V. Mnih, K. Kavukcuoglu, D. Silver, A. A. Rusu, J. Veness, M. G. Bellemare, A. Graves, M. Riedmiller, A. K. Fidjeland, G. Ostrovski and S. Petersen, "Human-level control through deep reinforcement learning," *Nature,* vol. 518, pp. 529-533, 2015, February

[2] "THE NATIONAL ARTIFICIAL INTELLIGENCE RESEARCH AND DEVELOPMENT STRATEGIC PLAN: 2019 UPDATE https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf," A Report by the SELECT COMMITTEE ON ARTIFICIAL INTELLIGENCE of the NATIONAL SCIENCE & TECHNOLOGY COUNCIL, 2019, JUNE.

[3] O. Vinyals, I. Babuschkin, W. M. Czarnecki, M. Mathieu, A. Dudzik, J. Chung, R. Powell, T. Ewalds, P. Geogiev and J. Oh, "Grandmaster level in StarCraft II using multi-agent reinforcement learning," *Nature https://www.nature.com/articles/s41586-019-1724-z,* vol. 575(7782), pp. 305-354, 2019.

Computing and Communications (RIT)

Assurance of Software Systems

The AFRL/RITA Automating Assurance in Embedded Systems group is composed of computer scientists and engineers that tackle research challenges in the areas of scalable formal methods; model-based engineering and validation; compositional verification techniques for resilience; and automation for abstraction validation, and synthesis. These research topics support security, resilience, and reliability in modern software development processes (Agile, etc). Typical summer topics may include: extracting, developing and validating new models and tests for AI-enabled software security vulnerabilities; benchmarking performance and coverage of implemented tests and generation of algorithms and documentation; enabling trust by developing formal and static analysis approaches to systematically address vulnerabilities that might arise in AI-enabled systems across multiple contexts; or examine the Problem-definition context (e.g. modeling, quantifying, and analyzing threats), Solution definition context (secure development, (semi-)formal, static, and dynamic analysis for vulnerabilities), and Requirements context (trust assessment – was the correct system designed and built correctly) to reduce the introduction and/or exploitation of vulnerabilities in modern AI and AI-enabled systems.

Tasks:

Multiple projects available under this topic, all structured with continuous assessment of state-of-the-art, familiarization with the relevant open-source software, enhancement of the methodology, technique and/or tools, and analyzing and reporting results.

Skills Preferred Include:

Proficiency in software development languages (C/C++, Java, Python etc), applied mathematics and formal methods background (Theorem Proving, Satisfiability, Dempster-Schafer), and familiarity with

model-based design and related tools (AADL, SysML, etc.), knowledge of AI/ML principles, Familiarity with static analysis tools, fuzzers, symbolic execution, linux environments, Version control (GIT, etc.)

Enhancing Test for Assured Software

The AFRL/RITA Automating Assurance in Embedded Systems group is composed of computer scientists and engineers that tackle research challenges in the areas of scalable formal methods; model-based engineering and validation; compositional verification techniques for resilience; and automation for abstraction validation, and synthesis. These research topics support security, resilience, and reliability in modern software development processes (Agile, etc). Typical summer topics may include developing theories of quantification and/or calculus of testing, model analysis including traceability to requirements, and software development/programing. State of the art techniques for machine learning and automation are used to pursue solutions for developing and verifying learning-enabled autonomous systems.

Tasks:

Multiple projects available under this topic, all structured with continuous assessment of state-of-the-art, familiarization with the relevant open-source software, enhancement of the methodology, technique and/or tools, and analyzing and reporting results.

Skills Preferred Include:

Proficiency in software development languages (C/C++, Java, etc), applied mathematics and formal methods background (Theorem Proving, Satisfiability), and familiarity with model-based design and related tools (AADL, SysML, etc.), knowledge of AI/ML principles, Familiarity with linux environments, Version control (GIT, etc).

Quantum Information Sciences: Quantum Algorithms

The Quantum Information Sciences branch (AFRL/RITQ) performs cutting-edge experimental and theoretical research in a wide range of topics at the frontiers of quantum computing and quantum networking. With a unique interdisciplinary team composed of physicists, engineers, mathematicians, technicians, and computer scientists, RITQ has numerous active research efforts in quantum algorithms and leading quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum devices.

Tasks:

The Quantum Algorithms team tackles understanding, characterization and exploration of commercially available quantum hardware systems. Application spaces of algorithm development include graph theory optimization and quantum machine learning. Typical summer projects may include programming on a commercially available quantum hardware platform, quantum simulations, software analysis, and algorithmic development.

Skills Preferred Include:

Mathematics or Physics background and familiarity with Python or a Quantum Language

Quantum Information Systems: Trapped Ion Systems

The Quantum Information Sciences branch (AFRL/RITQ) performs cutting-edge experimental and theoretical research in a wide range of topics at the frontiers of quantum computing and quantum networking. With a unique interdisciplinary team composed of physicists, engineers, mathematicians, technicians, and computer scientists, RITQ has numerous active research efforts in quantum algorithms and leading quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum devices.

Tasks:

The trapped ion team focuses on implementing trapped ion systems using barium 133 and/or ytterbium 171. These isotopes have a combination of properties that make them perform particularly well as a qubit. Past summer projects contributed to the effort at a variety of levels and include a wide range of topics. Examples include: the investigation of a new material for optics mounting, the development of electrical and mechanical ion trap demonstrations, the construction of key pieces of control electronics, and the creation of new versions of existing lab tools at new wavelengths.

Skills Preferred Include:

Physics or engineering background. Useful (but not required) skills include experimental design and setup, electronic/circuit design and assembly, mechanical design/CAD, programming (for example python, matlab, or Mathematica).

Quantum Information Sciences: Integrated Quantum Photonics

The Quantum Information Sciences branch (AFRL/RITQ) performs cutting-edge experimental and theoretical research in a wide range of topics at the frontiers of quantum computing and quantum networking. With a unique interdisciplinary team composed of physicists, engineers, mathematicians, technicians, and computer scientists, RITQ has numerous active research efforts in quantum algorithms and leading quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum devices.

Tasks:

The Integrated Quantum Photonics team centers on both the theoretical and experimental aspects of photon-based qubits. The team develops the technology to generate, manipulate, measure, and quantify entangled photons. Typical summer projects include the production and quantification of entangled photons, programming to automate test equipment, integrated photonic device modeling, and theoretical models for quantum transduction.

Skills Preferred Include:

Skills Preferred Include: Physics or engineering background, strong mathematics background, and a familiarity with python and c programming languages. Useful (but not required) skills include experimental design and setup.

Quantum Information Sciences: Superconducting Quantum Devices

The Quantum Information Sciences branch (AFRL/RITQ) performs cutting-edge experimental and theoretical research in a wide range of topics at the frontiers of quantum computing and quantum networking. With a unique interdisciplinary team composed of physicists, engineers, mathematicians, technicians, and computer scientists, RITQ has numerous active research efforts in quantum algorithms and leading quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum devices.

Tasks:

The superconducting team's research focuses on the investigation of new quantum devices, new qubit control and measurement techniques, and the exploration of fundamental physics relevant to quantum networking architectures, with an emphasis on hybrid superconducting systems – i.e., interfaces between superconducting quantum circuits and other leading quantum modalities, such as trapped-ions and quantum photonic circuitry. Typical summer projects may involve one or more of the following: numerical simulations; programming for data acquisition and data analysis applications; design and assembly of

laboratory hardware, including mechanical, electronic, and cryogenic components; and participation in quantum measurements.

Skills Preferred Include:

Skills Preferred Include: physics or engineering background; experimental design and setup; mechanical design/CAD; analog and digital circuit design; and python programming language.

Quantum Information Sciences: Theory

The Quantum Information Sciences branch (AFRL/RITQ) performs cutting-edge experimental and theoretical research in a wide range of topics at the frontiers of quantum computing and quantum networking. With a unique interdisciplinary team composed of physicists, engineers, mathematicians, technicians, and computer scientists, RITQ has numerous active research efforts in quantum algorithms and leading quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum devices.

Tasks:

The Quantum Theory team seeks to develop, analyze and advance research efforts across all disciplines, both theoretical and experimental, in the Quantum Information Sciences Branch. Typical summer projects may include but are not limited to: theoretical and numerical simulations of quantum interference effects, analysis and applications of coupled quantum devices, interactions of photons and matter qubits (trapped ions, superconducting qubits), analysis, geometric insight and applications of measures and control of entanglement, analysis/simulation of quantum networks, and entanglement of observers in arbitrary states of motion.

Skills Preferred Include:

Mathematics or Physics/Quantum background, and familiarity with Python and/or Mathematica or a Quantum Computing Language.

Quantum Information Sciences: Quantum Systems on an Unmanned Aerial System

The Quantum Information Sciences branch (AFRL/RITQ) performs cutting-edge experimental and theoretical research in a wide range of topics at the frontiers of quantum computing and quantum networking. With a unique interdisciplinary team composed of physicists, engineers, mathematicians, technicians, and computer scientists, RITQ has numerous active research efforts in quantum algorithms and leading quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum devices.

Tasks:

The Unmanned Aerial System (UAS) project focuses on demonstrating quantum systems in operation on a UAS. It combines expertise from across RITQ's core research efforts to work towards the demonstration of a mobile quantum memory. Examples of typical summer projects may include prototyping optical assemblies; testing and characterizing mechanical, environmental, and/or magnetic noise; constructing electronic circuits for experimental interfacing and control; programming experimental control components; and integrating, testing, and operating quantum systems for use on a UAS.

Skills Preferred Include:

Skills Preferred Include: Physics or engineering background. Useful (but not required) skills include experimental design and setup, electronic/circuit design and assembly, mechanical design/CAD, programming (for example python, MATLAB, or Mathematica).

Robust Deep Learning and Neuromorphic Hardware for Edge Computing

As a powerful component of future computing systems, deep neural networks (DNNs) are the next generation of artificial intelligence (AI) that explicitly emulate the neural structure and operation of the biological nervous system, representing the integration of neuroscience, computational architecture, circuitry, and algorithms. However, DNNs still have significant architectural limitations: (1) an inefficient processing pipeline for large-scale networks, (2) computationally expensive training methods that cannot keep up with increasing data density, and (3) improper network behavior and decreased accuracy due to anomalous or malicious input data.

Tasks:

The scope of this effort is to formulate the fundamental research to advance the understanding of neuroscience, facilitate the development of neuromorphic computing hardware and algorithms, and accelerate neuromorphic computing to an extreme efficiency. Specifically, this research focuses on: (1) building an efficient DNN on embedded development platforms to support edge-enabled applications, (2) improving learning algorithms to discover unknown objects with confidence, and (3) developing a working prototype of neuromorphic hardware with emerging circuitry and/or materials. Additional interest includes exploring robotic applications with respect to multimodal sensory information processed by DNNs and neuromorphic hardware.

Skills Preferred Include:

Potential students for algorithm development should have skills in Python and machine learning frameworks (e.g., TensorFlow and/or PyTorch). Students interested in hardware development and demo should have skills in microcontroller/FPGA and general familiarity with electronic circuit design.

HF Data Propagation Analysis

WSPRNet is a publicly available dataset going back to 2008 that is used for propagation forecasting/nowcasting by amateur radio operators. There is a dataset that is well in excess of 400GB of csv data spanning frequencies and amateur callsign operators across the globe. Additionally, sources of geomagnetic, ionospheric, and solar weather data exist through organizations such as NOAA. The goal of this effort will be to begin analyzing some of this data and use it as a baseline to conduct machine learning studies to try to create propagation predictions.

Tasks:

Using the datasets provided, develop a machine learning model (or models) to provide accurate predictive capabilities for ionospheric propagation. The goal will be full model development and conference presentation/publications and/or journal presentations/publications detailing the model and results from the research.

Skills Preferred Include:

Software/Computer Engineering/Computer Science background with experience in machine learning models in either MATLAB or Python

Nonconvex Optimization and Mathematical Foundations of Machine Learning

This research aims to further develop and formalize the mathematical and cognitive foundations of machine learning to provide rigorous analysis of generalization and robustness and to improve explainability of networks. Specifically, we will focus on the underlying optimization problems related to the design and training of ML models. Of particular interest is the design and development of models for multimodal and multitask machine learning. Optimization problems arising from applications are often inherently nonconvex and non-smooth. However, the tools used to study and solve these problems are

typically adopted from the classical domain. The purpose of this research is to develop accurate models and efficient algorithms which take advantage of useful structure or knowledge derived from the application in question and to build a theory of "benign" nonconvexity. Examples of this structure include sparsity, generalizations of convexity, and metric regularity. Some areas of interest are sparse optimization, image and signal processing, variational analysis, and mathematical foundations of machine learning.

Tasks:

Implementation of novel neural network architectures based on optimization algorithms; exploring design of explainable and robust features; empirical study of transfer and generalization; theoretical analysis of structured sparsity promoting functions for modeling applications.

Skills Preferred Include:

Experience with linear algebra, real analysis, and optimization preferred, familiarity with Matlab or Python.

Modular, Hierarchical Machine Learning

Typical AI/ML is monolithic. For example, a single artificial neural network (ANN) learns to classify every category of input data. Given multiple successful ANNs, there is not a simple way to combine or integrate them together to solve a new task. A new ANN must be trained to solve the new task (though some weight values may be used to seed the network). Just as digital logic provided a uniform information representation among analog sensors, reserach at AFRL is exploring high-dimensional vectors as a standard information representation for ANNs. Current research at AFRL is exploring the use of high-dimensional vectors to serve as a universal information framework allowing multiple ANNs to be arbitrarily configured. Research in this effort will focus on designing symbolic reasoning circuits, effectively using ANNs as sensors.

Tasks:

This research effort combines several different AI/ML approaches together, viz. hyperdimensional computing (HDC)/ vector symbolic architectures (VSA), cognitive map learners (CML), and reinforcement learning (RL). Reinforcement learning tasks will focus on sequential goal planning and path optimization (see MetaArcade, Mini-Grid World). Programming for either robot simulation or hardware demonstration will be based on Python (but Matlab will be an available alternative). Exceptional research results produced during internship will be prepared for publication in peer reviewed conference proceedings.

Skills Preferred Include:

Python (or Matlab) some background in AI/ML is great but not required.