Trusted Artificial Intelligence for Armaments in Uncertain Environments

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Executive Summary

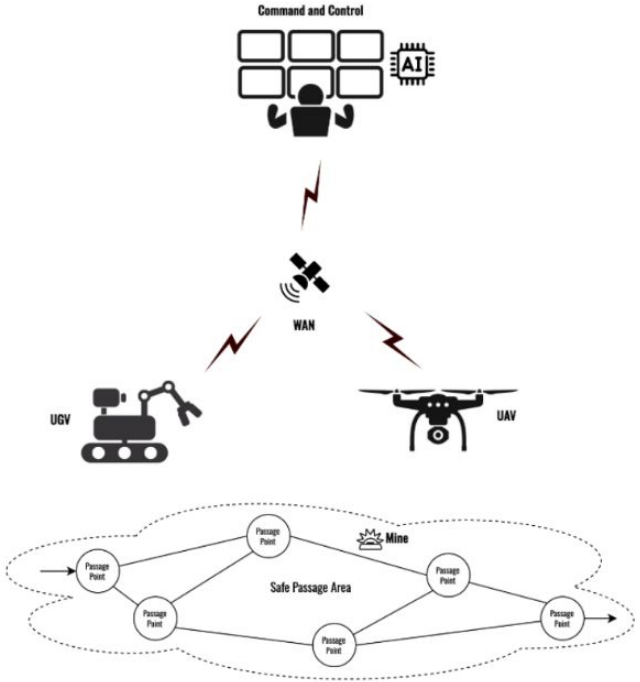
- Techniques to improve minefield traversal are introduced
  - Regression modeling to determine key factors in human and AI accuracy
  - Reinforcement learning methods to optimize UAV and UGV routing
  - Reliable system design to ensure warfighter trust
- Criteria for solution analysis are introduced and used to facilitate iterative design
  - These include human safety, traversal time, and accuracy variance
- Considerations for future project stages are explored

Challenge Introduction

- The integration of AI solutions is critical in maintaining high-performing, intelligent systems
- AI integration into military systems creates ethical challenges; human lives are on the line
- A reliable AI system functions as intended and performs well in high stress environments, developing trust amongst users

Problem

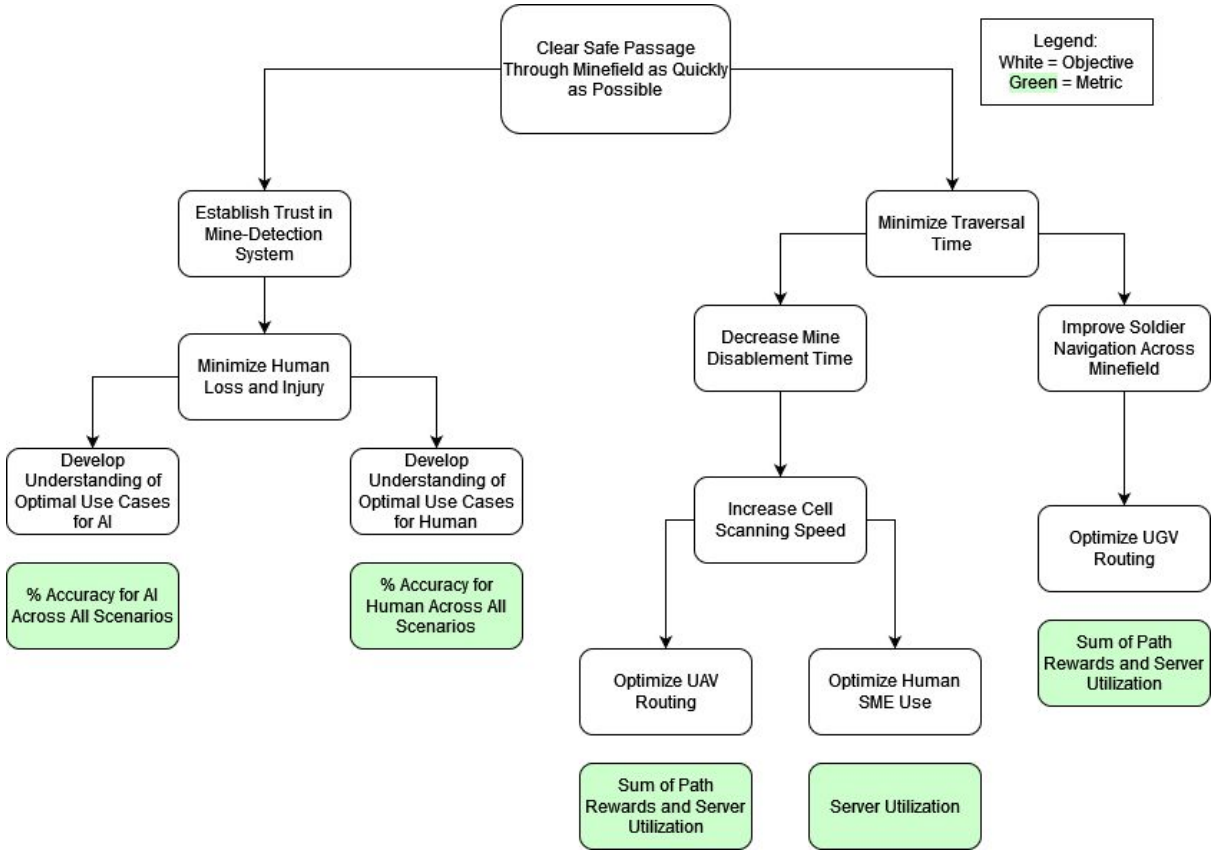
- How can safe passage through a minefield be achieved as quickly as possible while depending on unreliable subsystems?
- How can human trust in the AI mine-identification system be built?
    - Warfighter use of the system provides a competitive advantage on the battlefield



System Goals

- Clear safe passage through minefields as quickly as possible
  - Minimize Human Loss and Injury
  - Minimize Traversal Time
- Protect area assets and mission security
- Ensure trust and reliability in the AI mine-detection system
- Establish an overarching system that is more resilient than its subsystems

Objectives and Metrics for System Analysis



Criteria for Candidate Ranking

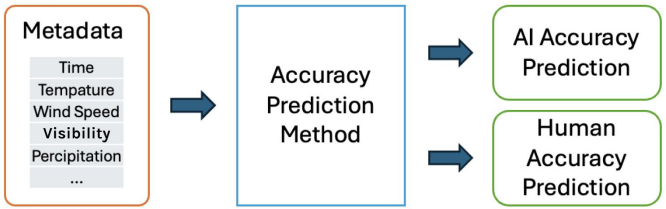
- Trust and reliability
- Traversal time
- Variability in solution performance across environmental conditions
  - Variation in confidence levels of detection accuracy
  - Performance in novel situations
- Resource utilization
  - What are the utilization rates of UAV, AI, human, UGV
    - Server utilization
    - Average number of processes occurring concurrently
- Monetary and time costs

Methods

- Accuracy Determination
  - Identifies environmental factors that are most influential in AI and Human mine-identification accuracy
  - Regression analysis, decision trees, random forests, neural networks
- UAV Routing
  - Optimizes UAV scanning path through full and partial observation of minefield
  - Formulation of a Markov Decision Process for use in a Reinforcement Learning model, Deep Q-Networks, Actor-Critic Methods
- UGV Routing
  - Optimizes UGV routing to minimize distance travelled and time spent
  - Routed based on path of UAV, Q-Learning, shortest path algorithms

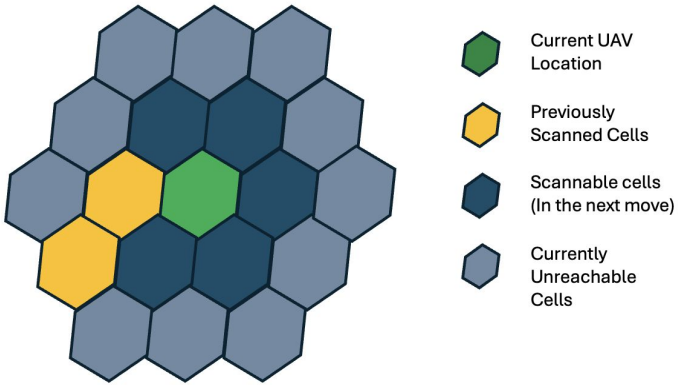
Accuracy Determination

- Analysis of environmental data to determine influential factors in Human and AI mine-detection accuracy
- Regression models can determine the marginal changes in accuracy due to changes in environmental factors
    - Struggles with non-linear relationships, high-dimensional data
- Decision trees, random forests, and neural networks can also identify influential factors
    - Perform better than regression models with large, complex datasets



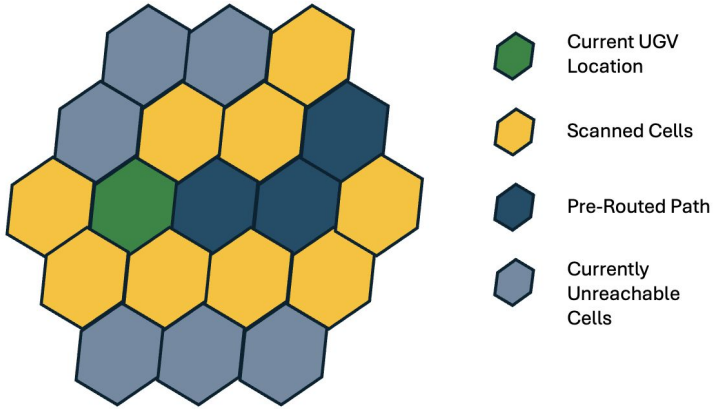
UAV Routing

- Optimization of UAV pathing to avoid unnecessary time costs and mine encounters
- A Markov Decision Process (MDP) can be developed for use in a Reinforcement Learning Model
  - MDP includes states, actions, and rewards
  - RL model finds optimal policy for MDP
- Partial and full map routing calculations can be synthesized
  - A full observation of the map allows for start to finish routing
  - A partial observation of the map allows for cell-to-cell routing based on adjacent cell conditions



UGV Routing

- Optimization of UGV pathing to travel along the shortest path
- UGV is treated as a secondary router; it follows the path determined by the UAV routing system
  - UGV could follow the path scanned by the UAV with the lowest probability of encountering a mine
- UGV utilizes a shortest-path algorithm such as A* to navigate along the shortest and lowest risk route



Future Considerations

- Scalability of system solutions to larger operations
  - Could future scenarios include multi-UAV or multi-UGV scenarios
  - Multiple warfighter battalions crossing the same minefield at once
    - Sharing of information between battalions, devices
- Identification of mines while troops/UGV have partially traversed a cell
  - Would it be faster to turn back around and take a different path?
- Physical limitations of UAV and UGV systems
  - In future stages, the UAV and UGV may not have infinite power supplies or ensured removal
- Effect on human and AI accuracy when images are sent over a WAN
  - A strategy to send some pictures back over a WAN before the UAV returns to the Command Center could improve traversal time

Future Plans and Actions

- Design regression and RL models
  - Additional data in the next stage will allow for more robust analysis of how system and AI behavior changes in different scenarios
- Perform testing and simulation to identify solution limitations
- Analyze how different algorithms perform on different subsets of data
- Test how solutions perform when the underlying situation changes