Optimization of ISR Collection Routes for Constellations of UASs using Weather effects on platform and infra-red sensor performance

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Workshop Focus: Tactical Decision Aids for Unmanned and Autonomous Vehicles

Relevant topic areas:
- Tools or processes that support tactical decisions in the operational environment
- Validation, verification, and confidence measures of performance predictions
- Use, design, and employment of numerical weather prediction models, to include ensemble modeling to support these models
- Ingest of local and remotely sensed observations
- Sensor developments in multi-spectral implementations in R&D, fusion and analysis
- Target and target scene models, to include buried objects and soil-covered targets
- User products and interfaces identifying problems and solutions in providing an appropriate support product
- The changing operational environment and customer base, including systems being emphasized or de-emphasized

ABSTRACT

Weather has a significant effect on the dependability, versatility, and effectiveness of the unmanned aerial systems (UAS) that provide intelligence, surveillance, and reconnaissance (ISR) over the battlefield. As larger constellations of heterogeneous, multi-purpose UAS are tasked to perform more diverse missions in unpredictable, dynamic environments, the ability to predict, understand, and proactively plan for adverse weather conditions will become a significant factor in their overall operational effectiveness.

Generating optimal collection plans for airborne ISR assets remains a challenging problem given the complexity of the search space, the number and variety of aircraft available to perform these missions, and the underlying geospatial data available. Not only does a collection plan have to satisfy multiple constraints (e.g., collision avoidance, limited flight endurance), but it must also meet numerous and often competing objectives, such as avoiding adverse weather effects on the UAS platforms, maximizing sensor performance through weather, and covering high priority named areas of interest (NAIs) in a timely fashion.
We have developed a tactical decision aid (TDA) called SPARTEN (Spatially Produced Airspace Routes from Tactical Evolved Networks) as part of the Army’s Geospatially Enabled Multimodal Situational Awareness (GEMS) program. This TDA generates coordinated mission plans for UAS constellations by allowing the mission planner to specify which objectives are important to them for each mission based on their specific tactical needs. Using a fast evolutionary algorithm-based, multi-objective optimization technique, we take into account a number of factors to generate optimal flight plans. Although we have formalized the computation of specific fitness values for each of ten distinct optimization objectives, we will only consider the adverse weather effects on the UAS platform and weather effects on infra-red sensor performance in this paper.

Our approach uses the a priori computation of local fitness values in time and space using cost factor maps that are attributed on the underlying air maneuver network (AMN). The AMN is a topological representation of the operational airspace containing a planar network whose nodes represent air control points and launch sites for UAS and are connected by edges. The AMN maintains topological and temporal reference frames to represent flyable air corridors and provides a data structure that lets the TDA treat continuous airspace as a discrete state space, where a valid route for any asset is an ordered list of edges. Each AMN edge carries a list of attributes relating to flight along that edge for each time interval such as sensor performance and weather effects. The attributes are calculated in advance, based on information such as weather forecasts.

The weather effects on the platform use a data feed from the Integrated Weather Effects Decision Aid (IWEDA) based on a weather forecast database for the specific area of analysis (AOA) and aircraft type. The sensor performance values use the same weather feed to make physics-based estimations of the probability of detection for the desired target types over time at each location in the AOA using considerations such as ground fog, precipitation and temperature difference between targets and the background terrain. ThermoAnalytics IR software, MuSES, is used to predict the target temperatures while the terrain dynamics are calculated using the land surface model developed at CRREL, FASST (Fast All-season soil STrength). MuSES uses MODTRAN to calculate transmission degradation between the platform and target due to atmospheric particles. FASST calculates the ground’s moisture, ice and vapor content, temperature, and freeze/thaw profiles, as well as soil strength and surface ice and snow accumulation/depletion. FASST’s fundamental operations are the calculation of an energy and water budget that quantifies both the flow of heat and moisture within the soil and also the exchange of heat and moisture at all interfaces (ground/air/snow/vegetation/trees) using both meteorological and terrain data. Thus the ISR routing solution is optimized over space and time to avoid inclement weather that may have a deleterious effect on the platform such as rim icing and turbulence, and optimize sensor placement to maximize the probability of detecting sought targets during a mission.

By employing novel visualization techniques using geographic information systems (GIS) to represent their effectiveness, we help the user ‘look under the hood’ of the algorithms and understand the viability and effectiveness of the mission plans to identify coverage gaps and other inefficiencies.

As more UAS are employed, the ISR collection routes that they fly must be better coordinated to maximize coverage effectiveness and to also take into account complex factors such as sensor performance for specific target types in different terrain and weather effects on the platform and sensor. For mission planners to develop confidence in these autonomous mission planning tools, the tools must demonstrate that they can reliably accomplish mission objectives by providing operators with a deep understanding of the capabilities and limitations of their UAS during varying mission scenarios.

Enclosure (OPSEC Approval Form)