NRI 3.0: Innovations in Integration of Robotics
COLLABORATIVE RESEARCH: NRI: Integration of Autonomous UAS in Wildland Fire Management

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Project URL: https://mae.osu.edu/laddcs/research

Scientific Goal: Integration of autonomous unmanned aerial systems (UAS) missions into prescribed wildland burn projects

Challenges

- Quantification of Unstructured Uncertainty: A broken environment presents hard to characterize probabilistic obstacles and *loads* that induce path-dependent resource constraints, e.g., heat loading, that make planning NP hard
- Lack of Trustworthy Environmental Situational Awareness: Multi-source data in a harsh environment is subject to interpretation (hot = fire or ash or hot shrubs?) and has a high conflict rate.
- Gusting Wind Conditions: Aviation weather data does not provide local, micro-level and short-range forecasts needed for reliable operations in a wildfire hazard, with potential for rapid escalation, e.g., firestorms.
- Impact of Environmental Uncertainty on Flight Certification: Impact on extended beyond visual line of sight (BVLOS) operations, communication delay and loss

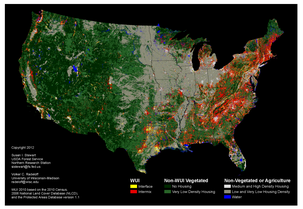
Technical Approach

- Build physics informed learning tools (e.g., iterative Koopman autoencoders) to learn local wind dynamics, and unsupervised clustering tools combined with evidential reasoning to create obstacle/load situational awareness (SA)
- SA information helps model trajectory planning with path-dependent integral chance-constraints, wherein UAS autonomously assumes mission-appropriate risk. Develop scalable graph search for this problem.
- Employ ultra-local disturbance observer models for nonlinearly stable and robust control of platform in hazard
- Conduct controlled wildfires (prescribed fires) and quantify fire severity, and measure and analyze the influence of forest attributes, land physiography, fuel composition and characterization, and weather conditions on fire behavior
- Quantify impact of environment on verification, validation and flight certification

Broader Societal Impact

STAKEHOLDERS

- Entire population living along the Wildland Urban Interface (WUI) in the Eastern United States
- Fire management and suppression units
- Participants in integration of UAS into maintenance of natural and man-made infrastructure. Examples: Ohio Department of Natural Resources, OH-DOT, Division of Forestry
- Applications involving unstructured phenomena & environments with poorly modeled dynamics or anomalous sensor interactions. Examples include space and cislunar domain awareness (S/CDA), surveillance tracking, and disaster response.



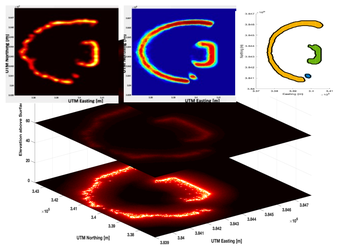
WUI Along the Eastern USA

Integrating Autonomous Platforms in Infrastructure Management

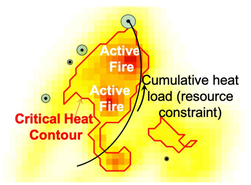
THE OHIO STATE UNIVERSITY · SYRACUSE · metro SCHOOLS

Scientific Impact

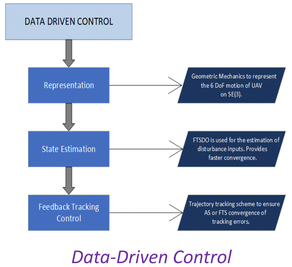
- This work impacts science of autonomy and multidisciplinary integration of aerial platforms in an unstructured, uncertain and dynamic hazardous environment.
- This project brings into focus the wildland urban interface (WUI) in the Eastern United States. This research will help discover how ecosystem composition (topography, weather etc.) and subsequent fuel loads affect fire behavior and provide avenues of fire mitigation in the future as climate change will lead to increased fires in the eastern USA and more extreme fire behavior.
- This project will create a framework for physics-informed learning from partial, noisy state observations, applicable to a broad range of prognostic applications, including short term, micro-level wind forecasting needed in this work
- Data-driven control schemes developed in this project will provide guaranteed stability and robustness in autonomous robotic operations with actuator constraints in an environment with unmodeled disturbances



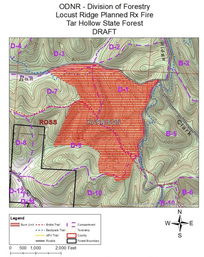
Unsupervised Clustering and Evidential Reasoning to Learn Obstacle and Loading Situational Awareness



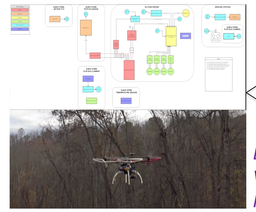
Resource Chance-Constrained Path Planning



Data-Driven Control

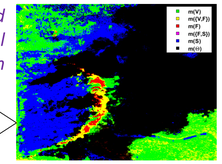


Controlled Burn Sites for Fall 2022



Environmental Impact on Verification, Validation and Flight Certification

Combining unsupervised clustering with evidential information fusion



Educational and Outreach Impact

- Engage K-12 teachers and students through curriculum development (short courses), summer events and internships
- Develop cross-disciplinary educational material that accentuates a constructive context for autonomous robotics
- Student led public awareness projects (podcasts) with partners like NPR

Engagement with Metro High Schools to Increase Student Participation in Autonomous Systems Research

Broader Impact

- Create scalable algorithms for solving resource constrained planning problems (gains in excess of 50X speed up over state of the art)
- Increase student participation in prescribed burn projects by 2X
- Improve wildfire propagation models in key metrics including flame length and rate of spread

2022 NRI & FRR Principal Investigators' Meeting
April 19-21, 2022

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