Autonomous Operations of Multi-UAV Uncrewed Aerial Systems using Onboard Sensing to Monitor and Track Natural Disaster Events

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https://aksanyal.expressions.syr.edu/research-videos/

This is an international collaborative project, in response to the US NSF and Indian DST joint call for proposals in August 2023.

Scientific Goal: Integration of autonomous uncrewed aerial systems (UAS) to monitor and track natural disaster events.

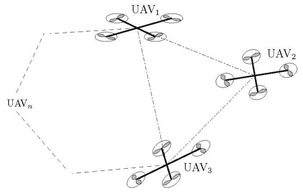
Introduction and Challenges

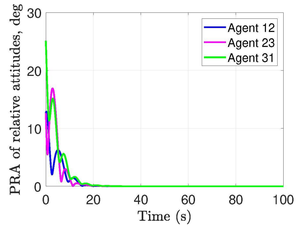
- Uncrewed aerial systems (UAS) to monitor and track natural disaster events like wildland fires and flooding water bodies
- UAS consisting of uncrewed aerial vehicles (UAVs) and ground station(s) providing real-time monitoring and tracking of unfolding disaster events, can help avoid large scale loss of lives/property
- Challenges include unstructured uncertainty, trustworthy environmental situational awareness, and flight certification

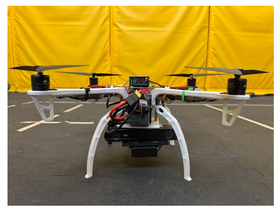
Technical Approach

- Each agent (UAV) in the UAS is modeled as an actuated rigid body (near right), making the UAS a multi-agent rigid body system (MARBS)
- Geometric controller and observer designs that are computationally light and implemented with commercially available sensors onboard rotorcraft UAVs (far right bottom)
- Sensor data from inertial and point cloud sensors like depth cameras processed by onboard GPU (far right top) to give state & disturbance estimates using a finite-time stable extended state observer (ESO) for active disturbance rejection control (ADRC) of UAVs
- For a MARBS with an undirected graph with unity edge weights, the attitude consensus control law for the *i*th rigid body agent is given by:

$$\tau_i = \quad -k_p \sum_{i \neq j} S_K(R_{ij}) - k_d \sum_{i \neq j} (\Omega_i - R_{ji}\Omega_j)$$







Scientific Impact

- Impacts to science of autonomy: multidisciplinary integration of aerial platforms in unstructured, uncertain, dynamic and hazardous environments
- New discoveries on impacts of topography, weather, vegetation and water bodies can provide better understanding and future preparedness for natural disasters
- Scalable solutions for onboard autonomous mission planning in unstructured uncertainty; creating an UAS that is certified for surveillance operations in disaster-strike areas

Broader Impact (on society)

Develop an understanding of how teams of autonomous UAVs could be used to maximize the data gathered and predict the intensity and spread of forest fires, floods and other natural disasters. Mitigate costs due to loss of lives and property from such disaster events.

Broader Impact (education/outreach)

- Supported or partly supported two PhD students (one female), involved one MS student and one BS student.
- BS student (an US Army veteran) is continuing as a PhD student from fall 2025.
- ESO design introduced as a topic in graduate course in Geometric Control.

Broader Impact (potential)

- New methods for collision-free cooperative operations of UAVs could potentially impact transportation (e.g., urban air mobility)
- Applicable to networks of other vehicles, e.g., satellite constellations for Earth observations and heterogenous teams of unmanned vehicles.

AUSL Autonomous Unmanned Systems Lab — Syracuse University SyracuseCoE

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