NRI: FND: COLLAB: Multi-Vehicle Systems for Collecting Shadow-Free Imagery in Precision Agriculture

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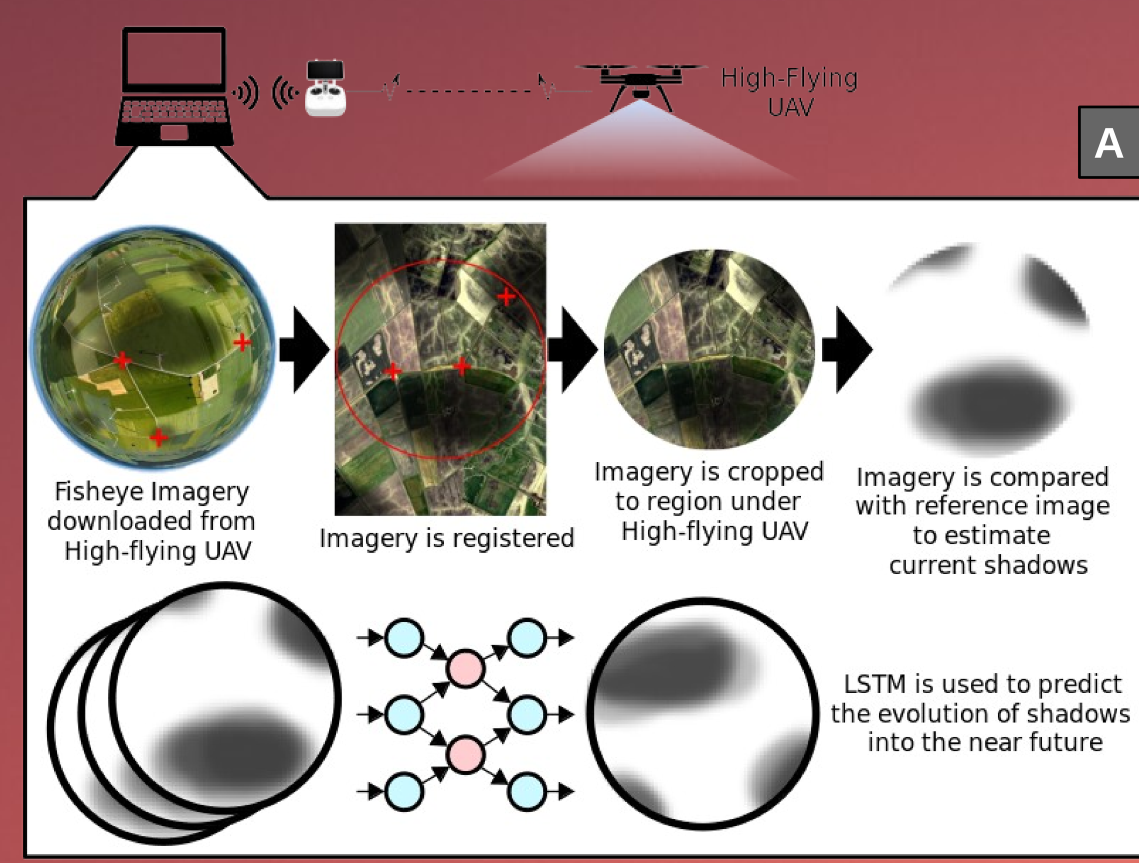
Project Website & Publication List: https://publish.illinois.edu/mvscsfipa/

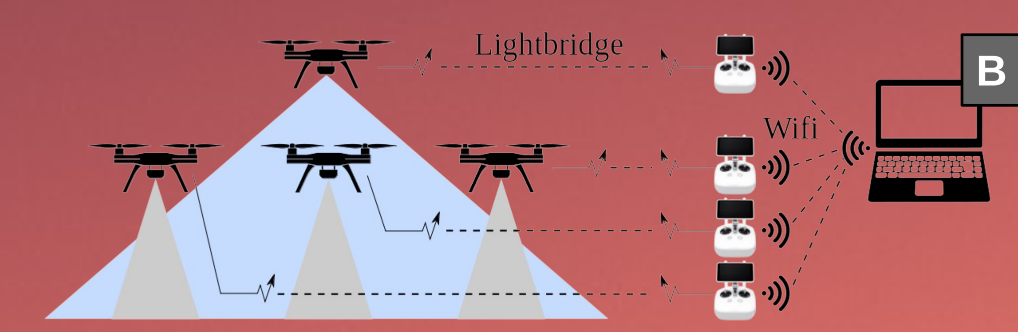
Challenge

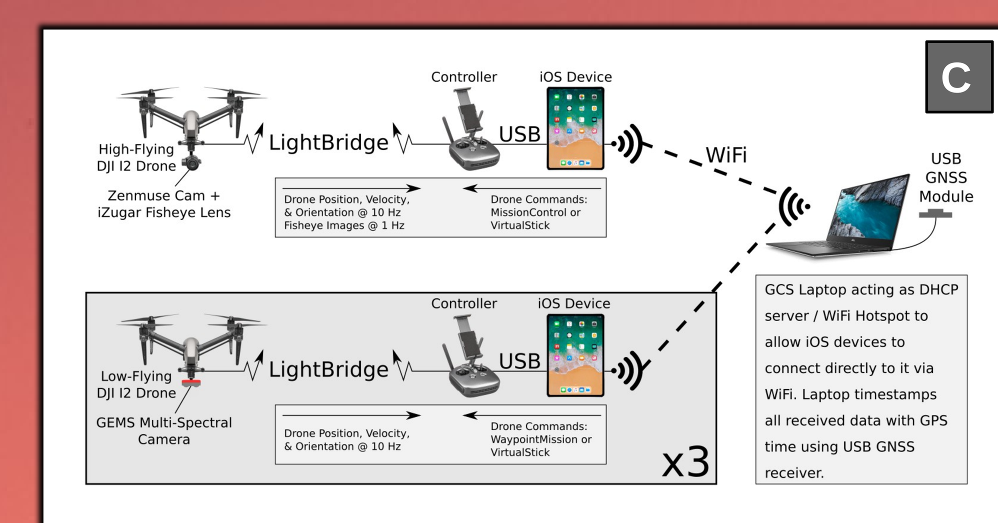
- Aerial imaging with multi-spectral cameras is widely used to detect crop nutrient deficiencies and other crop problems in precision agriculture
- Clouds cast shadows on the ground, confusing interpretation of multi-spectral remote sensing data
- Multi-objective control of multiple vehicles based on neural network predictions

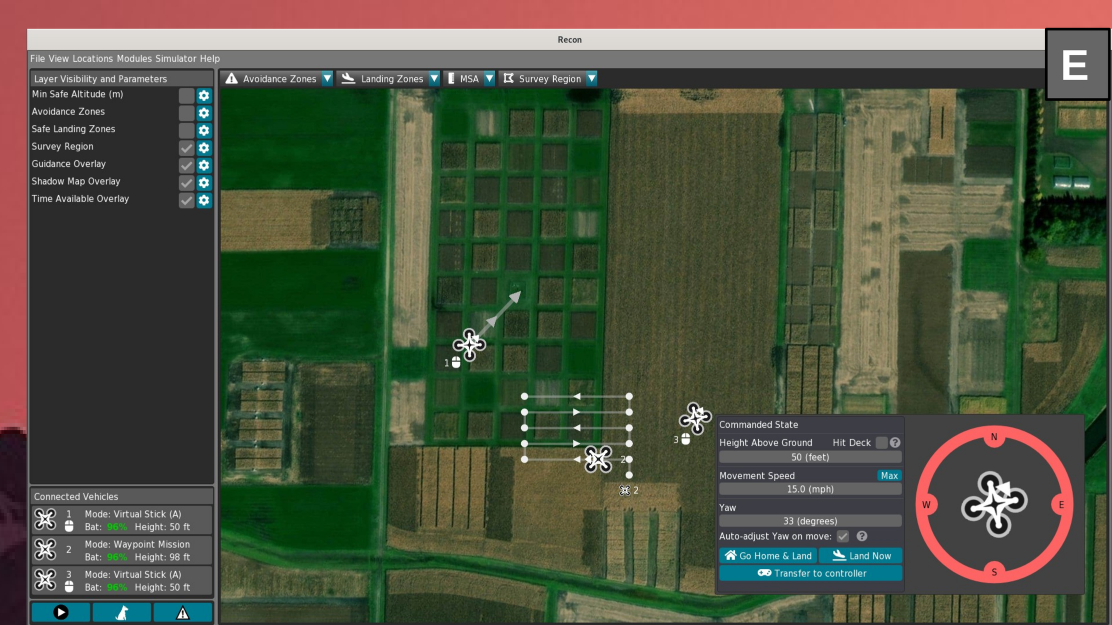
Solution

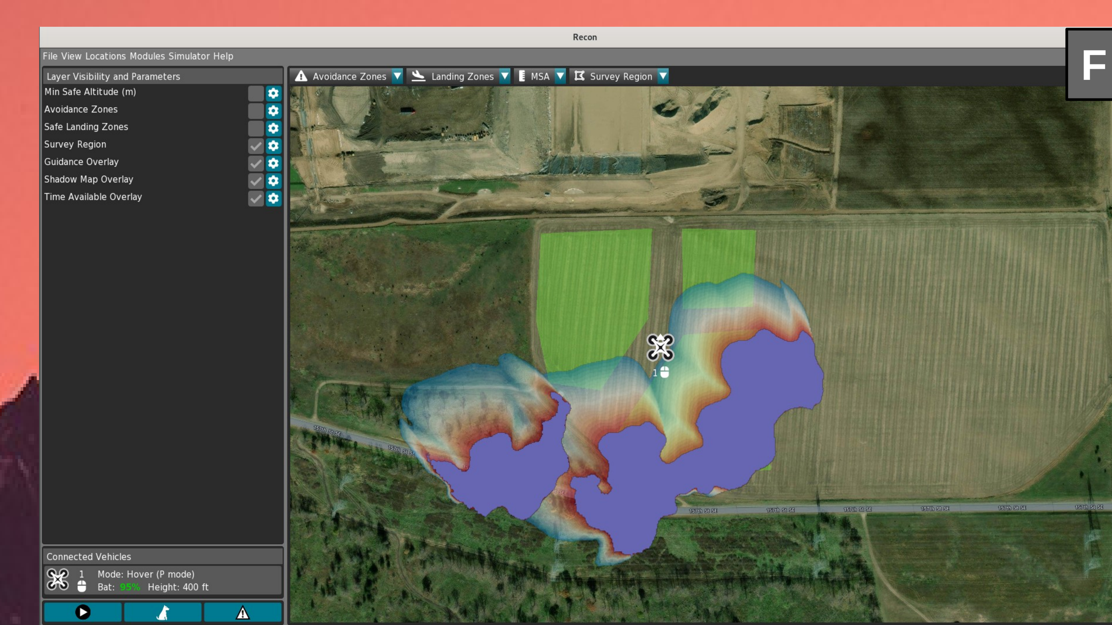
- Detect cloud shadows on ground using downward-looking fisheye imagery from a high-flying drone
- Predict the evolution of shadows into the future using LSTM NNs
- Novel closed-form control laws for a team of drones to collaboratively image area, avoiding shadows, to enable shadow-free reconstruction and stitching
- Stability and performance guarantees for neural networks used in time-varying prediction algorithms

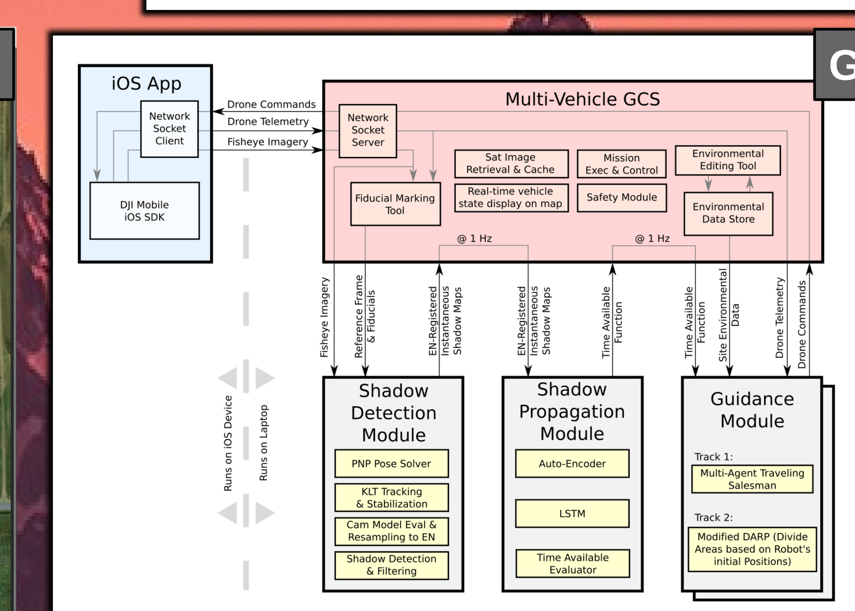












A	Solution Concept
B	High-level hardware diagram
C	Testbed hardware diagram
D	Testbed Equipment
E	Recon multi-vehicle GCS, developed under this program. This screenshot shows multiple vehicles being controlled simultaneously.
F	Recon multi-vehicle GCS. This screenshot shows a single vehicle streaming live video to the GCS, the shadow detection module is identifying cloud shadows in the imagery (shown in purple), and the shadow propagation engine is propagating shadows into the future (predictions are rendered as the red-to-blue heat map on the leading edge of the shadow).
F	Recon multi-vehicle GCS high-level software architecture

For more information on the Recon multi-vehicle GCS, developed under this program, see it on Github: https://github.com/poli0048/Recon
For an in-the-field video demonstration of Recon, see it on YouTube: https://www.youtube.com/watch?v=aSOjmPsa1Go

Scientific Impact

- Formal characterizations of the typical behaviors of neural networks and dynamical systems used in machine learning algorithms
- New closed-form multi-objective and multi-agent control design
- Novel application of reinforcement learning techniques to coverage control problem and comparison with classical traveling-salesman-based approach.

Broader Impact - On Society

- Enable the simultaneous use of multiple, collaborating robotic vehicles in precision agriculture, making it possible to scale up drone-enabled precision agriculture practices to realistic, industrial-scale fields
- Promote broader adoption of remote-sensing-based crop nutrient management solutions, thereby reducing excess nutrients left in the environment and reducing fertilization costs for farmers
- **Quantification:** Triple the amount of usable multi-spectral imagery that can be collected per drone by farmers and agronomists in a season by enabling data collection in a broader range of weather conditions

Broader Impact - Education & Outreach

- Development of new educational materials in robotics and control with strong emphases on applications of robotics in precision agriculture
- New module for UCB Girls in Engineering summer program for middle school girls and contributions to Women in Engineering at Illinois programs and Engineering Open House at UIUC

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