NRI: INT: COLLAB: Leveraging Environmental Monitoring UAS in Rainforests

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Motivation

Rainforest canopies are important ecosystems for diverse plant and animal life, however validating the model-based predictions for scientific decisions about these environments is difficult due to a lack of efficient data collection methods.

Key Problems

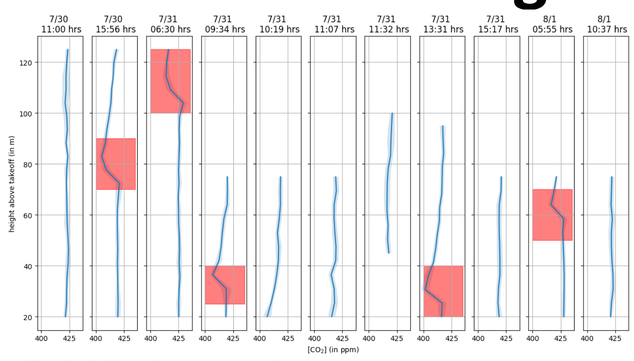
This proposal presents a vision aimed at advancing heterogeneous multi-Unmanned Aerial Systems (UAS) technologies, practices, and understanding to increase the reach of human sensing in challenging, hard-to-access environments while increasing scientific understanding of forest canopy health.

The vision addresses key goals in co-robotic system development:

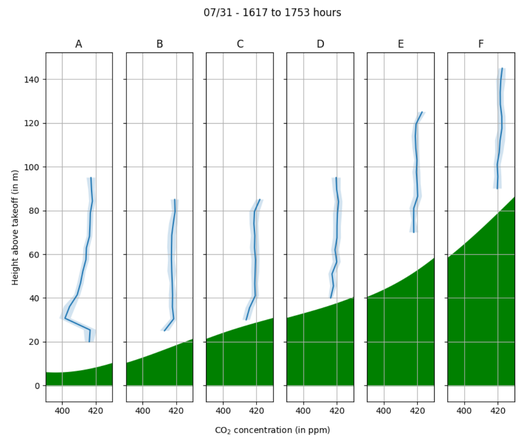
- the available attention of the humans involved,
- site selection for complementary sampling,
- and improvements in robot design and decision making for sample collection

These goals will be developed in local environments before being refined in yearly tests in the harsh, dense forests of Costa Rica, while contributing to progress in fundamental co-robotic challenges.

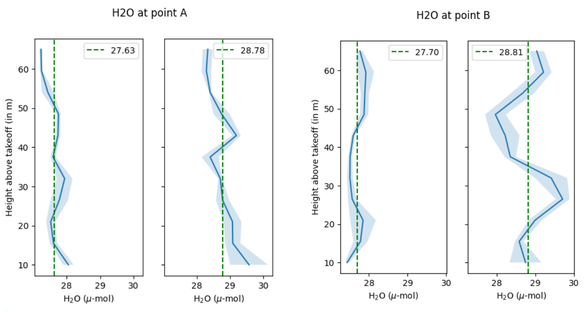
Scientific Sensing



Top Left: Evolution of the vertical profile of carbon dioxide concentration over point A. The carbon dioxide inversion patterns (shown in red boxes) are noticeable over several missions.



Top Right: Variation in carbon dioxide vertical profiles over points A-F. The inversion pattern clearly visible over point A becomes less noticeable, possibly attributed to increased turbulence as wind increases up the slope.



Bottom Left: Difference in vertical profiles of water vapor collected over points A and B before and after a rain event on 07/31/22. Our sensors captured the increased water vapor concentration resulting from precipitation.

Example deployment terrain and tower.

Refined CO2 sampler.

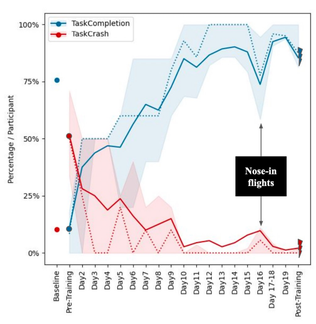
Prototype leaf collection system.

NRI Fit

The proposed work will advance the NRI 2.0 Co-Robotic agenda, through focusing on scalability of both systems and teams, inspired in the context of UAS-based forest canopy monitoring, taking a multidisciplinary approach that requires efforts at the intersection of robotics, computer science, systems engineering, and forest ecohydrology and management.

Robotic Results

- Dissertation experiments on development of pilot proficiency and training recommendations for novice pilots (left)
- Testing of the impact of distance and size of gestures on user identification in simulation, extending to cluttered outdoor environments and planned for field testing



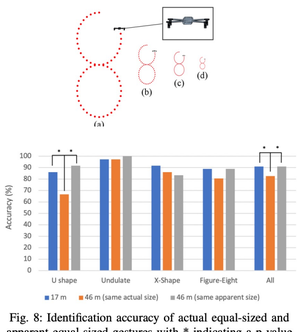
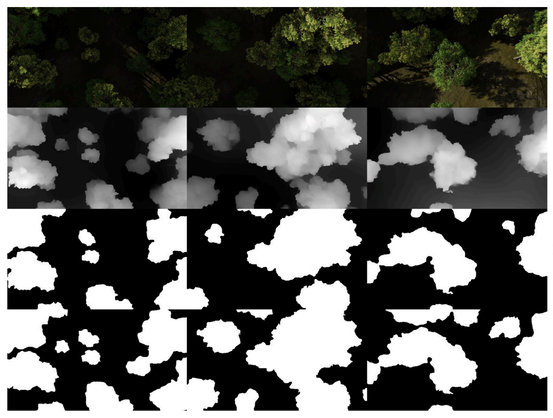


Fig. 8: Identification accuracy of actual equal-sized and apparent equal-sized gestures with * indicating a p-value less than 0.05



Video frames input into the pipeline.

Estimated depth maps generated for the frames

Segmented results from the pipeline.

Ground truth for each corresponding frame.

- Evaluation of a four-stage pipeline using computer vision and deep learning approach to estimate rainforest canopy depth.
- Real rain forest canopy evaluated to validate a multi-resolution video data approach.
- Depth results shown to be obtained using video data sets of multiple spatial resolution.

- Developed a prototype leaf collection system, then deployed that system for testing in Costa Rica.
- Refined CO2 sensor integration and workflow to build on promising data from 2021 field deployment.

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