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Stereo YOLO UAV Localization and Tracking Enabling Autonomous Sensor Deployment on Critical Infrastructure

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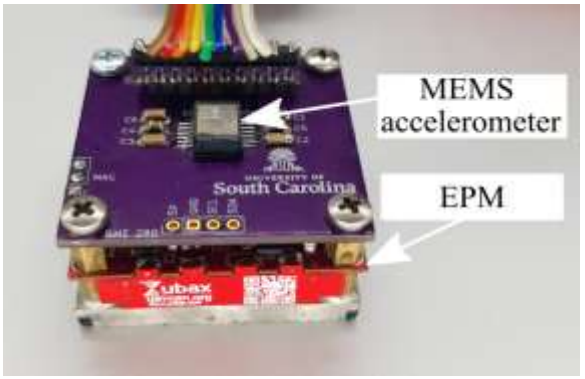
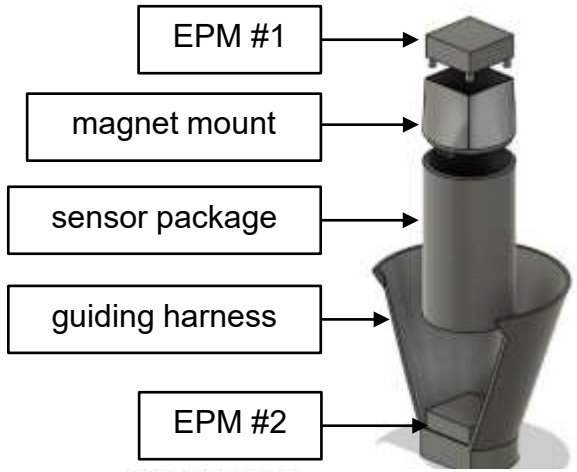
Outline

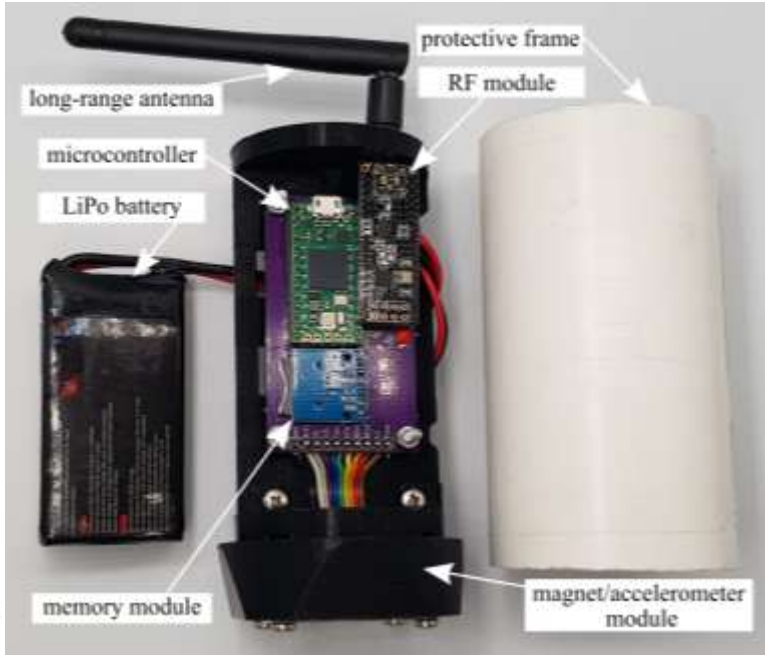
1. Background
2. UAV system and test site
3. Machine learning with YOLO
4. Results
5. Conclusions

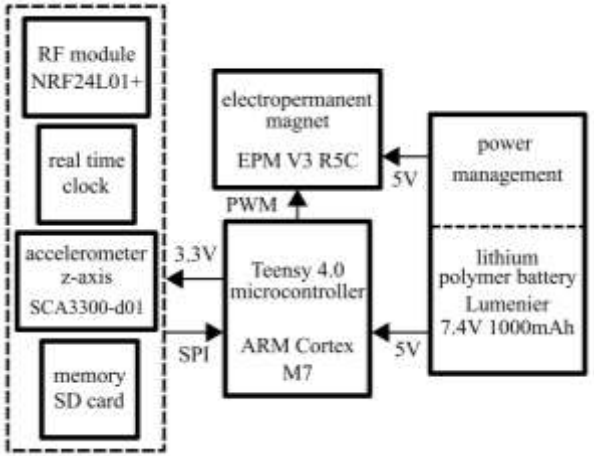
UAV structural health monitoring

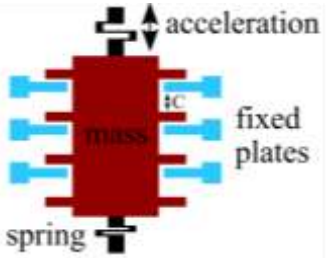
- Unmanned aerial vehicles (UAVs) have had an increasingly important role in the structural health monitoring (SHM) of aging infrastructure.
  - Requires less personnel
  - Safer
  - Cheaper
  - Faster
- Various UAV-based solutions have shown considerable results in the SHM environment.
- Physical sensor placement by UAVs show promising results in long-term monitoring.





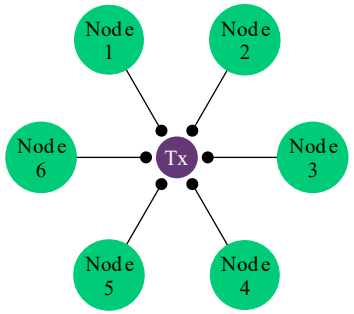


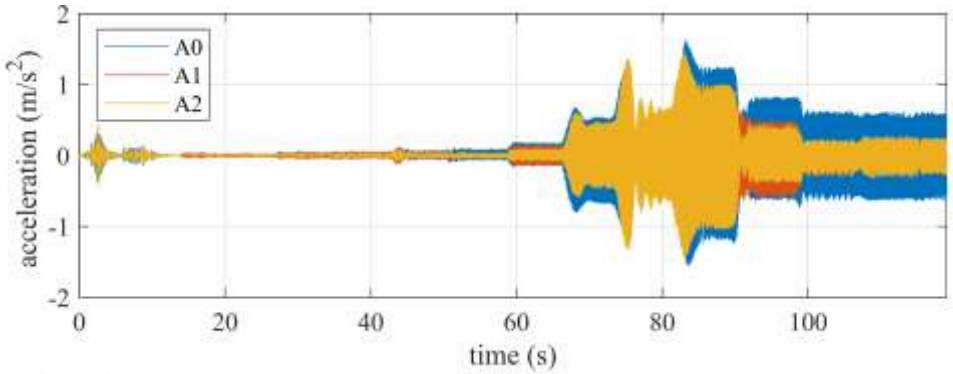


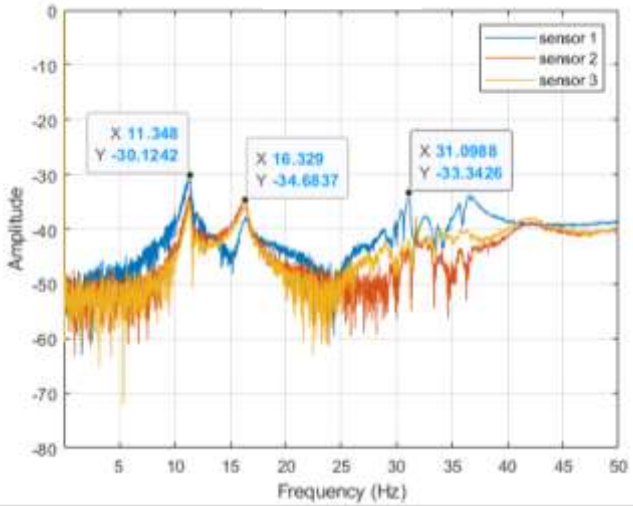


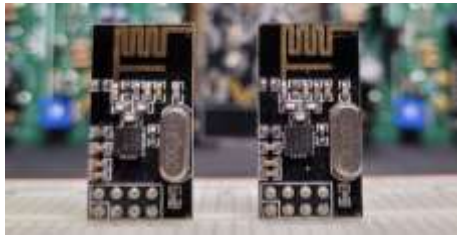
Wireless sensing networks

- Wireless sensor packages with electro-permanent magnets (EPMs) are delivered by UAVs, which "dock" sensors onto metallic structures by activating/deactivating the EPM during flight.
- Sensors measure vibration data to study the natur frequency of civil structures.
  - 2.4 GHz ISM Bandwidth
  - Enhanced ShockBurst protocol
  - Wireless range of 100 meters
  - Transmission rate of 2 Mbps
  - Up to six radio links per hub
  - Ultra-low power consumption



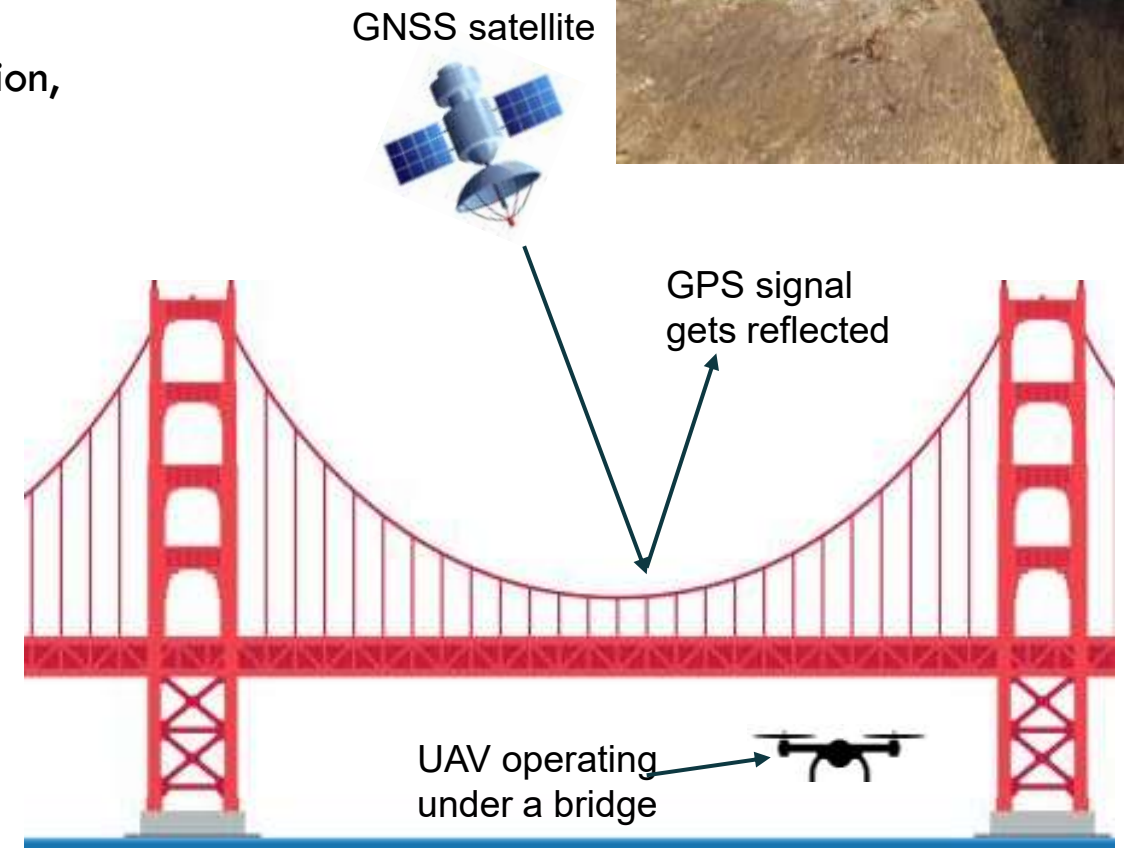






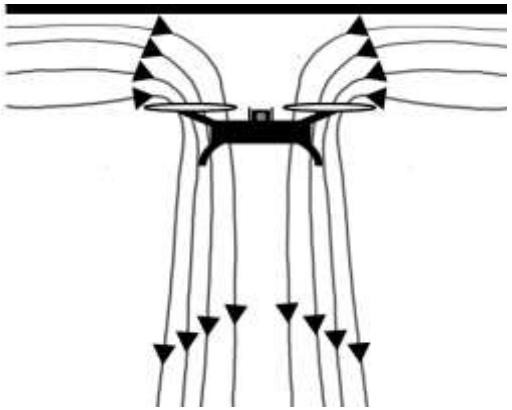
Line-of-sight and GPS signal

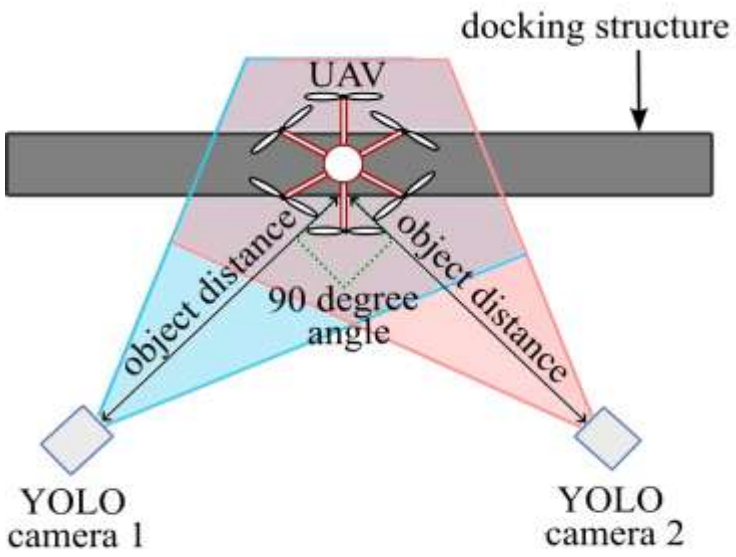
- UAVs are often manually piloted under structures to place sensors for analysis.
- Placement via manual control often leads to imprecise navigation during deployment.
- Line-of-sight issues complicate UAV navigation, as explained in the video on right.
- GPS signals near large metal structures (or indoors) suffer from signal blockage and multipath reception, affecting accuracy.
- As a result, UAVs struggle to stabilize in 3D space for sensor placement under metal structures.



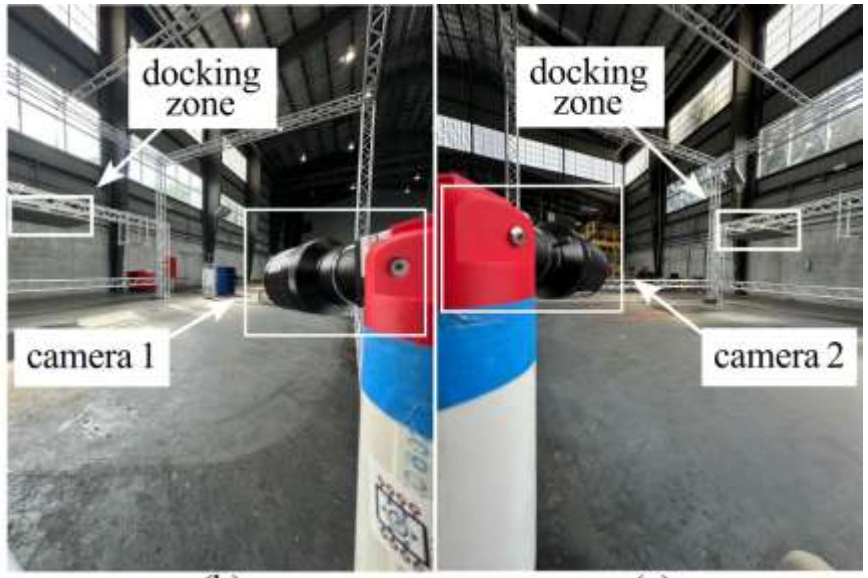
UAV ceiling effect and external vision

- Ceiling effects can further complicate manual control. UAV thrust significantly increases, as the distance from the propeller to the ceiling decreases.
- Trained object-tracking algorithms on the UAV on stereo cameras allow for three-dimensional detection and tracking.
- This approach allows for tracking of the sensor docking process without the need for structural modifications.





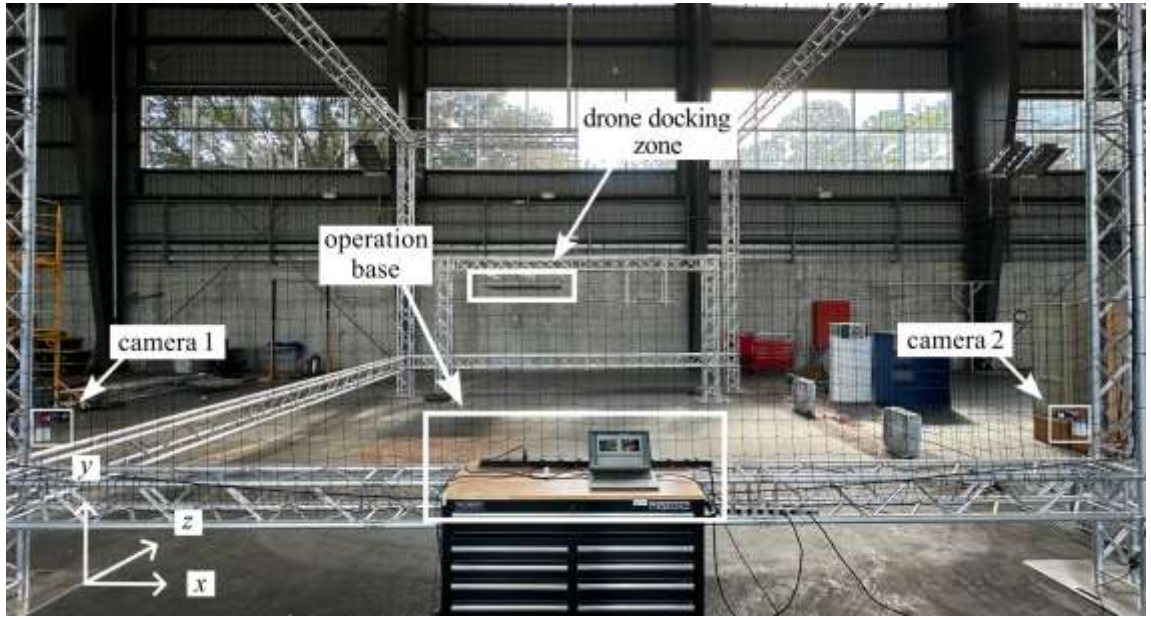
(a)



(b) (c)

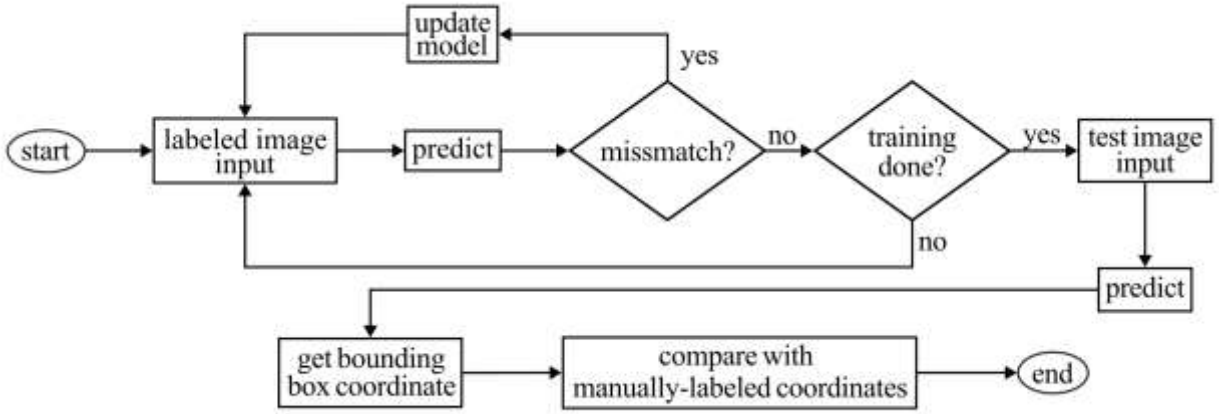
UAV system test site and technical aspects

- Utilizes a metallic structure, UAV, and sensor package. Metallic structure consists of three large beams with a horizontal “docking zone”.
- The UAV is equipped with an electro-permanent magnet-based sensor deployment mechanism.
- Two 2.8 mm focal length color-cameras were positioned at a 45° angle to the left/right of the central axis facing the structural docking zone (ferrous metal plate 152.3 x 152.3 cm in length/width)
- Cameras were positioned on support beam intersections, with the right and left cameras 7.065 m and 5.980 m from the center of the docking zone, respectively. Cameras were mounted 1.055 m from ground level.



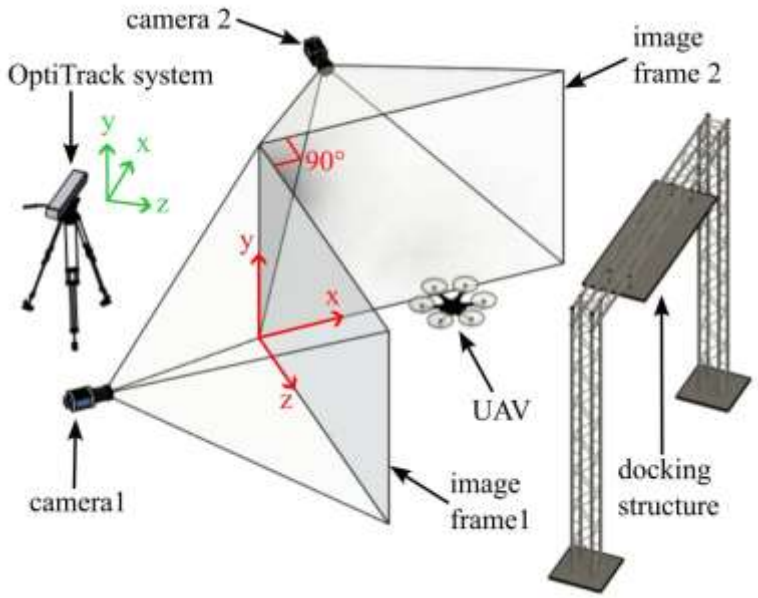
Machine-learning with You Only Look Once (YOLO)

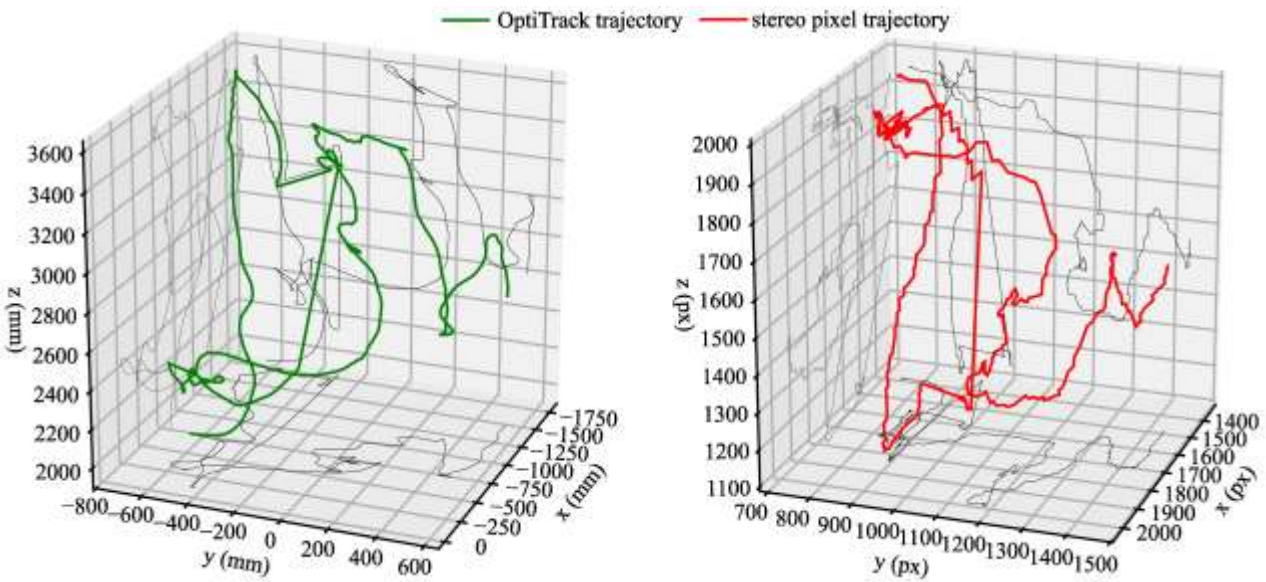
- 64 hand-labeled images of the UAV in the test environment were used for training, including a 6-image validation group after each training session.
- Confidence-threshold, intersection over union, and frame rate were adjusted for improved detection
- 55-second test flight was used for evaluation between YOLO system UAV coordinates and manually-labeled coordinates
- Linear interpolation was applied between video frames, and differences between coordinates were interpreted as YOLO "error"



Creating additional 3-dimensional spatial coordinates

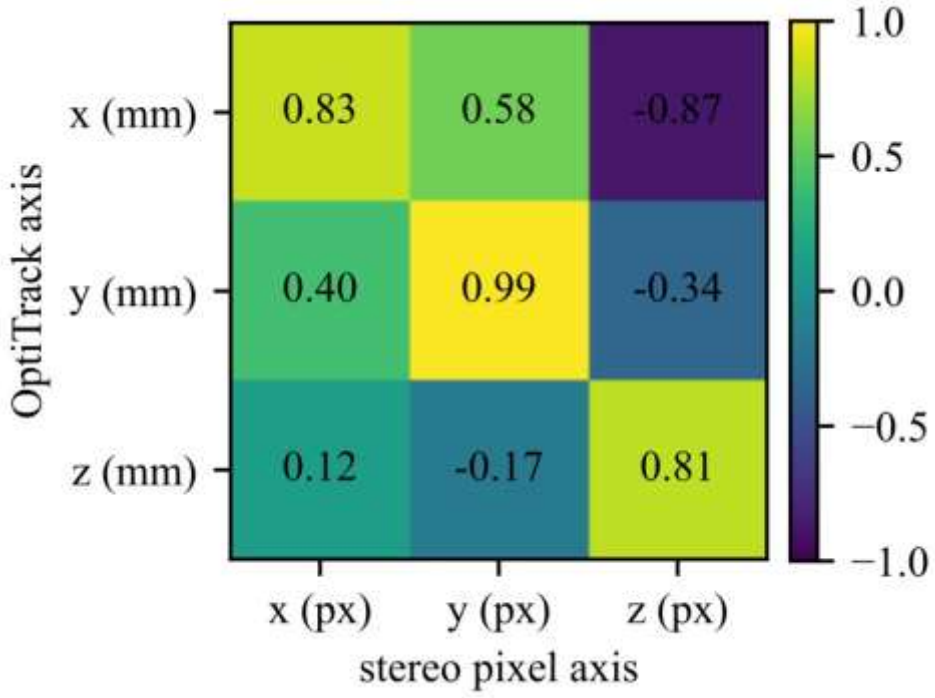
- Machine-learning (ML) processes can convert YOLO-based stereo pixel coordinates to spatial coordinates in mm.
- An optical tracking system, OptiTrack, uses IR filters to track IR markers on the UAV, working as a ground truth for mm-level spatial coordinate ML training.

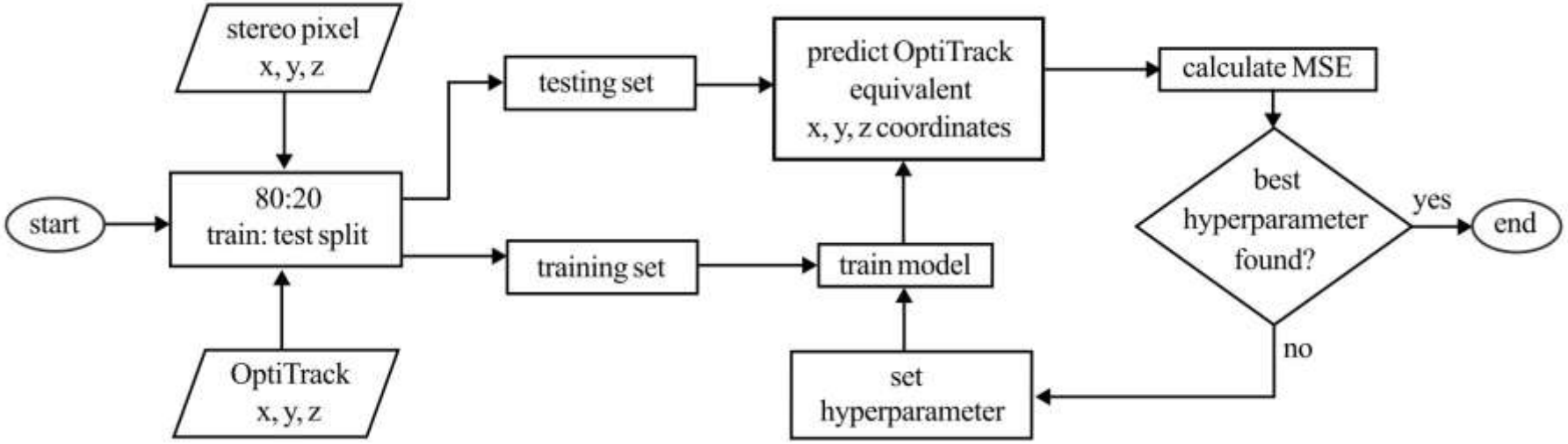




Tracking system linearity

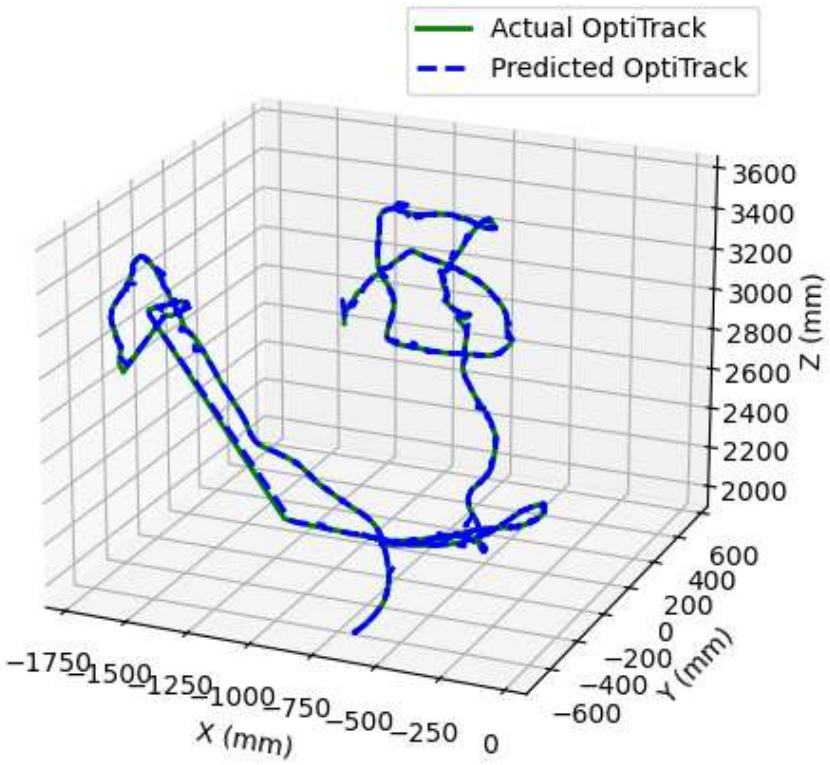
- The Pearson correlation matrix shows that pixel-based YOLO coordinates are not linear with their spatial distance coordinates.

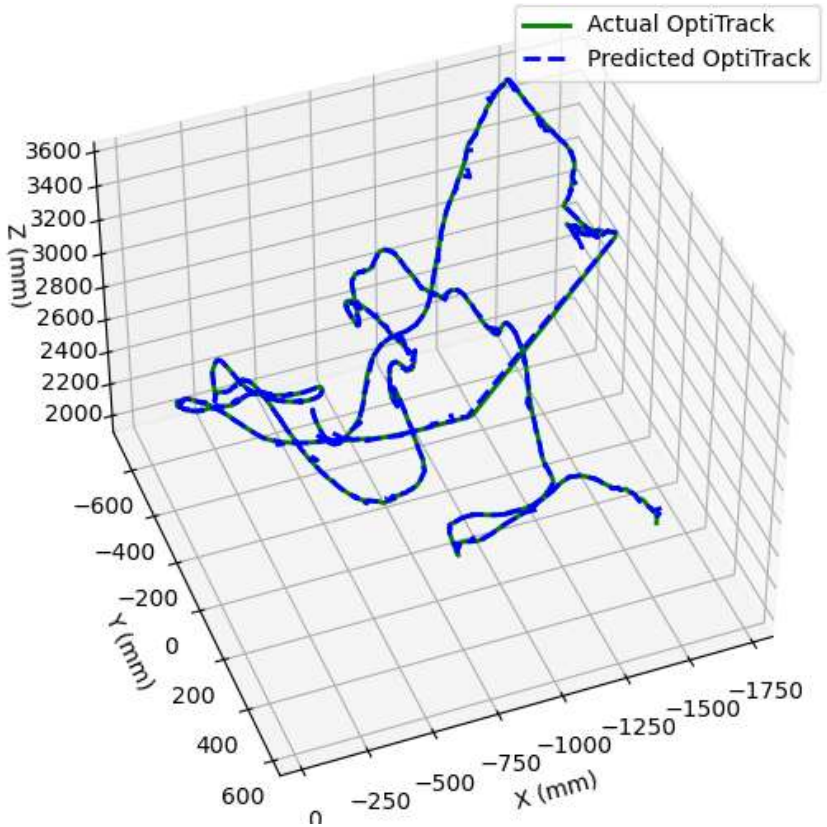




Spatial coordinate predictions

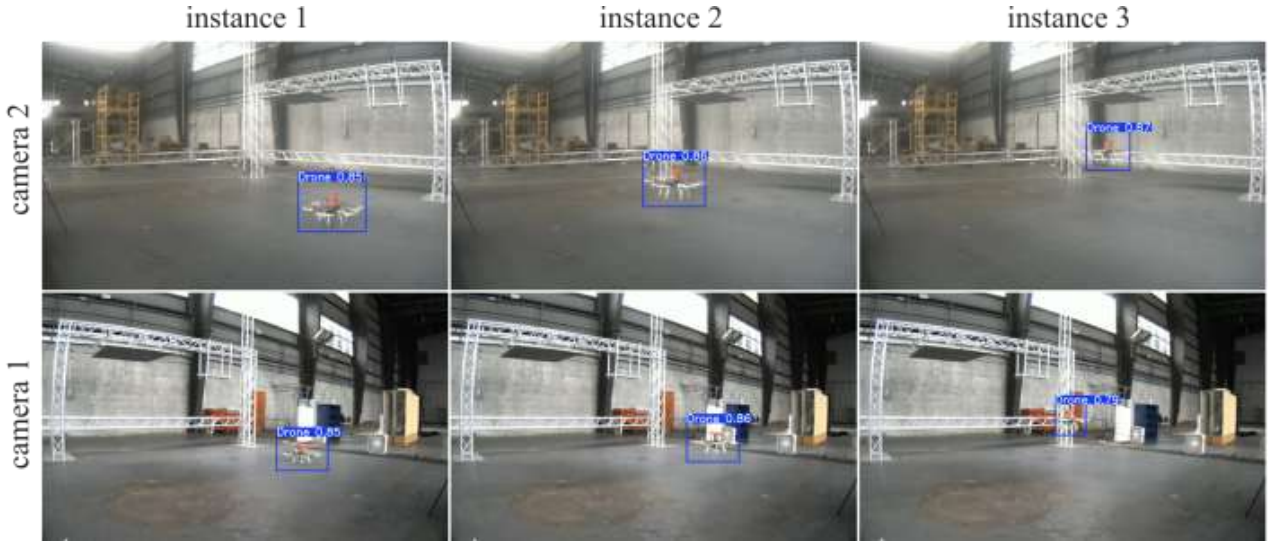
- Evaluated models: polynomial regression, random forest regression, support vector regression, gradient boosting regression.
- OptiTrack 3D coordinates are predicted from 3D pixel coordinates using the ML algorithm.
- Support Vector Regression (SVR) model has the best performance.

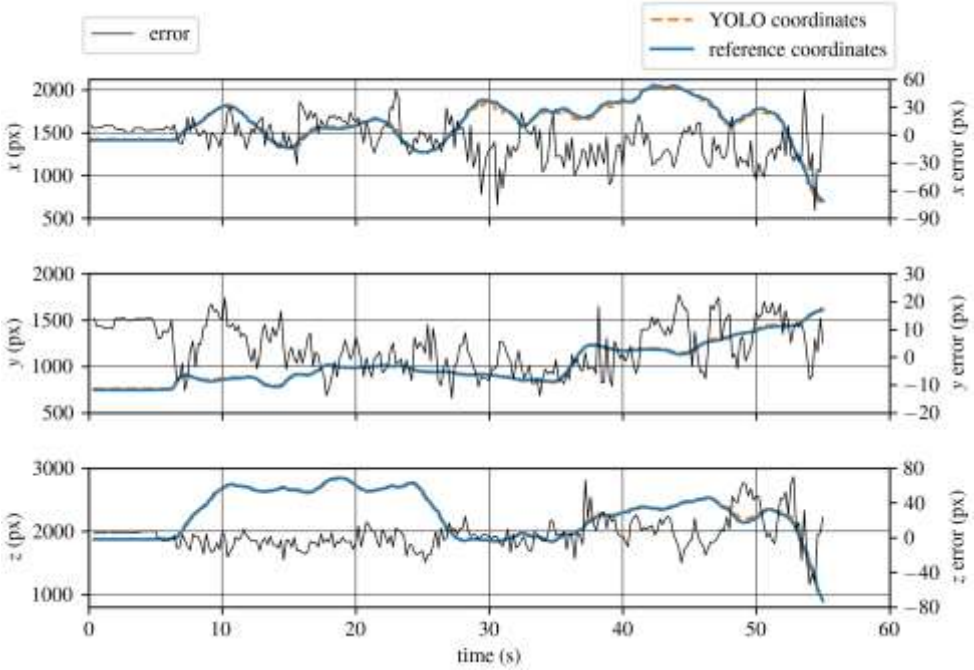




Results

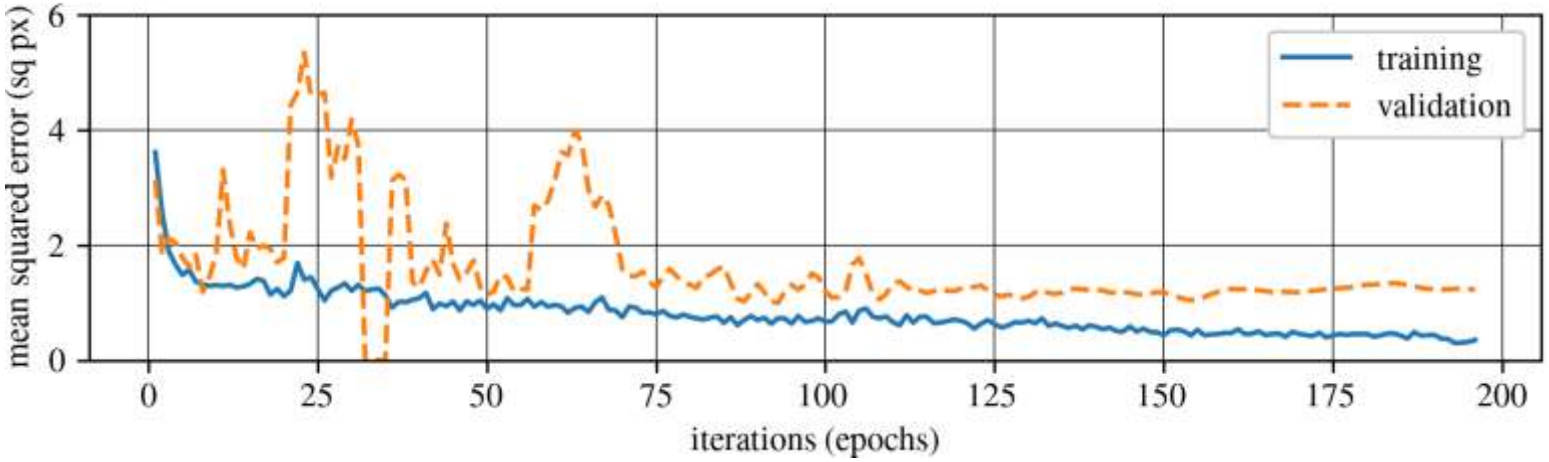
- YOLO annotation software was able to visually show correct bounding box placement throughout the UAV flight.
- Confidence threshold of 25% and intersection-over-union value of 0.1 allowed for most accurate data collection.
- Average differences between YOLO and manually-marked coordinates of the UAV flight were -5.840, 3.744, and 3.534 px in the X, Y, and Z directions, respectively

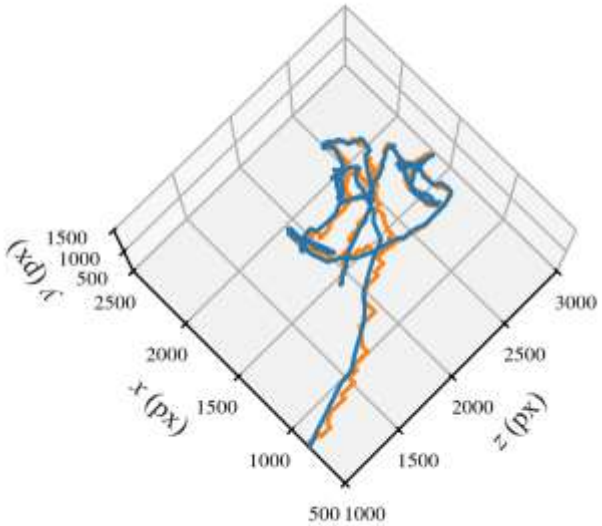


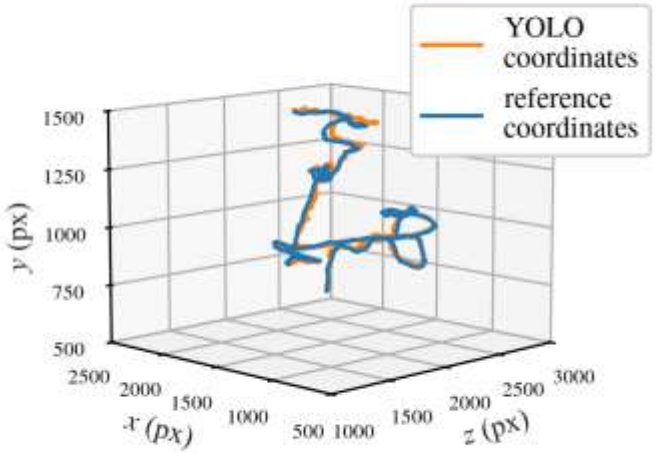


Results

- Final YOLO model had a training box loss of 0.770 sq px and a validation box loss of 1.227 sq px by 96 epochs
- Validation errors showed more stability with more epochs, while training errors showed continual improvements
- **Machine-learning-based tracking systems can be readily developed to provide accurate positional data of UAV sensor docking**

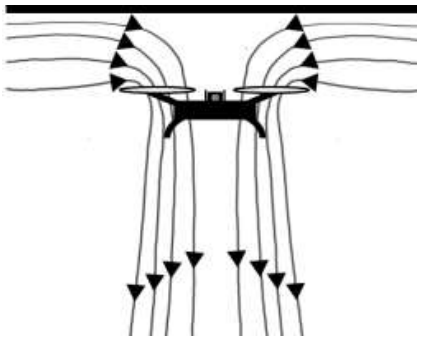


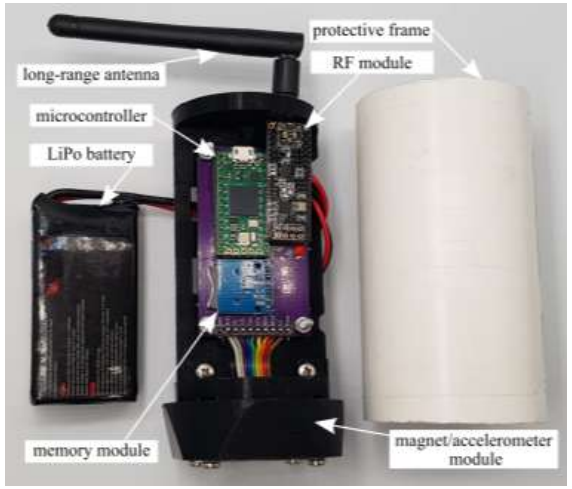


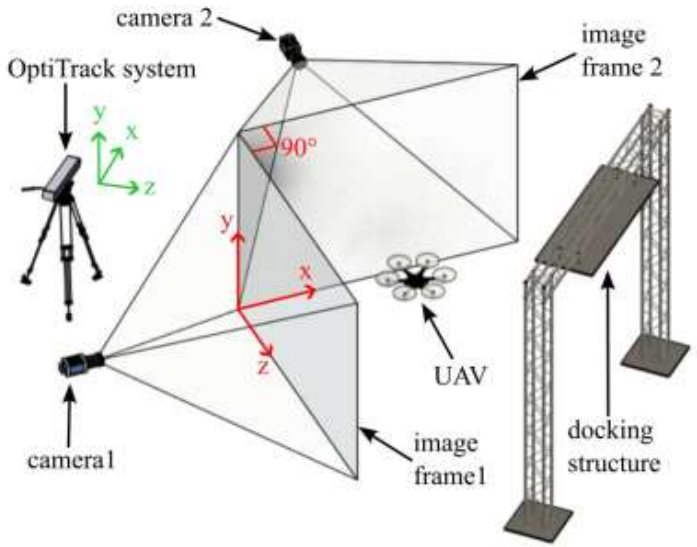


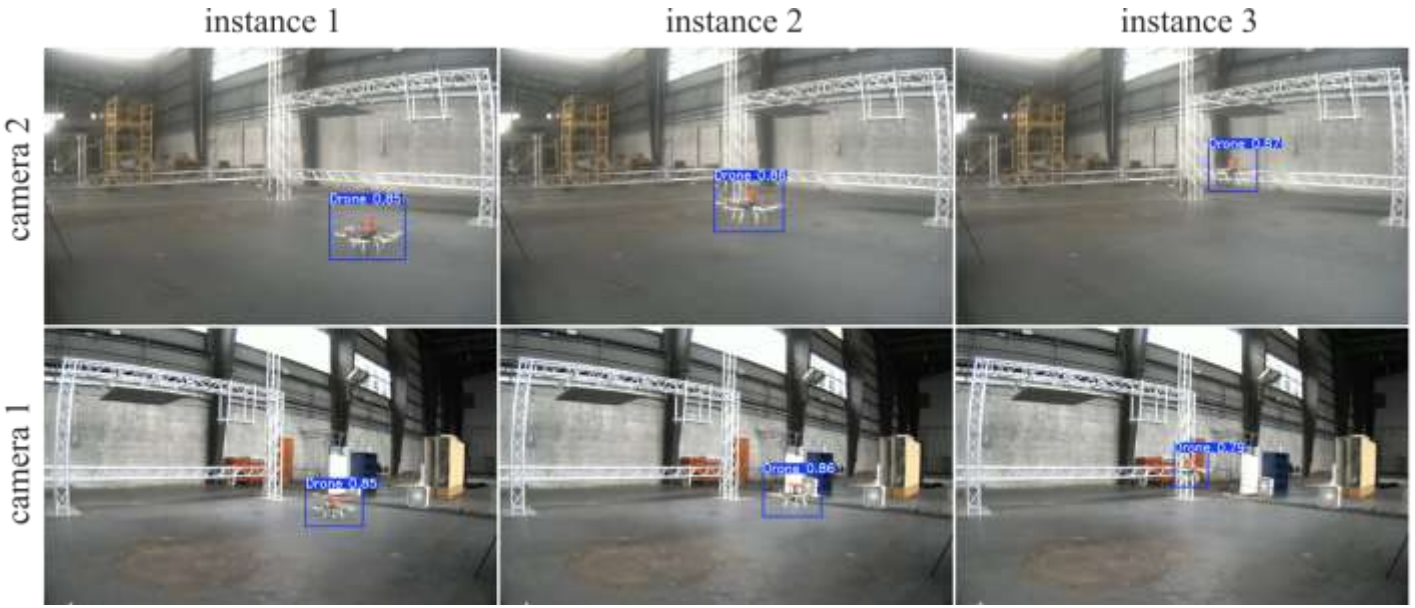
Conclusions

- UAV sensor placement
- Ceiling effect
- Spatial ML
- Object tracking









References

[1] Ryan Yount, Joud N. Satme, Austin R.J. Downey, and Jasim Imran. “Drone Deliverable Vibration Sensor.” University of South Carolina Summer Research Symposium. Columbia, South Carolina, USA. 2022 July 28.

[2] Joud N. Satme, Ryan Yount, Spencer Schwartz, Austin R.J. Downey, and Stanley Ling. "Analyzing the Ceiling Effect on UAV Thrust Variations Through Computational and Experimental Studies." Proceedings of the ASME 2025 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. Anaheim, California, USA. 2025 August 17–20. https://doi.org/10.1115/DETC2025-169020

[3] Md Asifuzzaman Khan, Samuel Tadamatla, Evan Phillips, Joud N. Satme, Mark Zheng, Austin R.J. Downey, Korebami Adebajo, and Nolan Shute. "Machine Learning-Based UAV Localization for Under-Structure Sensor Deployment in GPS-Denied Environments." SPIE Smart Structures + Nondestructive Evaluation. Vancouver, BC, Canada. 2026 March 16-19.

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Open-Source hardware Designs

https://github.com/ARTS-Laboratory/Paper-2026-Stereo-YOLO-UAV-Localization-and-Tracking

Open-source UAV Localization and Tracking

Thanks for listening!

Questions?

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