Development of an Autonomous UAV Structural Health Monitoring Sensor Deployment System Using Machine Learning Algorithms

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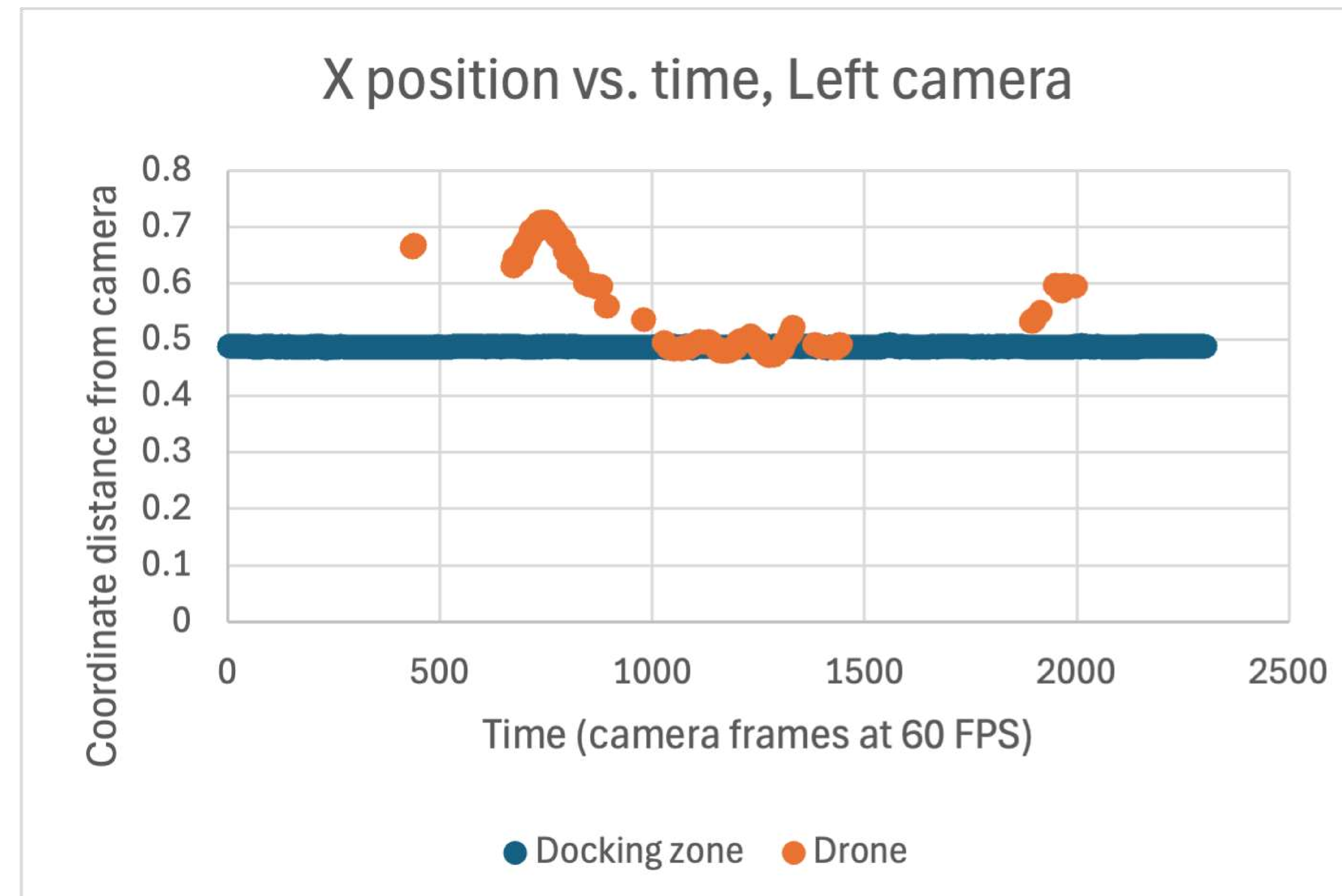
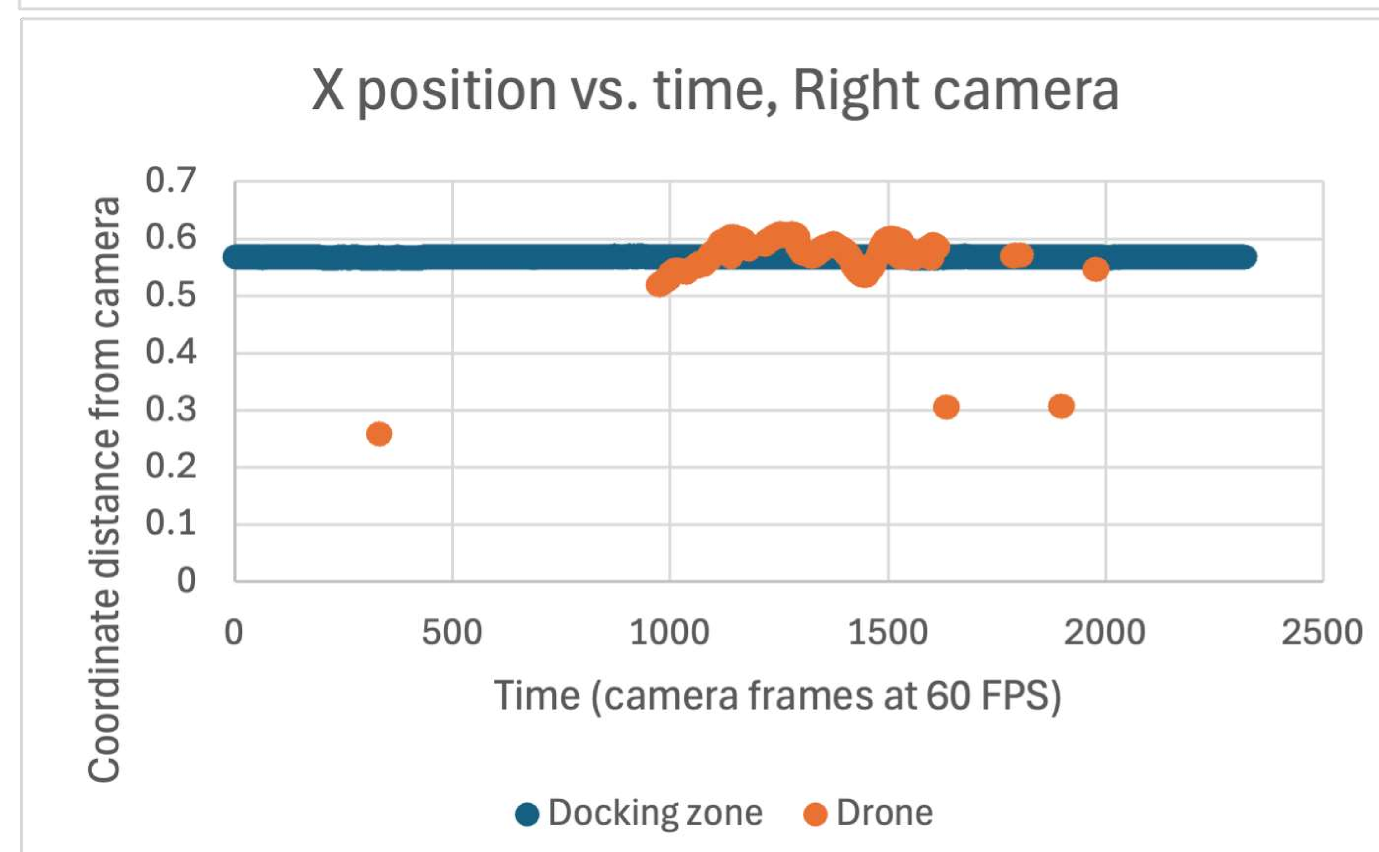
Introduction

- Structural health monitoring has increased in importance due to aging infrastructure
- The use of unmanned aerial vehicles (UAVs) has grown to assist with this process
- UAVs often come with its own risks to safety and property damage when physically placing sensors on structures
- A multi-camera autonomous approach can greatly help mitigate these risks

Methods

- A metallic structure, drone, and a sensor package was built
- Optical camera equipment and reflective markers were set up as a reference for determining accuracy
- Developed a new algorithm based on You Only Look Once (YOLO) that is trained on the new set-up
  - Multiple images of the sensor docking area and drone flight were labeled by hand to establish true data for the machine learning algorithm to analyze
  - Factors like confidence threshold, intersection of union, and frame rate were adjusted
- Two additional cameras were placed 15 feet from the docking zone, such that the central line of their field of view (FOV) intersects at a 90 degree angle
  - They were angled up at 30 degrees from horizontal to view the drone area
- All camera data were sent to a laptop capable of running both the optical tracking analysis software and the developed YOLO algorithm
- All results were gathered from the laptop and compared

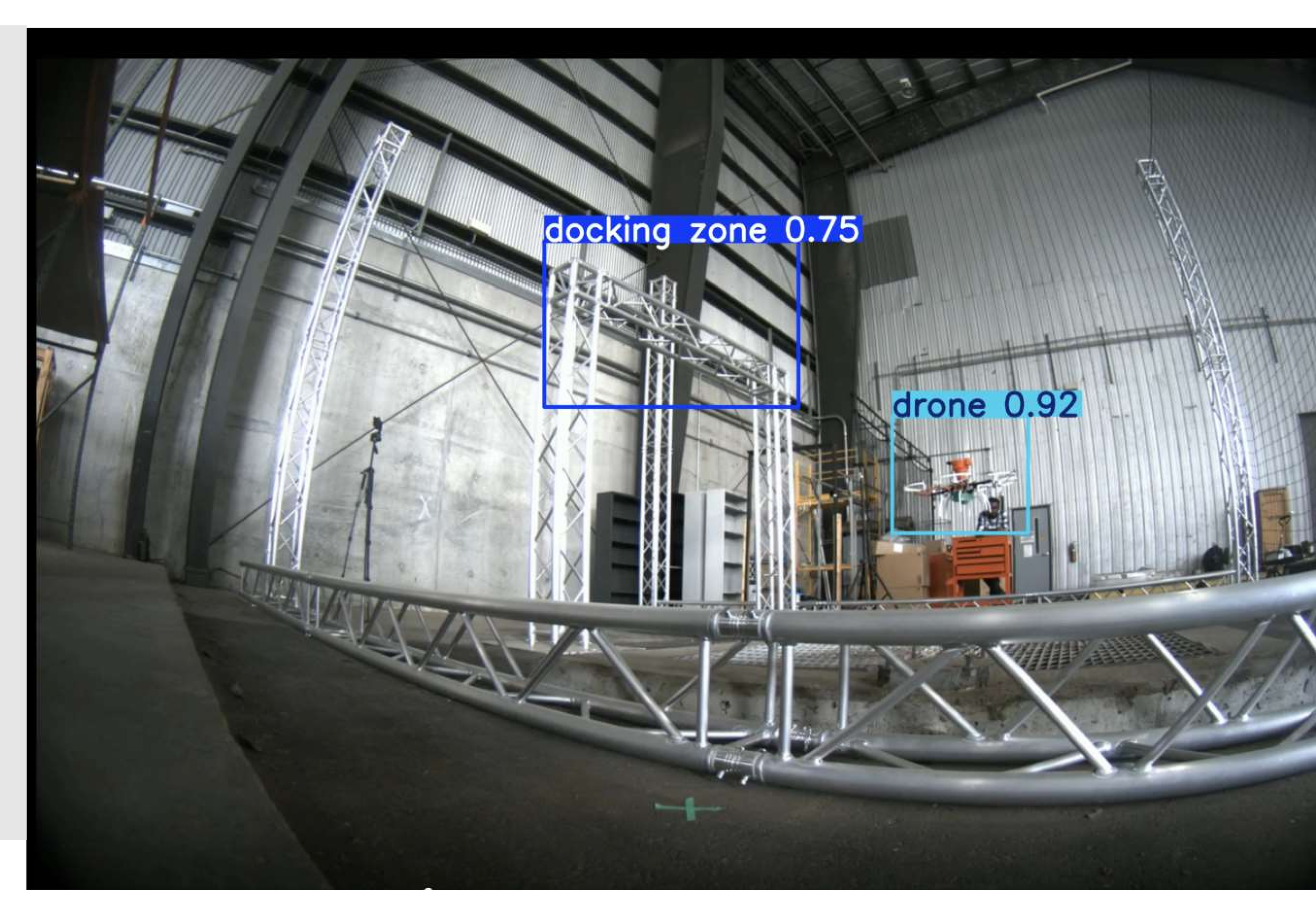




LEFT: X position values received from the left camera (top image) and the right camera (bottom image). X coordinates are movements left and right of the frame. Y coordinates are movements up and down the frame.

LEFT: Cameras that will provide video footage for YOLO processing. The left and right camera view are shown.

RIGHT: Camera output from the left camera with YOLO bounding box around identified docking zone and drone. Confidence level depicted as a percentage of it being the truth.



Results

- The YOLO algorithm provided fairly reliable XY data as compared to the optical camera control group, with accuracy increasing the closer the UAV is to the sensor docking zone, which is ideal for its use case
  - It also showed significant differences (relative to the angle of view) between the two cameras regarding the X coordinates
  - The differences between the X coordinates are viable for translation into physical Z coordinates (the distance away from the cameras)

Conclusion

- YOLO can be a viable method in determining the movement of a UAV across 3-dimensional space
  - The placement of two cameras at 45 degrees from a docking structure (and 90 degrees FOV intersection) allows for positional analysis in any direction
  - The positional analysis results are fairly accurate for its use case as a sensor placement system

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