Stereo Vision UAV Tracking for Autonomous Structural Health Monitoring Sensor Deployment

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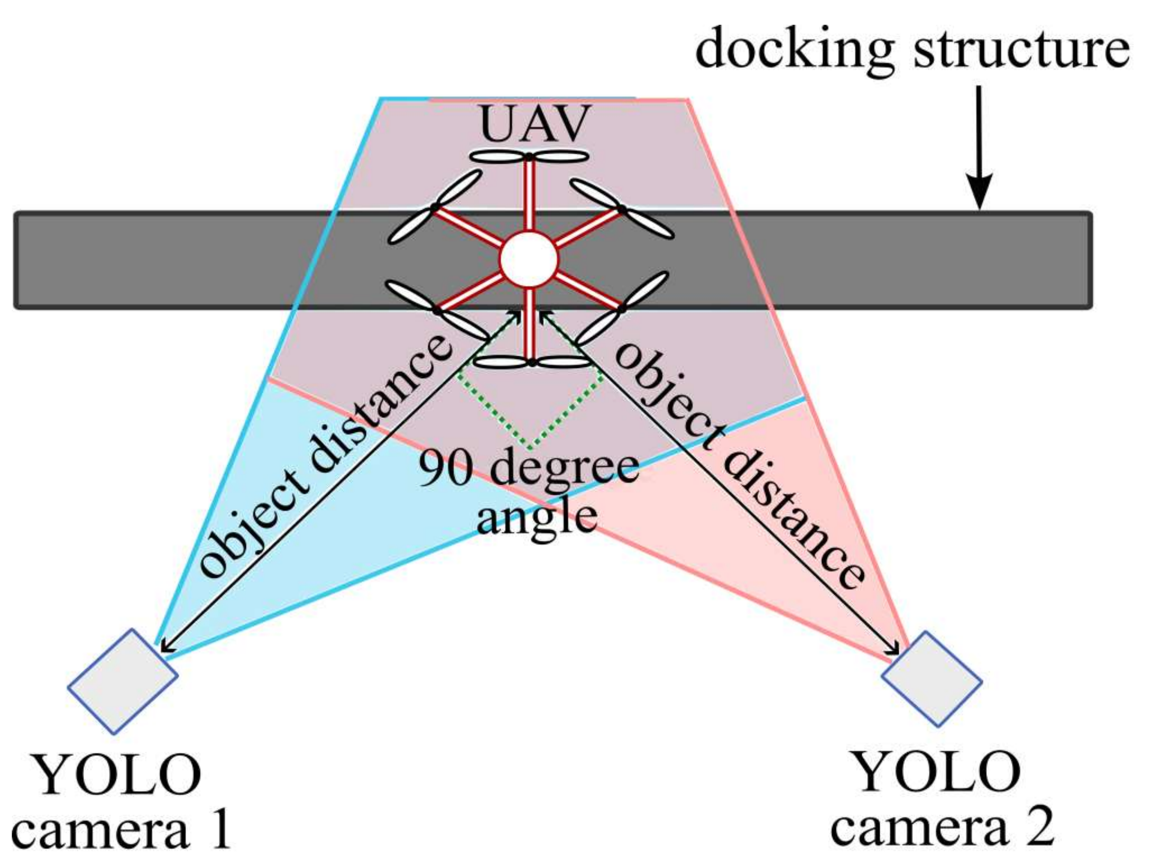
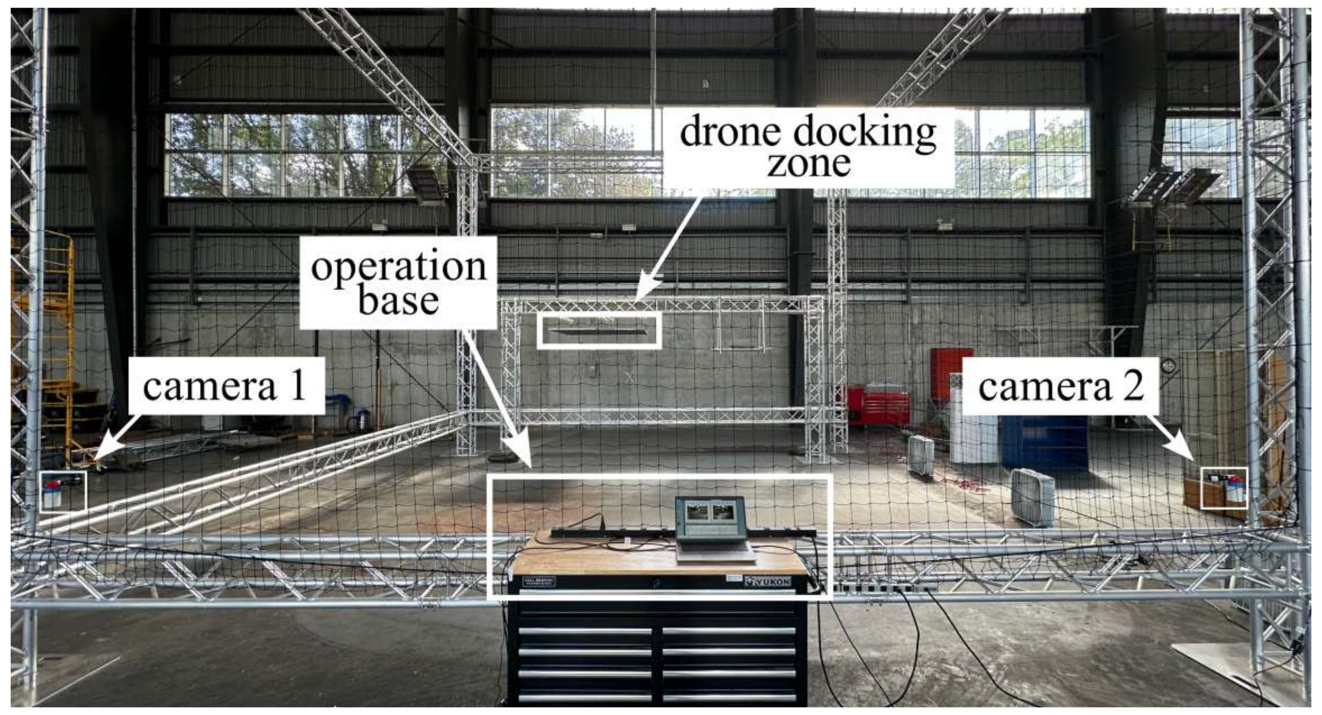
Introduction

- Structural health monitoring (SHM) systems are important in assessing the integrity of aging infrastructure.
- The placement of sensors is necessary in SHM, as the number of potential failure points accumulate over the lifespan of a structure.
- Sensors can be placed manually using highly trained personnel but at high risk and high cost in hazardous locations, such as bridges.
- Vision-based tracking systems can develop the essential framework for 3D modeling of sensor placement flights, reducing cost and risks.



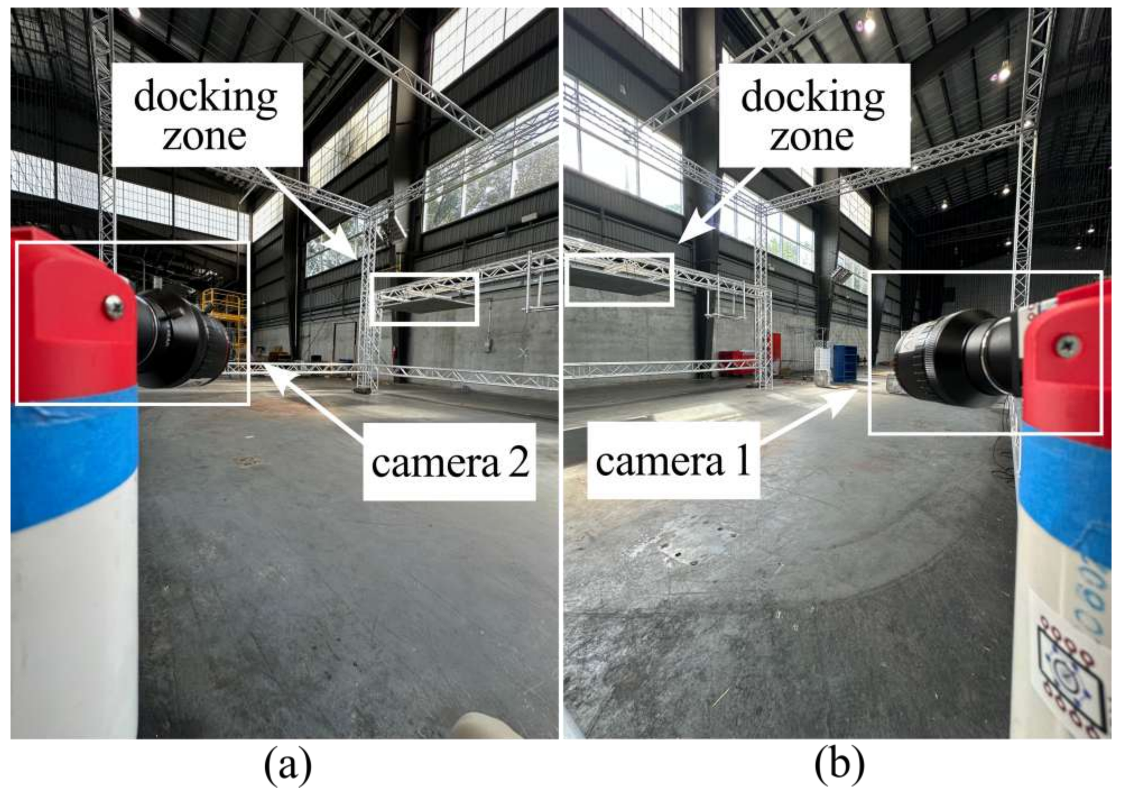
Relative angles of the left and right cameras.



Experimental setup of UAV cage, docking zone, operation base, and stereo cameras.

Methods

1. A UAV cage and bridge-like structure was built to serve as the sensor docking zone and flight environment.
2. You Only Look Once (YOLO) Version 8 was used as the baseline model for training and prediction of UAV location, using labeled images of the UAV in the test environment.
3. Two optical cameras were placed on the left and right corners of the UAV cage, facing towards the docking structure at a 45-degree angle. They were mounted 1.05 m from the ground and aimed at zero horizontal elevation.
4. Optical cameras were connected to a computer to run YOLOv8 on video output. 5 of 30 FPS were taken to be manually labeled to establish reference coordinates in determining model accuracy.

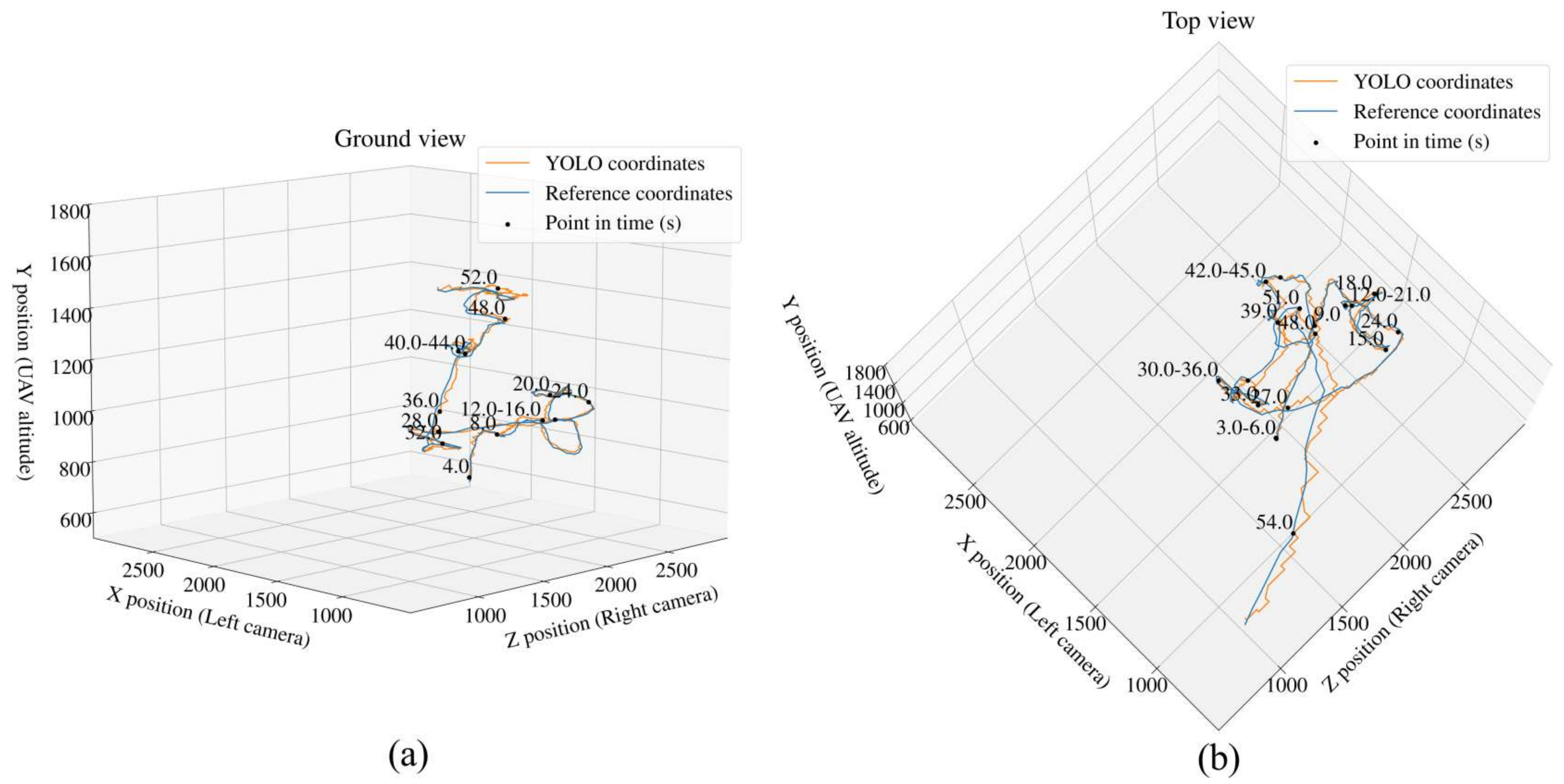


Camera positions, showing: (a) the right camera view, and; (b) the left camera view.

Camera views, showing: (a) the left camera view, and; (b) the right camera view with YOLO bounding box confidence levels.

Results

- Video analysis showed the YOLO bounding boxes of the drone were accurately placed during the entire duration of flight. Only nine frames were missing coordinates.
- Graphs of the drone path show similar YOLO and manually labeled coordinate locations. Numerical analysis showed an average coordinate error of 0.30% compared to the 275 manually labeled frames.
- X-axis (left camera) errors were at 0.35% on average.
- Z-axis (right camera) errors were at 0.17% on average.
- Y-axis (left and right camera, UAV altitude) errors were at 0.38% on average



YOLO and reference coordinates of UAV flight, showing: (a) the ground level view, and; (b) the top level view with associated time stamps.

Conclusions

- Stereo vision is a viable solution in determining UAV location in a controlled environment.
- Stereo vision accurately provided UAV coordinate location in all directions. Uniform time sampling provided (relative) speed information.
- Stereo vision flights can be used to build flight models for autonomous flight paths, allowing sensor docking using little human input.

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