ICRA2026 Late Breaking Results Poster presented at
2026 IEEE International Conference on Robotics and Automation (ICRA 2026)
June 1-5, 2026. Vienna, Austria

A Display-Based Testbed for Bridging the Gap Between Drone Simulation and Real-World Testing

Renma Hara and Kai Cai

I. INTRODUCTION

Drones are increasingly used in various fields including delivery services, agricultural monitoring, and disaster response. Experimental evaluation using actual drones is essential for developing and validating new technologies. However, conducting such experiments is often difficult due to safety concerns, legal restrictions, and the need for large flight spaces.

Simulation environments are widely used to address these challenges. Although simulations allow large-scale experimentation at low cost, they cannot fully reproduce the physical behavior and sensing noise present in real drone systems. As a result, there remains a gap between purely simulated experiments and real-world field tests.

To bridge this gap, several research efforts have developed drone testbeds using augmented or mixed reality technologies [1]–[3]. However, these systems typically require large experimental facilities or complex equipment.

In this study, we develop a compact and versatile indoor testbed for image-based drone experiments using displays. The main contribution is a display-based testbed that tightly integrates physical drone dynamics with virtual environment rendering, allowing a real drone to interact with dynamically generated environments on screens. This approach enables efficient and controllable experimentation while preserving key real-world sensing and actuation effects. We validate the effectiveness of the proposed system through three case studies of distinct application scenarios.

II. TESTBED ARCHITECTURE

System overview of the testbed is shown in Fig. 1. The main components are (1) a display, (2) a drone, and (3) a computer.

The display is placed horizontally on a desk or floor and presents images representing the experimental environment. The drone flies above the display and captures images using a downward-facing camera. These images are transmitted to the computer via Wi-Fi.

The computer processes the captured images to obtain environmental information and estimates the drone's state. Based on this information, the system calculates control commands and sends them to the drone. The drone executes these commands and continues capturing images, forming a *closed-loop* control process.

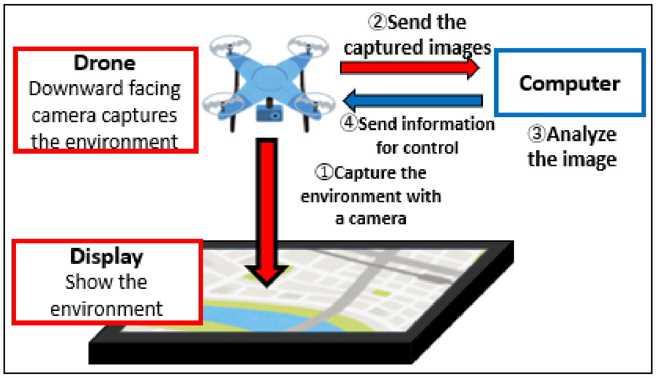

Fig. 1. Overview of the testbed

A. Generating Images for Environment Representation

Experimental environments are generated as images displayed on the screen. Objects such as targets, obstacles, and navigation markers are embedded within these images.

Key locations (e.g. start points, way points, goals, and obstacles) are defined using coordinates. Paths between nodes can be manually specified or automatically computed using (say) shortest-path algorithms. Markers such as QR codes can also be placed at node locations to provide positional information to the drone.

This image-based approach allows rapid modification of experimental environments and supports both static and dynamic scenarios.

B. Virtual and Physical Movement

To extend the effective experimental area beyond the physical display size, the system combines real drone motion with virtual environment motion. Instead of moving the drone across a large physical area, the environment image displayed on the screen can be shifted. From the drone's perspective, this creates the same visual effect as physical movement through the environment.

A conversion between pixel displacement on the display and real-world coordinates allows consistent integration of virtual and physical movement. As a result, experiments can represent environments significantly larger than the actual display area.

C. Drone Position Estimation using AR Board

Drone position estimation is performed using an AR board consisting of multiple ArUco markers displayed on the screen. By detecting these markers in captured images and applying the Perspective-n-Point (PnP) method, the drone's

This work was supported by JST ASPIRE Grant no. JPMJAP2519.

R. Hara and K. Cai are with the Department of Core Informatics, Osaka Metropolitan University, Osaka 558-8585, Japan (e-mails: sd24233f@st.omu.ac.jp, cai@omu.ac.jp).

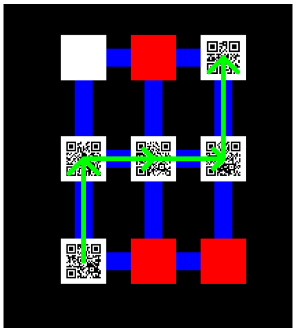

Fig. 2. Drone's path (Delivery)

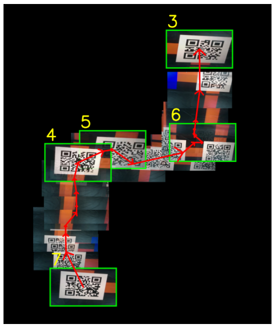

Fig. 3. Mapping image (delivery)

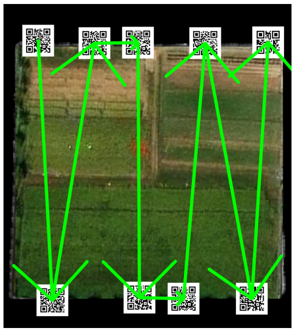

Fig. 4. Drone's path for farmland monitoring

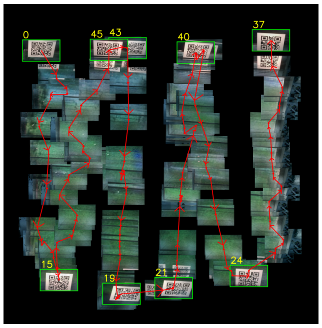

Fig. 5. Mapping image (farmland monitoring)

pose relative to the environment can be estimated. The estimated position is used both for trajectory analysis and for stabilizing drone motion during experiments.

III. EXPERIMENTAL CASE STUDIES

To demonstrate the effectiveness of the proposed testbed, three representative experimental scenarios were conducted.

For the drone, a lightweight, compact DJI Tello drone [4] is used. For the display, two displays (each of (width)1209.6 × (height)680.4 (mm), with resolution set to be 960 × 540 (px)) are connected to create a single large display.

A. Drone Delivery

In the first case study, the drone performs a delivery task by navigating from a start node to a goal node while avoiding obstacles. The environment is defined using node coordinates and obstacle locations. QR codes embedded in the environment provide navigation information. During flight, the drone reads these codes, obtains path information, and moves toward the goal. An example is as follows, and the flight path is displayed in Fig. 2.

- start = 7 (initial position of the drone)
- goal = 3 (target position of the drone)
- obstacles = (2,8,9) (position of obstacles)

Experimental results (Fig. 3) show that the drone successfully follows the planned path by combining physical motion and virtual environment movement.

B. Farmland Monitoring

As a second scenario, the drone performs farmland monitoring. An aerial image of farmland is used as the experimental environment. Nodes are automatically generated along the boundaries of the farmland, and a monitoring path is manually designed as in Fig. 4. The drone follows this path in a zigzag pattern to capture images across the entire field.

The results (Fig. 5) demonstrate that the drone can systematically scan the farmland environment and generate a mapping of monitored regions.

C. Disaster Response

The third scenario is search operations by the drone in a disaster environment (as in Fig. 6). The environment includes different types of obstacles and search targets (green squares). Some obstacles can be flown over (blue squares), while others must be avoided (red squares). The drone follows a predefined search map consisting of nodes and connections.

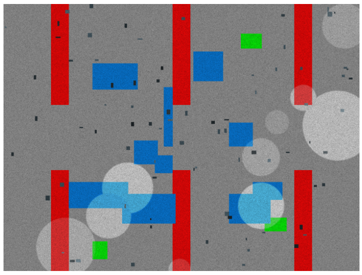

Fig. 6. Disaster environment

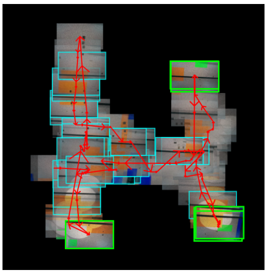

Fig. 7. Mapping image (disaster response)

During the search, the drone detects obstacles and targets using image analysis and records their locations. The results (Fig. 7) confirm that the system can identify objects (obstacles/targets) and map the explored region during the mission.

IV. CONCLUSION

This paper presented a compact indoor testbed for image-based drone experiments that integrates real drones with display-based environments and AR-based position estimation. The system enables efficient and flexible experimentation while preserving key real-world characteristics. Experimental results demonstrate its effectiveness across multiple scenarios. Future work will extend the framework to multi-drone coordination and more complex environments.

REFERENCES

[1] M. Afanasov, A. Djordjevic, F. Lui, and L. Mottola, "FlyZone: A testbed for experimenting with aerial drone applications," in Proceedings of the 17th Annual International Conference on Mobile Systems, Applications, and Services, pp. 67-78, 2019.

[2] K. A. Pant, L. Lin, J. Kim, W. Sribunma, J. M. Goppert, and I. Hwang, "Mixed-sense: A mixed reality sensor emulation framework for test and evaluation of uavs against false data injection attacks," in Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 12414-12419, 2024.

[3] R. Perez-Segui, P. Arias-Perez, J. Melero-Deza, M. Fernandez-Cortizas, D. Perez-Saura, and P. Campoy, "Bridging the gap between simulation and real autonomous uav flights in industrial applications," Aerospace, vol. 10, no. 9, 2023. DOI: 10.3390/aerospace10090814

[4] "Tello Official Product Page," RYZE, `https://www.ryzerobotics.com/jp/tello`, (accessed Jan. 2026).