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An Open-Source Mixed-Reality Simulation Environment for Unmanned Aerial Systems (UAS) Cybersecurity

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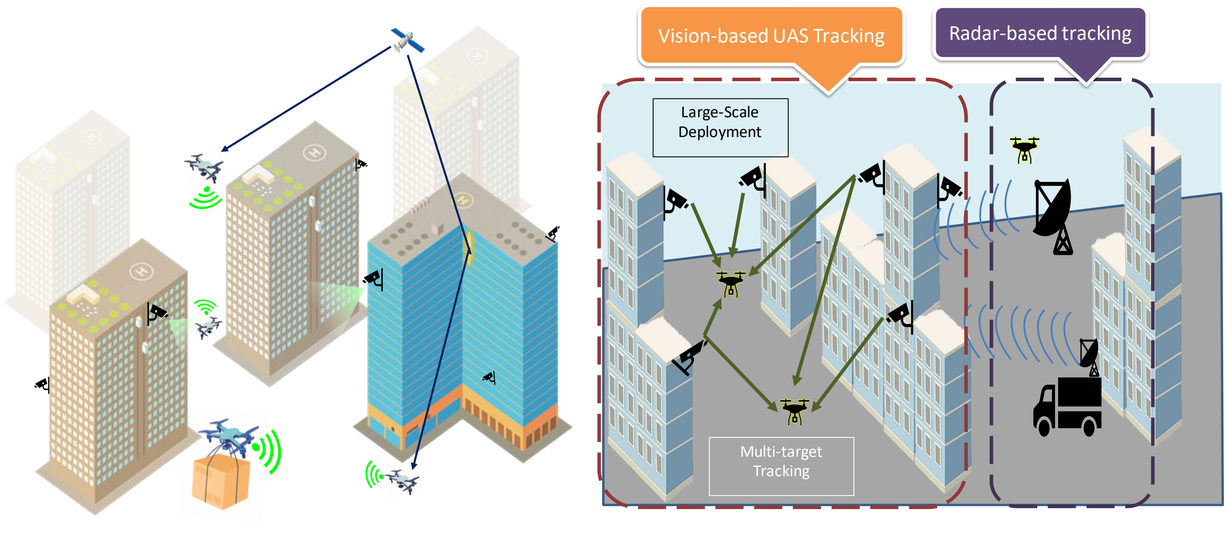
Motivation

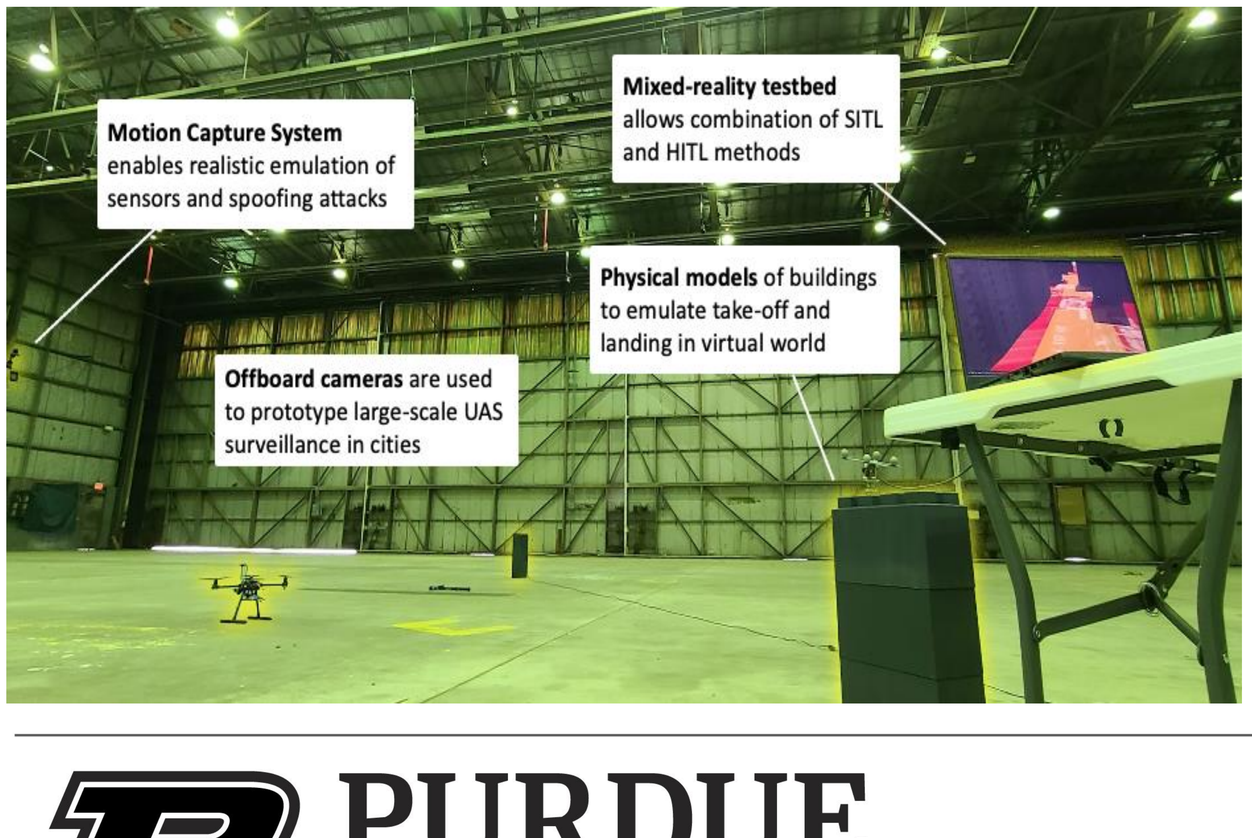
Safe and secure operation of UAS

The wide adoption of UAS in civilian and military applications requires rigorous **testing** and **validation** of UAS before deployment. However, due to regulations and physical limitations, **real-world** testing is difficult and expensive. A comprehensive simulation environment is necessary to allow UAS and cybersecurity researchers quickly iterate their designs and algorithms.



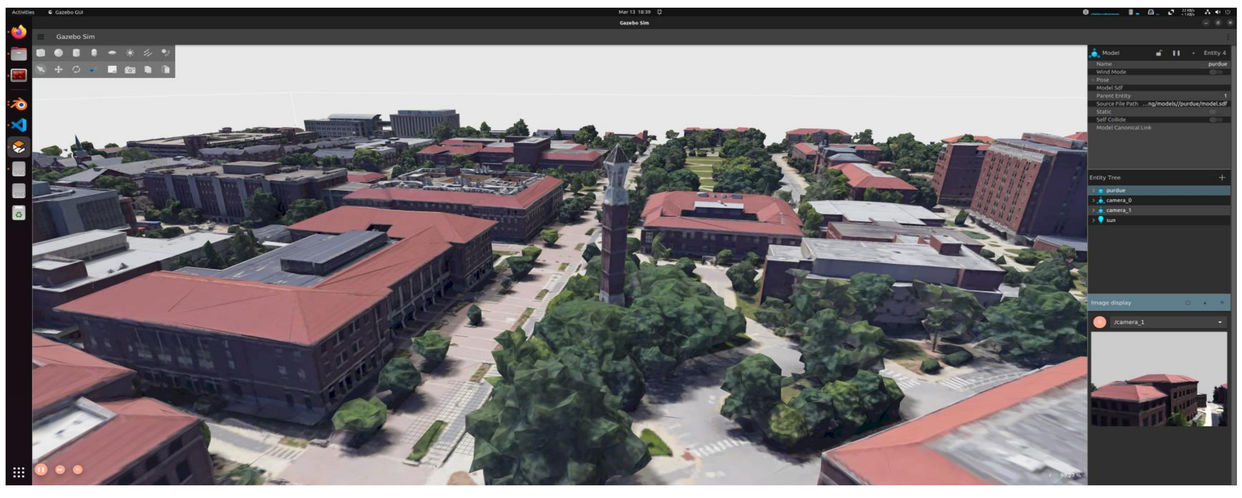
Salient Features

- **A simulation testbed** which combines hardware-in-the-loop (HITL) methods with software-in-the-loop (SITL) methods for verification and validation of UAS systems prior to their deployment.
- The testbed uses an **integrated mixed-reality approach with high-fidelity sensor emulation** [1], which recreates the complex geometrical effects that occur in dense urban environments.
- **3D GNSS multi-path characterization plugin**, which can be used for path planning and secure UAS navigation.
- It can be used to emulate the discovered cyberattack vulnerabilities, such as GNSS spoofing for (command and control) C2 takeover of drone.
- An extrinsic **vision sensor network** for UAS tracking in urban canyon environment [2].
- **Open-source** implementation for easy prototyping and wider use in the community.



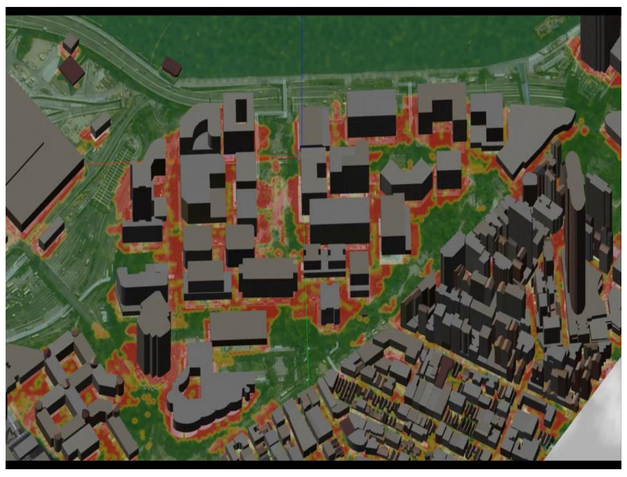
Main Results

- A high-fidelity 3D model of Purdue University is deployed in open-source **Gazebo** simulator.

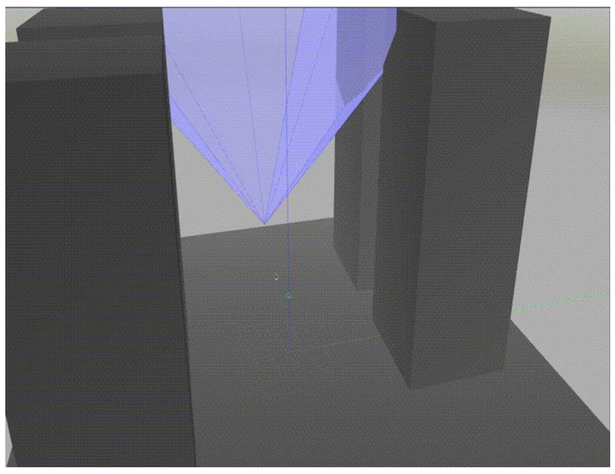


3D model of Purdue University

- Using the simulated environment, GNSS positioning errors in urban canyons are depicted as a **heat map**.
- A **ray-tracing** algorithm is used to compute multipath errors in urban environments.
- The red regions represent areas affected by **multipath effect** due to high rise buildings in urban canyons.

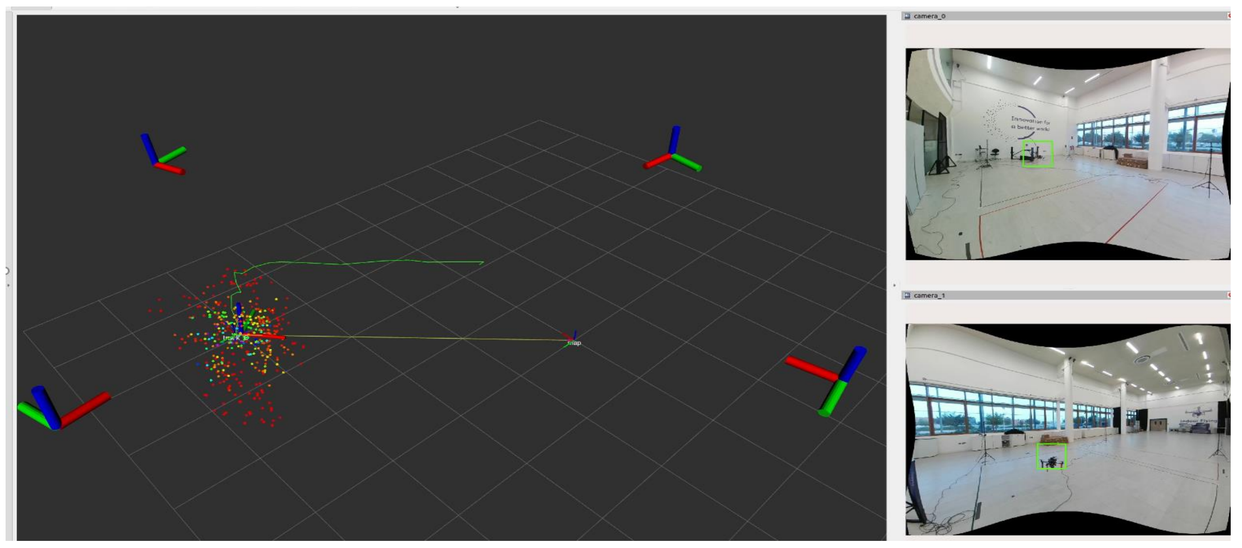


GNSS Error Heat Map



Ray-tracing in Gazebo

- **Vision-based offboard sensing hardware** (camera node boxes) with auto-calibration algorithm for multi-UAS surveillance in harsh outdoor conditions.



Live demo of UAS tracking system

References

[1] Pant, K. A., Yang, Z., Goppert, J. M., and Hwang, I. (2023). An Open-Source Gazebo Plugin for GNSS Multipath Signal Emulation in Virtual Urban Canyons. In *AIAA SCITECH 2023 Forum* (p. 2586).

[2] Yang, Z., Goppert, J. M., and Hwang, I. (2022). Target Tracking System for Urban Counter-UAS Using a Camera Network. In *AIAA SCITECH 2022 Forum* (p. 1474).

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