An Open-Source UAV for Autonomous Visual-Inertial Navigation and Manipulation

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INTRODUCTION

Unmanned Aerial Vehicles (UAVs) have become essential tools for executing complex tasks in fields such as mapping, logistics, and object manipulation. However, autonomous operation in indoor or dense urban environments, where GPS signals are unreliable, remains a significant challenge. This paper presents the development of Hermit, a modular and open-hardware UAV platform developed by the Pequi Mecânico Robotics Group [1] at the Universidade Federal de Goiás (UFG) to overcome these limitations. The system integrates advanced visual and inertial sensors with a robust software architecture based on ROS2 and PX4 [2], enabling localization, mapping, precision takeoff and landing, and aerial manipulation. The objective is to demonstrate an integrated and cost-effective solution for navigation and environmental interaction under adverse conditions.

MATERIALS AND METHODS

The Hermit's architecture was designed to be robust and modular, integrating both hardware and software for multimodal tasks. The physical structure is based on a carbon fiber X500 frame with PETG mounting parts, bringing the total weight to 2.5 kg. Its processing core consists of a Jetson Orin Nano onboard computer for high-level tasks and a Pixhawk 6x flight controller running the PX4 Autopilot firmware. The software stack, built on ROS2 Humble, ensures real-time communication, with key functionalities like perception and control encapsulated in Docker containers for modularity. For precise navigation in GPS-denied environments, the system fuses data from an Intel RealSense T265 visual-inertial camera, a D455 depth camera, and an ARK Flow optical sensor. This sensor data is processed by an Extended Kalman Filter (EKF) on the flight controller to achieve stable localization. A computer vision pipeline using a YOLOv8 model[3] handles the detection of objects and landing targets. K-means clustering is applied to bounding boxes to estimate the target center, which is fused with depth data from the D455 and the drone's odometry for precise 3D localization.

RESULTS AND DISCUSSION

The system was tested through simulations, structured field trials, and in demanding environments, including the RoboCup 2025 Flying Robots Demo [4]. This international event benchmarks autonomous aerial robots on tasks emulating logistics and search-and-rescue scenarios. The fusion of visual-inertial odometry and optical flow data enabled stable positioning. The vision pipeline performed reliably, identifying centroids from a video stream. However, achieving high-precision autonomous landing and manipulation remains an ongoing challenge. Inconsistencies in synchronizing the onboard estimate with ground truth impaired terminal alignment. Thus, while detection was successful, precise landing and grasping still required manual oversight.

Fig 1 Hermit UAV platform developed by the Pequi Mecânico Robotics Group.

CONCLUSIONS

This paper presented the Hermit, an open-source UAV that achieved stable autonomous navigation and reliable visual target detection in GPS-denied environments. While the perception system proved robust, inconsistencies in position estimation hindered high-precision landing and manipulation. Future work will focus on improving perception–control fusion to enable full autonomy for complex logistical tasks.

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