Fully Autonomous Live 3D Reconstruction with an MAV: Hardware- and Software-Setup

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In this demo we present a versatile Micro-Aerial Vehicle (MAV) setup demonstrating fully autonomous live 3D reconstruction in real-world scenarios. With the aim of reproducability we provide key information on both the hardware- and software-setup.

The value of vision algorithms for robotic perception has long been appreciated, but as their deployment onboard real platforms in real setups is often too cumbersome research progress is hindered. For this reason, great simulation tools have emerged, as for example, the work in [1] offering a far simpler alternative for prototyping new state-estimation and path-planning algorithms. However, the transition from simulation to reality is still a big step and of paramount importance for true robustness and applicability.

In order, for example, to reconstruct a structure of interest in 3D, the agility of an MAV can give access to all the necessary viewpoints much more effectively than using a tripod, however, a reliable platform and onboard estimation processes are imperative to accomplish the mission safely and accurately. In this spirit, we demonstrate autonomous path-planning with an off-the-shelf MAV and our software setup.

In a series of real-world experiments we deploy an adapted version of the autonomous reconstruction path-planner in [2]. With the overall objective of the planner to create an accurate and complete 3D reconstruction of an arbitrary environment, real-world experiments required an MAV platform with sufficient computational resources, robust state estimation capabilities, and a way to capture the 3D structure of the environment. Namely, for the MAV we use the commercially available *Holybro X500* quadrotor frame with a *Pixhawk 4* flight controller. The MAV is equipped with a stereo Visual-Inertial (VI) sensor featuring a high-quality inertial measurement unit and hardware-synchronized global-shutter cameras. Low-level motor control and sensor fusion is handled by the flight controller, while higher-level state-estimation and path-planning is executed on an *Intel NUC* companion computer mounted on the frame. For convenience, we have designed a hot-swap power controller to keep the computer powered at all times while switching the main batteries between consecutive flights.

Figure 1. MAV capable of fully autonomous flight with on-board perception during a 3D reconstruction experiment.

Although our MAV is equipped with an RTK GPS system, we only use the VI sensors for state estimation in our experiments, demonstrating its applicability in GPS-denied environments. We use VINS-Fusion [4] for stereo VI state-estimation. For obstacle avoidance and 3D reconstruction we calculate a 3D point cloud from stereo images using dense stereo matching[1] and incrementally merge these point clouds into a global map using Voxblox [3]. With this setup, shown in Fig. 1, we are able to demonstrate fully autonomous flights in the accompanying video[2] using on-board sensing and computation exclusively. Detailed instructions on the hardware- and software-setup are made publicly available[3].

References

[1] F. Furrer, M. Burri, M. Achtelik, and R. Siegwart. *RotorS – A Modular Gazebo MAV Simulator Framework*. Springer, 2016.

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[3] H. Oleynikova, Z. Taylor, M. Fehr, R. Siegwart, and J. Nieto. Voxblox: Incremental 3d euclidean signed distance fields for on-board mav planning. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2017.

[4] T. Qin, J. Pan, S. Cao, and S. Shen. A general optimization-based framework for local odometry estimation with multiple sensors, 2019.

[1] `https://github.com/ethz-asl/image_undistort`
[2] `https://youtu.be/ytru7-iqqB4`
[3] `https://github.com/VIS4ROB-lab/mav_hardware`