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SFly: Swarm of Micro Flying Robots

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Abstract— **The SFly project is an EU-funded project, with the goal to create a swarm of autonomous vision controlled micro aerial vehicles. The mission in mind is that a swarm of MAV's autonomously maps out an unknown environment, computes optimal surveillance positions and places the MAV's there and then locates radio beacons in this environment. The scope of the work includes contributions on multiple different levels ranging from theoretical foundations to hardware design and embedded programming. One of the contributions is the development of a new MAV, a hexacopter, equipped with enough processing power for onboard computer vision. A major contribution is the development of monocular visual SLAM that runs in real-time onboard of the MAV. The visual SLAM results are fused with IMU measurements and are used to stabilize and control the MAV. This enables autonomous flight of the MAV, without the need of a data link to a ground station. Within this scope novel analytical solutions for fusing IMU and vision measurements have been derived. In addition to the realtime local SLAM, an offline dense mapping process has been developed. For this the MAV's are equipped with a payload of a stereo camera system. The dense environment map is used to compute optimal surveillance positions for a swarm of MAV's. For this an optimiziation technique based on cognitive adaptive optimization has been developed. Finally, the MAV's have been equipped with radio transceivers and a method has been developed to locate radio beacons in the observed environment.**

I. Extended Summary

The goal of the SFly project [1] was to create a swarm of autonomous Micro Aerial Vehicles (MAV's) for applications in search and rescue missions. This video (additional videos are available on the SFly Youtube Channel [2]) demonstrates the use of the developed MAV's in a simulated disaster response situation. In the demonstrated mission, the MAV's are used to provide an aerial overview of the disaster scene and to locate victims.

In the first step of the mission a swarm of 3 MAV's autonomously explores the environment and captures aerial image data which is used to compute a 3D model of the disaster site. Based on the computed 3D model optimal coverage positions, to overlook the rescue operations, are computed and the MAV's are send to these positions. In the final step, possible victims are located by scanning for radio beacons which are worn by by people in the disaster area. For this the MAV's are equipped with radio transceivers.

The requirements of the SFly project made it necessary to develop a new MAV platform (Fig. 1). The SFly MAV (developed by the project partner Ascending Technologies) consists of a hexacopter base with a diameter of around 55cm [16]. It is equipped with an IMU for attitude control as well as pressure sensor and GPS. A highlight is the onboard computer, an Intel Core2Duo, which is powerful enough to do the real-time image processing of the onboard cameras. The MAV is equipped with a downward looking monocular camera which is used for flight control and a configurable stereo setup that can be either used for mapping or obstacle detection. The weight of the system is 1.5kg.

For flight control a local visual SLAM algorithm is running onboard and in real-time using the downward looking monocular camera. This allows stable hovering and also take-off and landing maneuvers [17], [5], [12]. The full state of the MAV is computed by fusing the visual SLAM poses with measurements from the IMU. This also resolves the absolute scale problem of monocular SLAM. The theoretical background for this is described in [3], [4], [8], [9], [11], [13], [14], [15]. The system is able to navigate autonomously by waypoint following.

The stereo system of the MAV can either be configured as downward looking or front looking. In front looking configuration the stereo system can be used for obstacle detection and avoidance. Stereo computation and path planning for obstacle avoidance runs in real-time on the onboard processor [10].

In its downward configuration the stereo system can be used to acquire data for 3D environment mapping. 3D mapping runs offboard on a ground station and fuses together the map data from all the MAV's of the swarm. The 3D mapping pipeline first computes an initial posegraph from stereo visual odometry and then performs loop detection using a vocabulary tree and posegraph optimization and then merges together the individual results of the MAV's. A full bundle adjustment is used as a final optimization step.

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