Bauhaus-Universität Weimar

SLAM for UAS: Simultaneous Localization and Mapping for Unmanned Aerial Systems

Fig. 1 - Asctec Pelican Quadrocoptor

TECHNICAL DATA –ASCTEC PELICAN	
UAV Type	Quadcopter
ONBOARD COMPUTER	Up to 3rd Generation Intel® Core™ i7 processor
SIZE	651 x 651 x 188 mm
MAX. TAKE OFF WEIGHT	1,65 kg
MAX. PAYLOAD	650 g
FLIGHT TIME INCL. PAYLOAD	16 min.
RANGE	4,500 m ASL, 1, 000 m AGL
MAX. AIRSPEED	16 m/s
MAX. CLIMB RATE	8 m/s
MAX. THRUST	36 N
WIRELESS COMMUNICATION	2,4 GHz XBee link, 10–63 mW, WiFi (optional)
INTERTIAL GUIDANCE SYSTEM	AscTec AutoPilot with 1,000 Hz update rate
FLIGHT MODES	AscTec AutoPilot with 1,000 Hz update rate
EMERGENCY MODES	Direct landing, Comehome straight, Comehome high

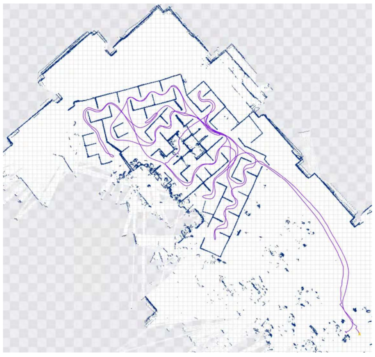

Fig. 2 - Map acquired using SLAM algorithm [1]

Simultaneous Localization and Mapping (SLAM) enables autonomous exploration of unknown indoor and outdoor environments without or few manual interaction as well as preliminary information. SLAM approaches solve the problem of mapping unknown environments while simultaneously estimating the UAS pose within these maps. Pose estimation is usually tackled by the fusion of measurements from GPS, IMU and other sensors like compass and barometer based on Kalman Filtering, Extended Kalman Filtering or Particle Filters. Especially in GPS-denied environments pose estimation based on the aforementioned sensors is known to be affected by high drift rates due to dead reckoning. Hence, several systems which additionally incorporate laser range finders and cameras were proposed. These exteroceptive sensors are often used in conjunction since they rely on different measurement principles and therefore offer complementary failure modes. Fig. 2 shows a map acquired using a SLAM algorithm.

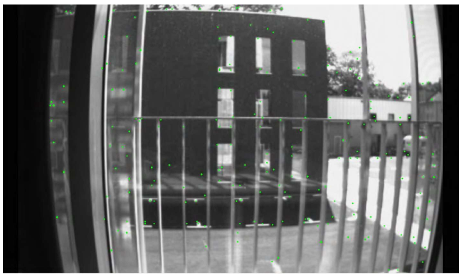

Fig. 3 - Feature detection using SVO

A central issue in SLAM is to estimate the pose of the UAS, which can be done using techniques based on stereo-cameras and laser-scanners. **Visual odometry** consists of two main steps: feature detection and motion estimation. An overall estimation frequency of at least 10 - 15 Hz should be achieved due to the fast flight dynamics. We used the Harris-based Shi-Tomasi corner detector [2] along with the Lucas-Canade method [3] for a fast matching of features in all four images of two subsequent stereo frames. The relative orientation of the moving left and right camera are computed using the RANSAC approach [4].

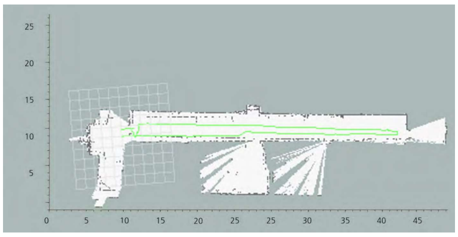

Fig.4 - Map created with Hector-SLAM [1]

For the **laser scanner-based odometry** the Hector SLAM [1] approach is utilized, since it enables the processing of measurements acquired with a scan rate of up to 100 *Hz*. While a navigation filter is used for the 6DOF pose estimation, a 2D SLAM component provides a map as well as the positioning and heading of the UAS related to this map. Please note that for a full 3D pose estimation additional sensors, e.g. a downward looking sonar, is required. Since the used implementation solely uses IMU data, only 2D pose estimations are possible here.

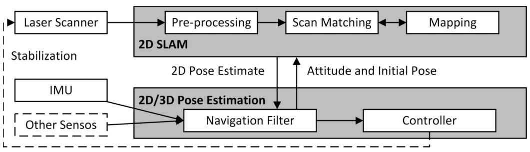

Fig. 5 - Pose estimation using sensor fusion

Preliminary results

As can be seen In figures 2, 3 and 4 the results are accurate enough to facilitate the idea of an autonomous flight. Thus far, we have conducted the experiments using the Asctec Pelican UAS (Figure 1) placed on a stable wheeled platform. For safety reasons we have not yet tried using the UAS in indoor flights.

In the future we would like to develop a system which allows the UAS to autonomously navigate and simultaneously map an unknown indoor environment without the need for a human operator.

In order to achieve the above mentioned goal we first have to implement a reliable localization system and a reliable obstacle detection and avoidance mechanism which is currently under development.

References

[1] S. Kohlbrecher, O. von Stryk, J. Meyer and U. Klingauf: A flexible and scalable SLAM system with full 3D motion estimation. IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), 155-160, November 2011.
[2] J. Shi and C. Tomasi: Good Features to Track. 9th IEEE Conference on Computer Vision and Pattern Recognition, Springer, 1994.
[3] B. D. Lucas and T. Kanade: An iterative image registration technique with an application to stereo vision. In Proceedings of the 7th international joint conference on Artificial intelligence (IJCAI'81), Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2, 674-679, 1981.
[4] R. I. Hartley and A. Zisserman: Multiple view geometry in computer vision. Cambridge University Press, 2nd edition, 2004.