Cooperative localization and tracking in landing scenarios with autonomous boats and quadcopters (1-2 students)

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Background Description

Autonomous cooperative landings have many applications, for example in search and rescue scenarios, autonomous product deliveries and emergency landings. To perform such a landing, a cooperative control algorithm is applied to the vehicles to drive them to rendezvous. An important aspect of any such cooperative rendezvous control algorithm is the relative state estimation. For the landing to be safe and efficient, the information from the different sensors need to be fused and weighted in a real-time. This master thesis project will focus on the relative state-estimation between an unmanned aerial vehicle (UAV) and a mobile landing platform using commercial grade positioning sensors.

The master project will be a part of tests performed in the WASP [1] Autonomous Research Arenas (WARA) [2][3]. WASP and WARA are part of a large research project with connections to industry. This project will be performed in collaboration with Saab[4], and Combitech[5]. There is a larger demonstration planned in Västervik in the autumn of 2019.

The UAV is a commercial grade quadcopter and the mobile landing platform is a modified fast military assault craft developed for the Swedish Navy.

Detailed Project Goal

The goal of this master thesis project is to derive and implement a filter that estimates the relative state between the UAV and the landing platform, and to write the software for extraction, communication, and fusion of data from the sensors.

The quadcopter is equipped with GPS, IMU and a camera, and algorithms can be implemented in the Robot Operating System (ROS). In previous work, visual markers (AR tags) have been pasted onto the boat for the camera to detect. Given knowledge of the size and geometry of the markers, the relative position and attitude could be estimated for the quadcopter. However, due to robustness issues, the detection of the marker was intermittent and occasionally unreliable.

For the control algorithm to work sufficiently well, requirements on the accuracy and precision of the estimation algorithm are:

- >50 m away from the boat, only GPS precision is needed.
- Within 5-50 m, a precision of 0.5 m is needed .
- At less than 5 m, a precision 10 cm is needed.

Exchange raw measurements of GPS and IMU, and include UWB

To increase the accuracy of the relative state-estimator, the boat and the drone can exchange the raw measurements of their respective GPS and IMU sensors [9-12]. Then the filter on the drone will have access to the motion measurements and the pseudo-range measurements of the GPS satellites of both the boat and the drone. The advantage with this setup, is that the same systematic error in the GPS measurements will cancel each other out in the estimation of the relative position and orientation. This setup should preferably be augmented with Ultra Wide Band (UWB) [8] sensors to get an accurate measurement of the distance between the boat and the drone.

This track can further be divided into data collection and algorithm development:

Concerning the data collection, the goal is to install the sensors (GPS+IMU+UWB) onto the boat and drone, and then setup the communication network enabling exchange of the raw data from these sensors into the ROS framework. The communication could be done using regular WiFi or the UWB transmitter.

The goal of the estimation algorithm, is then to merge the raw measurements of the sensors, and estimate the relative position and orientation of both platforms. The algorithm development could be performed independently of the data collection. The performance can initially be analyzed through Monte Carlo simulations, and if there is time, the Cramer-Rao lower bound on the variance can also be derived for the estimator.

Desirable Skills

Required skills:

1. Kalman filtering
2. Modelling of Dynamical Systems

Nice to have:

1. Particle filtering.

2. Statistics
3. Experience with ROS/Python/C++

References and Background Material

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