University of Southern Denmark

Master project - Autumn 2020

Vision based navigation and precision landing of a drone

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Institute name: Teknisk Fakultet (TEK)
Project type: Master Project
Number of ETCS-points: 40
Project period: 2020-09-01 - 2021-06-01

Contents

1 Introduction

When drones are set to fly autonomously they rely heavily on the Global Navigation System (GPS). Most of these systems comes with an error in the range of meters. To achieve better, real time kinematics (RTK) can be used, which reduces the GPS error to centimeters. However, RTK is pretty expensive and hence not an optimal solution for low cost applications. Moreover, for indoor navigation, the use of GPS would not be possible because of the reduction in signal strength.

A solution to this problem could be to use a camera placed on the drone and analyzing the incoming data using computer vision. By placing markers on the ground, the position of these objects could be found with high precision. This would lead to autonomous flight tasks where high precision of the position is needed.

This paper proposes methods for navigation in environments using computer vision. The basic idea of this can be seen in Figure 1. Here the drone will fly autonomously using GPS coordinates until a higher accuracy is needed. In this case, it will be the navigation and precision landing of the drone using markers on the ground. Hence, the drone will follow the markers till a landing is required which is illustrated as step 3. The markers considered in this case will be ArUco markers, where the detection of these markers have been shown to be very accurate and reliable in changing light conditions [3]. In this example, the same marker is used for illustration, but different bit encoded ArUco markers will be used to navigate the drone to the landing sight. This is a cheap and effective solution when lack of GPS precision is present e.g using low cost GPS systems or inside buildings [1].

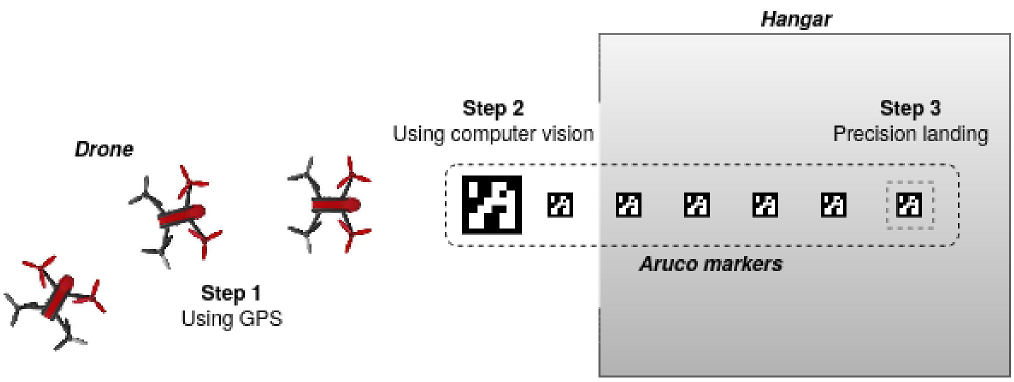

Figure 1: Illustration of the steps of a drone navigated autonomously using GPS to indoor navigation using computer vision leading to a precision landing

The robot operating system (ROS) will be used in order to achieve autonomous flight of the drone with Gazebo as the simulation environment so that the drone can be sufficiently tested before flying. Testing of the drone will take place at Hans Christian Andersen Airport in Odense which is why the building labeled *Hangar* is used in Figure 1.

The reason for choosing this area of subject is because of the ongoing HealthDrone project. This project is about transportation of patient samples between Odense University Hospital (OUH) and Svenborg Hospital using drones autonomously. This is a three-year innovation project funded by Innovation Fund Denmark and is to be completed in 2021 [2].

To accomplish this, an efficient and robust solution for indoor navigation and landing must be considered for where battery recharging or replacement are to be performed as well as delivery of patient samples. The reduce delivery time, the indoor navigation and landing of the drone must be a fast as possible. Furthermore, because the drone is to land on a recharging or battery replacement station, the landing must be performed with a very high precision. Due to the fact that the drone is to be operated in changing weather conditions, it must be able to detect and decrease its altitude according to the markers on the ground in windy conditions. This demands for a robust solution for the transition of using GPS coordinates to computer vision for indoor navigation.

1.1 Problem Statement

The drone must be able to fly autonomously according to ArUco markers on the ground using computer vision. This leads to the challenge of finding a robust solution for the transition of using GPS coordinates to indoor vision based navigation even in windy conditions. Furthermore, the precise landing should be implemented in such a way that the settling time, from which the drone is hovering above the marker to the landing is performed, is minimized. The same goes for the error associated with the precise landing.

This leads to the following problems:

- How can computer vision be used to detect objects?
- How can a smooth transition between using GPS coordinates to vision based navigation be found?
- How can navigation between objects be performed?
- How can a precise landing be executed?
- How can the settling time of the landing be reduced without causing instabilities to the drone?

1.2 Specification of requirements

From the outline of the project as well as the problem statement, the following requirements for the project have been formulated:

- The error of the landing must not exceed ± 10 cm.
- The drone should be able to make the transition of using GPS coordinates to indoor vision based navigation even in windy conditions e.g up to 8 m/s.
- The landing must be performed within 5 seconds from which the drone is hovering 2 meters above the landing sight to a landing is performed e.g a settling time below 5 seconds is wanted.

2 Materials and methods

A tentative time schedule for the project has been formulated which can be seen in Figures 2 and 3. The first part of the project will focus on the creation of CAD models for buildings and markers. This will be used heavily in the simulations. The implementation of ROS will be initiated from where the basis of the project will take place and sensor simulations of the drone for IMU, GPS and camera data have to be extracted for further analyzing. Hence, the main focus of the project for 2020 will be the computer vision part where marker detection, pos estimation, navigation between markers and landing will be in focus. This will be programmed in python with OpenCV as the computer vision software.

The first draft of the report is expected to be given to the supervisor in the end of December 2020. This will involve theory, methods used and initial testing of simulations of the drone.

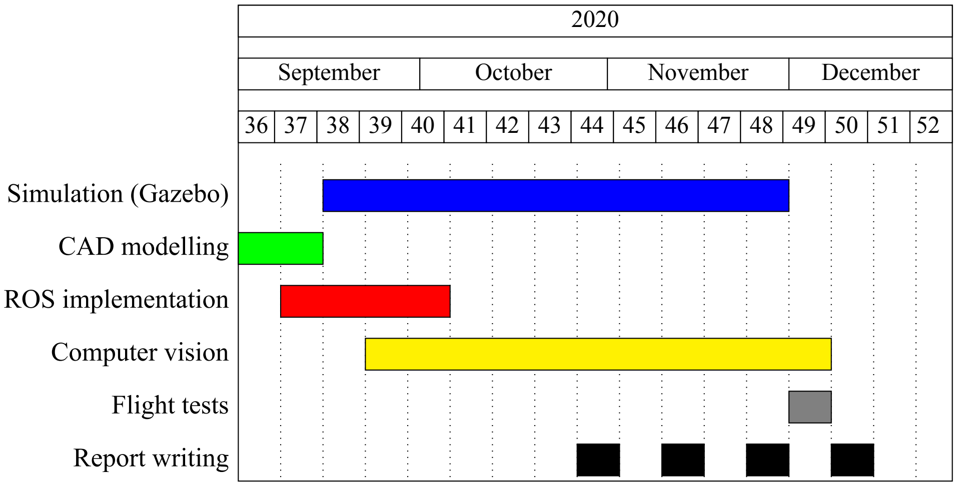

Figure 2: Tentative time schedule for 2020

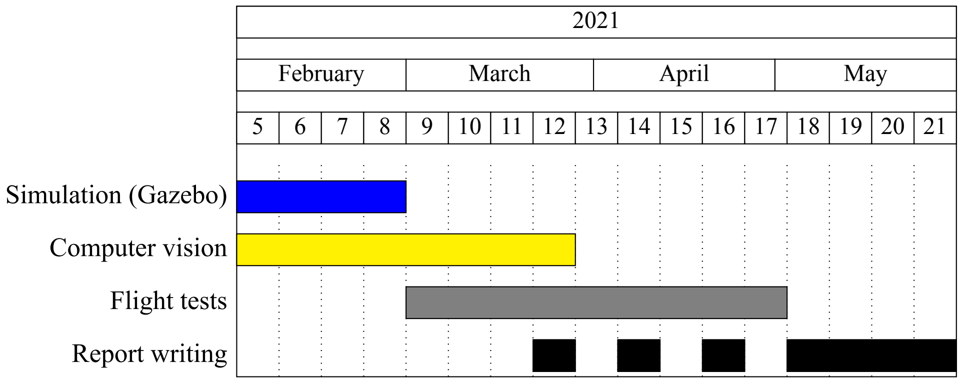

Figure 3: Tentative time schedule for 2021

In the second part of the project, the focus will be to reduce settling time of the landing as well as wind simulations. In this stage, the drone will be tested in real conditions. Hence, lot of time has been put side for testing of the drone, where computer vision would still play a big part because chances to the software will be expected when shifting to real flight from simulations.

The final report as well as software used in the project will be handed in the end of may 2021, where the project is expected to be done.

The materials used in this master thesis can be seen in table 1. This consists of a drone where the markers on the floor are expected to be made from foil. The markers can be placed on the floor and used throughout the project. This project is expected to have a tentative budget in the region of 3000 kr.

Table 1: Tentative budget for the master project is set to be approximately 3000 kr. The used materials and prize can be seen in the table

Description	**Prize**
Quad with a DJI SK500 frame and Pixhawk 2.1	$\approx$ 2500 kr.
Printed foil to markers	$\approx$ 500 kr.
Overall	$\approx$ 3000 kr.

References

[1] Dias S. S. & Santos D. A. Dos & Barbosa J. P. D. A. *A Visual-Inertial Navigation System Using AprilTag for Real-Time MAV Applications*. Available at: `https://doi.org/10.1109/M2VIP.2018.8600901`. Accessed: 17-08-2020. 2018.

[2] HealthDrone. *HealthDrone*. Available at: `https://sundhedsdroner.dk/`. Accessed: 18-08-2020. 2018.

[3] Monteleone S. & Catania V. & De Paz J. F. & Bajo J. & La Delfa G. C. *Performance analysis of visualmarkers for indoor navigation systems*. Available at: `https://doi.org/10.1631/FITEE.1500324`. Accessed: 17-08-2020. 2016.