Autonomous control of quadcopter swarms in confined spaces

Sebastian Green, Pontus Månsson

Popular science summary of the master's thesis project:
Autonomous control of unmanned aerial multi-agent networks in confined spaces [Green and Månsson, 2019a]

Aerial drones have in recent years seen large improvements through lower production costs and improved performance. While a single drone can be used to accomplish a large variety of tasks, having multiple agents work together opens up a lot of opportunities for performing tasks in parallel, or dividing the workload into smaller, simpler operations. Manually controlling multiple drones at the same time is difficult, whereby we present two ways to autonomously control a large group of drones, demonstrated on the Crazyflie system.

Introduction

Most of the drones available for purchase at the time of writing utilize some form of driver assistance, usually in the form of onboard sensors and controllers to stabilize the quadcopter. This is to allow the operator to focus on positioning and the task at hand while the electronics control how much thrust should be generated by each motor to ensure the drone does not spiral out of control. This kind of assistance works well when the operator only has a very limited number of vehicles to control; however, as the number of vehicles increases, the task of manually operating them quickly becomes unmanageable. This thesis explores ideas for autonomous control of a swarm of drones, specifically a swarm of Crazyflie quadcopters. A picture of the Crazyflie 2.1 nano-quadcopter can be seen in Fig. 1.

Figure 1: *Crazyflie quadcopter*

Swarm modelling

Flying vehicles can be a pain to work with, due to their fragile and unstable nature. While a car may crash into obstacles or roll and get damaged, it can usually be stopped simply by applying the breaks and cutting the power. Doing the same to a drone during a flight results in a hard crash landing. Therefore, we have developed a simulation model of the Crazyflie swarm that allows testing of different controllers without damaging anything. An overview of the model can be seen in Fig. 2.

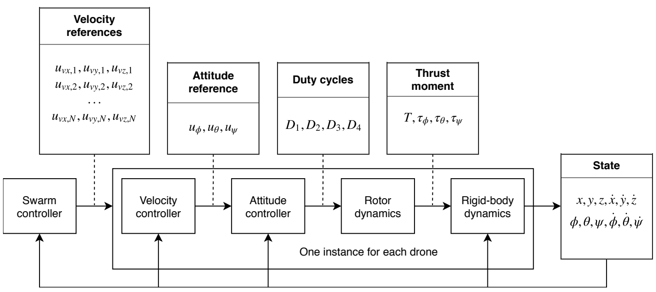

Figure 2: *Crazyflie model overview*

Swarm control

The two controllers implemented are based on the principles of *distance control* and *flocking*. The purpose of both controllers is to figure out what velocity each drone should have as well as in which direction. Each controller has a set of rules or objectives that it tries to accomplish, which affects the velocity reference sent to the drones. This is all done on a single computer which communicates with all the drones wirelessly.

Flocking

The flocking controller implemented is a variant of the flocking behaviour derived from the basic rules outlined in [Olfati-Saber, 2006]. Each behaviour corresponds to a goal of the individual drone, and as such the controller is completely dynamic in the sense that no formation or leader is predetermined. The three main behaviours are: following a reference, avoiding neighbours, and matching velocities as illustrated in Fig. 3.

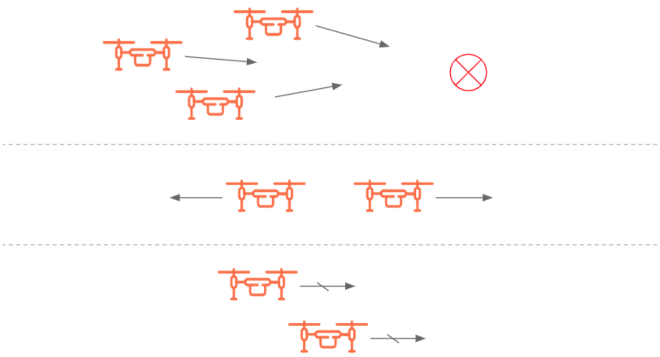

Figure 3: *Flocking controller illustration*

Distance control

As the name suggests, the distance controller has set target distances between each and every drone. This makes it possible to set up specific swarm formations, such as a line, circle or pyramid. To address the earlier mentioned operator issue, the operator only has to set a single position; the center position of the swarm. The controller then takes care of the rest, moving the whole swarm while keeping the formation and making sure the drones do not collide into each other.

Results

The simulated swarm model proved surprisingly accurate compared to the real drones, and gave good insight into the characteristics of the swarm as seen in Fig. 5. Animations of the model running, as well as some videos of the real swarm flying can be found on Youtube [Green, 2019]. The simulation environment as well as the software for controlling the drones is available on Github [Green and Månsson, 2019b]. Both controllers worked very well with the precise accuracy of the Lighthouse positioning system, and a picture of four drones flying can be seen in Fig. 4.

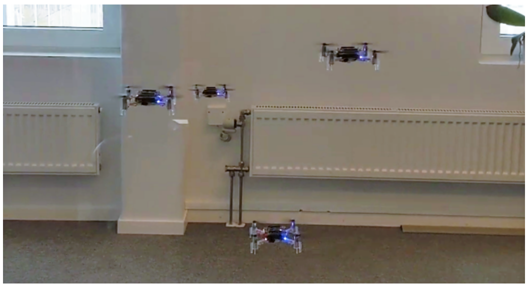

Figure 4: *Four drones in autonomous flight*

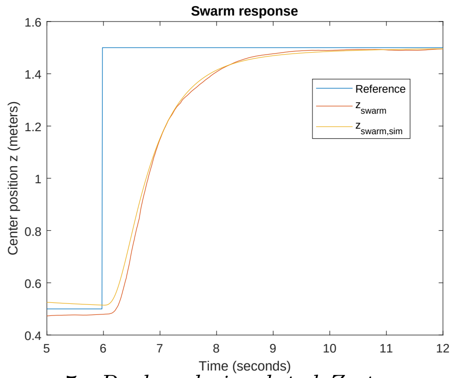

Figure 5: *Real and simulated Z step response*

References

Olfati-Saber, R. (2006). "Flocking for multi-agent dynamic systems: algorithms and theory". *IEEE Transactions on Automatic Control* **51**:3, pp. 401–420.

Green, S. (2019). *Crazyflie thesis playlist*. `https://www.youtube.com/playlist?list=PLTolAbCMaBCRM7MJTkO-CZOYIo9oHVG9a/`.

Green, S. and P. Månsson (2019a). *Autonomous control of unmanned aerial multi-agent networks in confined spaces*. TFRT-6084. Dept. of Automatic Control, Lund University, Lund, Sweden.

Green, S. and P. Månsson (2019b). *Crazyflie swarm project*. `https://github.com/greensebastian/crazyflie-swarm`.