ESA-PDEng Project 2018

Introduction

The Model Driven Engineering (MDE) approach is a new software engineering trend that is becoming increasingly popular these days among different organizations and companies. A representative example is the European Space Agency (ESA) which is developing its own platform, TASTE, that enables developers to combine various kinds of technologies in a single model. ESA not only develops this platform, but also promotes this novel technique to the outside world. For this purpose, ESA is collaborating with the TU/e PDEng programs in the current project.

The main objectives of this project were two. Firstly, the team of PDEng trainees had to use ESA’s open-source modelling platform and give feedback on it in order to improve its robustness and promote the model-based system development approach. Secondly, we had to create a formation flying demonstration with Crazyflie drones, which can be used on the ESA Open Day 2018, in order to showcase the role of software in spacecraft.

These high-level objectives were translated into three business deliverables. First, we had to move the position control algorithm from the ground station onto the drones. Second, we had to improve the absolute position determination system, by having several high-definition (HD) webcams observing the scene from above at different angles. Last, we had to implement a lightweight physical enclosure (e.g., with 3D printing) that acts as a safety measure and means of identification for the drones.

Out of these three business deliverables, we managed to successfully implement and deliver the latter two, while also making good progress on the first one. Our shortcoming on the first deliverable can be partly attributed to technical difficulties, inexperience of the team with the relevant technologies, and time constraints. Regardless, we provided the customer with a solid codebase that can be used as a basis for future development, along with valuable feedback on the TASTE platform.

Methods

Due to the multidisciplinary nature of the project, our team consisted of twelve trainees from different backgrounds, namely two Automotive Systems Design

(ASD) trainees, four Mechatronic Systems Design (MSD) trainees, and six Software Technology (ST) trainees. The team followed the Agile approach to software development and, in particular, the Scrum framework. With regard to the team structure, we organized ourselves into two cross-functional sub-teams that collaborated closely. To be more specific, the teams were working on the first two business deliverables in parallel, as they were mostly independent of each other. The third business deliverable was sufficiently small to be handled by a single team member.

For the position control algorithm, we tried to implement a position controller that would run as an outer loop onboard the drone. This controller would feed the proper values into the attitude controller that was already running as the inner loop onboard the drone, implemented in the drone's Ada firmware. Our position controller was implemented as a Simulink block in our TASTE application, consisting of various control components.

Regarding the camera system, we extended an existing solution that was provided to us by ESA, by replacing the colored identification tags with ArUco markers and introducing more cameras. The former was made possible by making use of the OpenCV library, while the combination of feeds from multiple cameras was made possible by a Kalman filter implementation in MATLAB. This filter was later on compiled into the equivalent C code by means of the built-in code generator.

Finally, for the physical enclosure, we researched existing solutions that could be implemented by 3D printing CAD models. We came up with an array of proposals and we rated them against a number of characteristics such as weight, material, safety, identification possibility, and docking possibility.

Results

The new position control algorithm was partially implemented, due to a number of issues on the Ada firmware that we did not manage to resolve within the given time frame. More specifically, the firmware lacked an Extended Kalman Filter (EKF) for sensor data fusion. In addition, the sensor calibration sequence of the firmware proved to be unreliable. As a result, we reverted to the stock C firmware for the demonstration scenario and provided our codebase to ESA in order to extend it in the future.

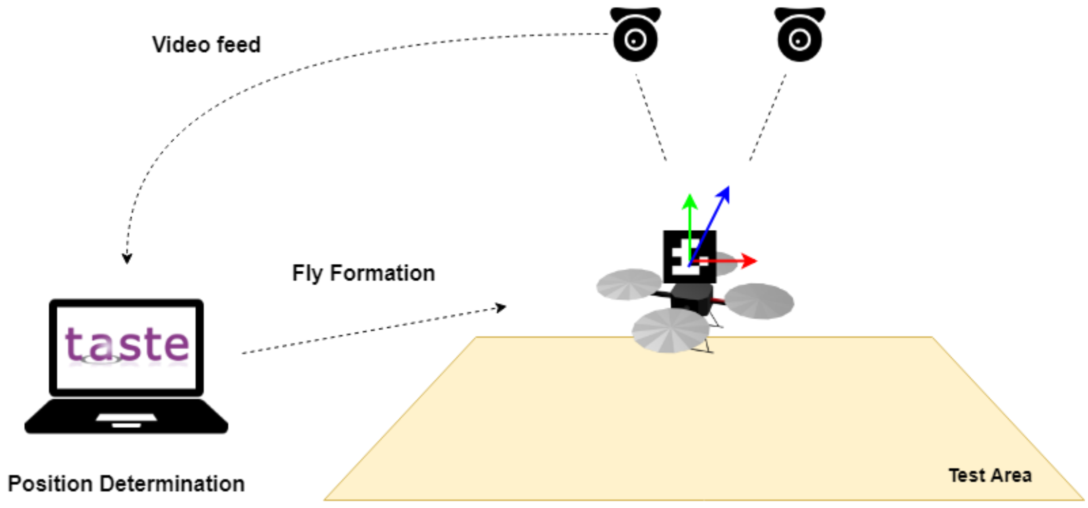

Figure 1. Illustration of the final demo setup.

With regard to the camera system, our solution proved to be superior to the previous one, since the introduction of multiple cameras allowed for increased accuracy of the absolute positioning algorithm. Moreover, the ArUco markers are more robust against fluctuations of the light conditions (i.e., ambient light), due to their relying on black-and-white contrast rather than color identification.

Finally, we managed to address the customer's concern with reference to the physical enclosure. After presenting our proposals to them, they accepted our recommended design, which we proceeded to order for 3D printing and delivery to them.

Conclusions

The PDEng team managed to provide significant value to the customer, despite the unforeseen technical difficulties in the onboard position control algorithm. We managed to deliver two out of three business requirements, along with valuable feedback on the TASTE platform itself, which was one of the main objectives of the project.