Workplan for project A3: Motion Control of Unmanned Aerial Vehicle

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1 Background

Unmanned aerial vehicles, also known as UAVs, are becoming nowadays more and more popular because they are small, cheap to produce, have low operating and maintenance cost, have great maneuverability, can perform steady flight operations and are able to enter high-risk areas without having to compromise human safety. Most applications that involve UAVs have been used in open areas without any obstacles and with a human in control of the UAV. But in recent years people have come up with more modern applications of UAVs that will need UAVs to fly autonomously in densely populated areas, with a lot of other autonomous UAVs around, e.g. Amazon Prime Air delivery system, AltiGator drones services for inspection and data adquisition, or multi-UAVs used to deploy an aerial communications network. This places high demands on UAVs' obstacle avoidance capabilities for both moving and static obstacles.

There are many different manufacturers and a vast amount of different UAV models, all with different motors, weights, sensors and lift-to-weight ratio. To make a standard autonomous flight applicable to all these kinds of UAVs, a simple and easy-to-implement multi-UAV mathematical model, that will still be able to avoid obstacles with as few sensors as possible, is needed.

This project aims to study and develop a mathematical model of a quadrotor UAV and the available sensors in it. From the trajectory and pose tracking a state feedback controller will be designed. In order to facilitate the multi-UAV navigation, potential fields or an A* algorithm will be used to make several quads fly to their goals while maintaining collision avoidance with respect to other quads and obstacles. To check the validity of the models, a simulated test environment in MatLab filled with a random reasonable amount of static obstacles and autonomous UAVs will be used.

2 Goals

- Find and read a combination of papers that describe the modelling of the UAVs, sensors, tracking potential field and simulation well enough for us to be able to complete the project.
→ The literature goal can be considered complete when the literature proposed by the supervisor and other interesting documents proposed by the students have been collected so there are at least 3 papers analysed and compared for each section (modelling of the quad, of the sensors or for the tracking) and a presentation about the theory behind all parts have been presented and accepted by the supervisor.

- Mathematical Model. Have a robust model for the kinematics and dynamics of the UAV, and its sensors.
→ The mathematical model goal is to be able to describe the UAV with a matrix that includes its position, its linear velocity, its angles (roll, yaw and pitch) and its angular velocity, all of them related to a certain fixed reference frame that we can relate with, for example, the initial frame.we should also have derived an equation for each of the necessary sensors: IMU sensor (accelerometer and gyroscope), an 360 degree proximity sensor and GPS. Each model will be tested with simple input data in MatLab and the results will be compared to calculations done by hand, if it satisfies the expected results calculated by hand the model can be considered complete.

- The goal for the control part is to be able to control the trajectory and stability of the UAV with a state feedback controller.
→ The control goal can be considered as completed when we are able, for a certain desirable movement of the UAV, to obtain the appropriate force of thrusters for the UAV to achieve the desired position as the UAV stays stable and follows the trajectory vector obtained from the potential fields. This will like above be tested with simple movements/scenarios that can be calculated by hand and then be compared to the model. The state feedback controller should also satisfy the robustness criteria, observability, controllability and be stable.

- When the simulation is completed it should be able to actually run multiple UAV:s in a 3D-space without colliding. This also verifies that all the previous steps have been appropriately carried out so the main purpose of the project is achieved. Extract results.
→ The simulation goal can be tested by testing the proper functioning of the mathematical models that have been implemented with numerical examples and compare outputs in the simulation with the models output from earlier tests. Then we need to test our simulation, at least in a 2D-simulation and preferably in a 3D-simulation. The simulation should have at least 95% of the UAVs arriving to their goals without getting stuck or colliding.

When we have completed the goals for a section in the first level of the work tree we will give a small presentation to our supervisor about that section. We will present the goals we aimed at for that part of the project, the model we came up with or the results we had, and then motivate that we have completed the said goals. This will give us a chance to show that we really understand what we have done and will probably help with the report later on since it'll give us a chance to explain what we have done and why we have come up with those results, just like we will do in the report. The report should be done by the 30th of April, and the rest of the deadlines are specified in the Project Model section.

3 Organization

Member name	E-mail	Telephone number	Position
Christos Verginis	cverginis@kth.se	0704438285	Supervisor
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4 Project Model

Phase	Sub-phases	Description	Schedule
Modelling	Quad	Complete the UAV (kinematics and dynamics) mathematical modelling goal. It is done in parallel with the sensors sub-phase.	1-Feb → 4-March
	Sensors	Complete modelling all the sensors that should be used as to complete the modelling goal. It is done in parallel with the quad sub-phase.	1-Feb → 4-March
Control	Tracking	Make a controller that makes our UAV go in a certain direction with stability. It is the first step of out control phase since it is more related with the previous phase.	26-Feb → 16-Mar
	Navigation	Starts after the tracking so we can work with the potential fields method to obtain the direction the UAV needs to follow, and then check how the tracking is done. When this sub-phasre and the tracking are completed and checked with the simulation, the goal for the control is achieved.	5-Mar → 23-Mar
Multi-agent case	Model	Starts after the single case modelling and control are finished and tested. Work on the model for a multi-UAV scenario.	26-Mar → 6-Apr
	Control	Work on the control for a multi-UAV scenario. The multi-agent case goal is completed after this sub-phase and the model are finished and its effectivity has been checked with a simulation.	26-Mar → 6-Apr
Simulation		Simulation starts when modelling is finished as to check its validity and complete the modelling goal. Simulation is resumed again when the control has finished to check again its validity and the same for the multi-agent case. Finally, a week is spent to put together all the other parts, and finish all the program and the interface so the simulation goal can be achieved.	12-Mar → 13-Apr
Report		The report is roughly written during all the other phases, but in the end we will leave 3 weeks specially to focus on finishing the report. It may be modified after the presentation with the feedback, and it should be on time for the final report deadline	9-Apr → 27-Apr & 8-May → 23-May
Presentation		A whole week is spent when the preliminary report is finished as to make the presentation as best as possible to fit the time we have available.	30-Apr → 4-May

In the case the schedule was not kept, certain phases will overlap another ones, but we will not delay the next phase, so the workload will increase.

Milestone	Deadline	Goals
Status report 1	12-Mar	For the first status report, we will have done all the modeling and a half part of the control, which is the main core of the project.
Status report 2	9-Apr	For status report 2, we will be almost done with the final part of the simulation so the project itself will be almost completed. We will focus on organizing and structuring all our work in the report. So the preliminary final report can continue on this second status report.
Preliminary final report	30-Apr	It would have been a while since the simulation phase ended and we had time to work exclusively on the report for two weeks, so the report will be correcly structured, al the pases would be explained and the results and conclusions will also be added.
Presentation	8-May	We will have a whole week to prepare for the presentation, which means detecting the most important parts that we should include in our slides, the parts that have to be explained the most, what we can skip, and how to organise all this information so it can be easily understood by the audience. The slides also have to be done.
Final report	23-May	Improving the report thanks to the feedback obtained with the preliminary report and the presentation.

Responsibility	Responsible
Communication with supervisor	Paula Carbó
Documentation and backups	Vilhelm Dinevik
Schedule and deadlines	Paula Carbó
Report writing and follow-up	Vilhelm Dinevik
Regularly meeting for both students	Paula Carbó

5 Risk analysis

Risks	P	C	R	Counter measure
Diseases in the group	2	2	4	Reactive: Rearrange workload Proactive: Nothing
Loss of documents and information	2	4	8	Reactive: recollect information again Proactive: Have bakups for everything, use Google Drive and GitHub
Running out of time	4	2	8	Reactive: Re-evaluate work plan and consult with supervisor Proactive: Have a good work plan, check on each other if we'll complete deadlines in time, check more when deadlines are closing in
Bad communication with supervisor	2	2	4	Reactive: Send reminders if we get no answer in x amount of time. Proactive: Schedule meetings now (once a week for example) and modify these dates if there is no need to meet. Ask supervisor how long 'x amount of time' should be. Plan accordingly
Inappropriate UAV Model	3	3	9	Reactive: Find out what the problem is and redesign UAV model Proactive: Test the calculated model with 3 individual tests of simple rotation and movement around and along one axis in a 3D space where the starting and final position is known either on paper or with matlab, check that you get the expected outcome.
Inappropriate sensor Model	3	3	9	Reactive: Check datasheets for each sensor, obtain the model again. Check if other sensors would be more suitable for the UAV application. Proactive: Study exactly how we need to control our drone and obtain the minimum number of sensors that can provide us this data. Run tests when a sensor is modeled with a known result and see if the results are the same.
Faulty state feedback controller	4	3	12	Reactive: Redesign the whole controller. damage control! Proactive: Check the Observability, Controllability, Robustness Criteria and pole placement of the designed State feedback controller.
Potential Field/ A*-algorithm	3	4	12	Reactive: Rewrite the potential fields method Proactive: make simple tests with known vector fields/results to check that we follow the correct trajectory to the goal
Multi-agent case	4	2	8	Reactive: Remodel the multi-agent case. Proactive: Make sure the mathematical model of the UAV is general enough as to suit different kinds of quads easily. test the completed Multi-agent case in simple obstacle free simulations in matlab to see that it works.
Simulation	4	2	8	Reactive: Check for weird data and try to figure out what the problem is, check that the modelling, controller and/or the potential fields are correctly implemented. Proactive: Choose a reasonable linear velocity so it is impossible for two UAVs to collide even if they encounter each other in the opposite direction. Make it easy to extract information and data from the simulation, analyse the data.
Bugs in the matlab code	4	1	4	Reactive: find the section of the bug and implement rubber duck debugging, use each other as the rubber duck. Proactive: for every new part that we implement in the code we should retell what that part do and explain it row by row to each other.

Every group member is individually responsible for seeing to that the group actually execute proactive countermeasures. Which group member is responsible for what is specified in the organization section. In case a certain risk has no one responsible for it, then it means both students need to make sure they are following the proactive measures and also both will need to apply the reactive measure in case the risk ends up happening.

6 Documentation/Communication rules

- We will use Github and Google drive for documentation. MatLab, Latex and any other code will be stored on GitHub, and the rest will be stored on Google Drive.
- Meetings with supervisor are scheduled once a week, on Thursday morning. The time and the confirmation for the next week are decided at the end of each meeting. In the case a meeting is cancelled, the designated responsible for communication with supervisor is in charge of scheduling another meeting for the next week or the week after. The purpose of these meetings is ask the supervisor questions or doubts, explain how the project is advancing, present goals accomplished in the case a section of the project plan is finished, check results and ask for how to improve them.
- Meetings with both students are not fixedly scheduled but regularly scheduled, at least once or twice a week depending on the availability of each one. The purpose of these meetings is advance on the project, distribute work to do for each section in the case the workload could be splitted, check the deadlines for the documents and make sure the work plan is being followed according to the planned schedule, and prepare questions for the supervisor in the case there was any.
- We checked with our supervisor that in the case we needed something from him, we can send and e-mail, and we are expected to get a response the same day. If we don't get it within a day, we can send a reminder.

A Appendix

A.1 Time line

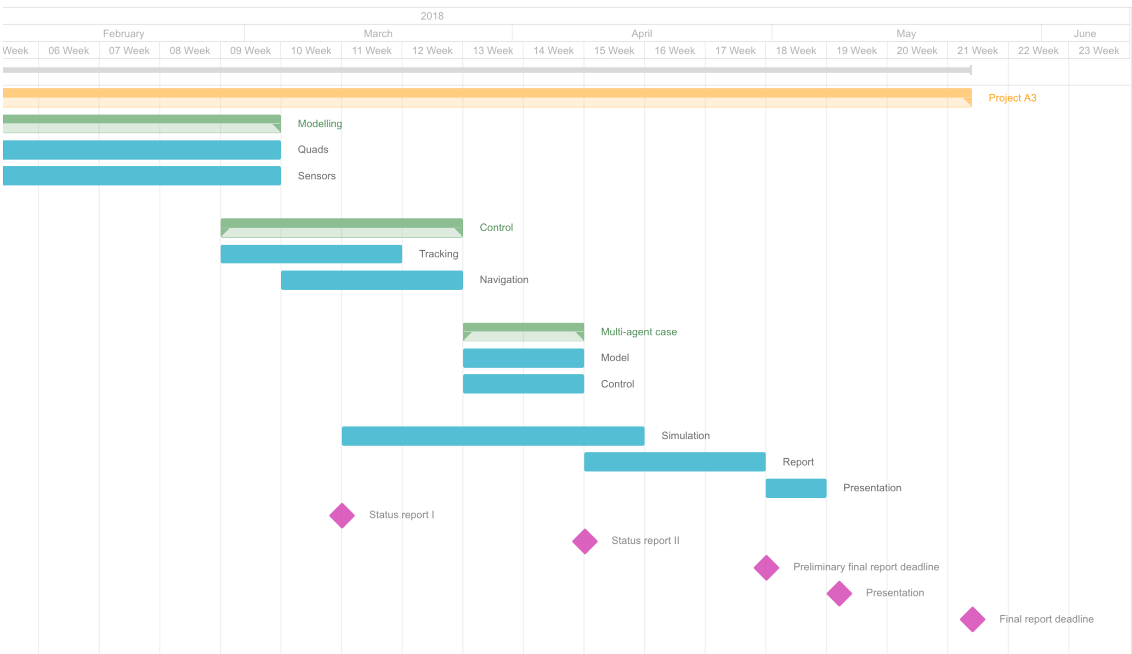

Figure 1: Time line for the project

This time line is a visual complement to the table in the project model section. In the mentioned table there is already an explanation on how are the phases related to each other and the milestones.

A.2 Work tree for the project model

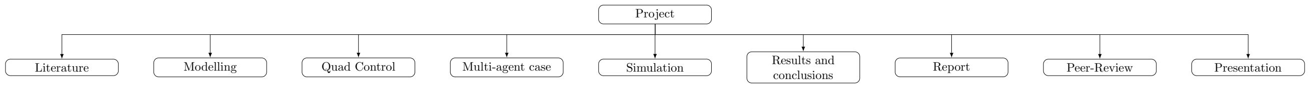

Figure 2: First row of work tree

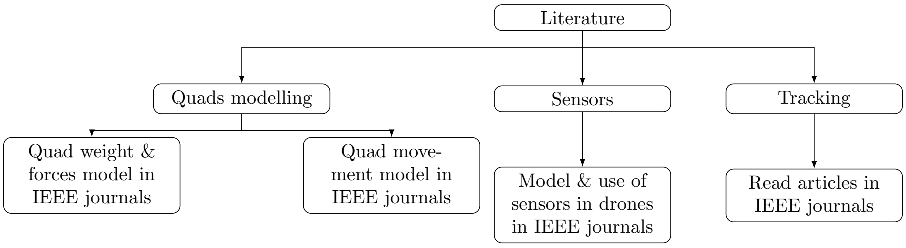

Figure 3: Expanded work tree for the literature section

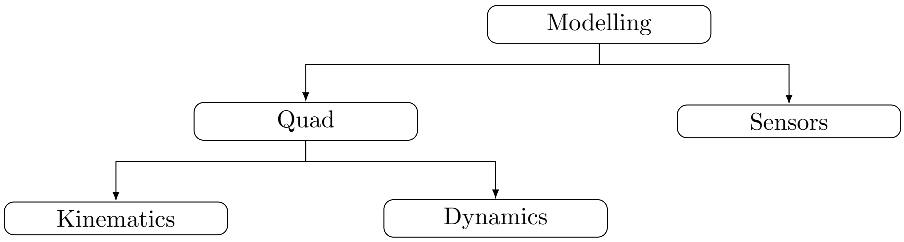

Figure 4: Expanded work tree for the modelling section

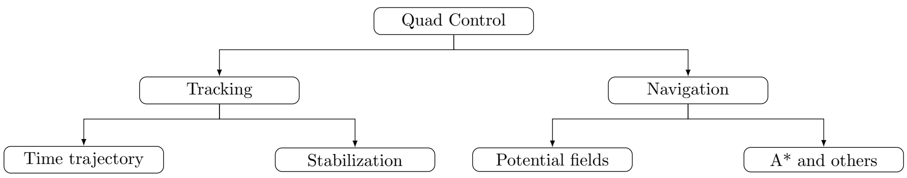

Figure 5: Expanded work tree for the single-quad control section

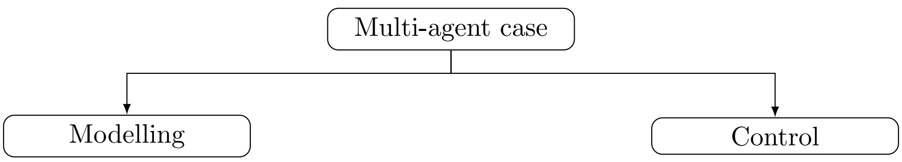

Figure 6: Expanded work tree for the multi-agent case section

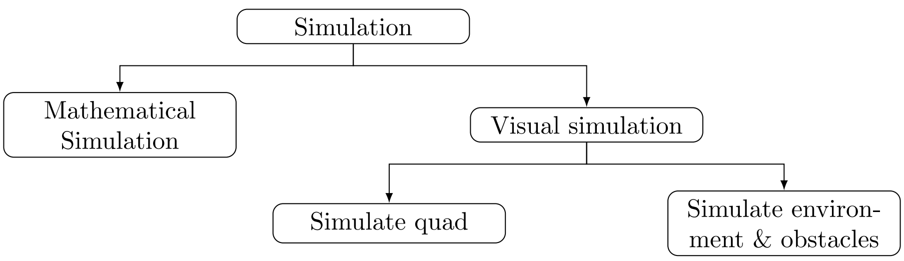

Figure 7: Expanded work tree for the simulation section

We will have a more detailed part of the simulation part of the work tree in status report 1 and a more detailed part of the report and peer-review part in status report 2.