Project Plan

Remotely Operated Underwater Vehicle

Version 1.2

Author: Marcus Homelius
Date: December 13, 2017

Status

Reviewed	Marcus Homelius	2017-09-21
Approved	Jonas Linder	2017-09-21

Course name:	Automatic Control Project Course	E-mail:	tsrt10rov2017@gmail.com
Project group:	ROV2017	Document responsible:	Marcus Homelius
Course code:	TSRT10	Author's E-mail:	marho949@student.liu.se
Project:	Remotely Operated Underwater Vehicle	Document name:	ProjectPlan.pdf

Project Identity

Group E-mail:	tsrt10rov2017@gmail.com
Homepage:	http://www.isy.liu.se/edu/projekt/tsrt10/2017/rov/
Orderer:	Jonas Linder, Linköping University **Phone:** +46 13 28 28 04 **E-mail:** jonas.linder@liu.se
Customer:	Rikard Hagman, Combine Control Systems AB **Phone:** +46 72 964 70 59 **E-mail:** rikard.hagman@combine.se
Course Responsible:	Daniel Axehill, Linköping University **Phone:** +46 13 28 40 42 **E-mail:** daniel@isy.liu.se
Project Manager:	Amanda Andersson **Phone:** +46 76 843 40 79 **E-mail:** amaan181@student.liu.se
Advisors:	Kristoffer Bergman, Linköping University **Phone:** +46 73 847 31 51 **E-mail:** kristoffer.bergman@liu.se

Group Members

Name	Responsibility	Phone	E-mail (@student.liu.se)
Amanda Andersson	Project manager	+46 76 843 40 79	amaan181
Marcus Homelius	Documentation	+46 70 245 90 96	marho949
George Jajji	Design	+46 70 790 16 17	geoja551
Martin Johannesson	Hardware	+46 76 949 79 69	marjo790
Mattias Mucherie	Information	+46 76 238 53 06	matmu715
Fredrik Nilsson	Software	+46 73 575 49 11	freni169
Anton Nordlöf	Modelling & Simulation	+46 76 145 04 90	antno848
Alaa Saeed	Tests	+46 76 207 57 86	alasa433

Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2017-09-14	First draft.	All	MH
0.2	2017-09-18	First revision.	AA, MH	AA, MH
0.3	2017-09-21	Second revision.	MH, MM	MH
1.0	2017-09-21	First version.	AA	AA
1.1	2017-10-12	Adding activities for the Pathfinder, and SF8 and updating the planed time and dates.	AA	FN, AA
1.2	2017-11-30	Changed date for BP5, delivery, test protocol and user manual.	AA	AA

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1 Customer

This project is a collaboration between Linköping University and Combine Control Systems AB. Combine Control Systems AB provides the group with a BlueROV from Blue Robotics. The orderer in this project is Jonas Linder from Linköping University, the customer is Rikard Hagman from Combine Control Systems AB and the advisor is Kristoffer Bergman from Linköping University.

2 Project Overview

A MSc project [1] was performed during the spring 2016 where a BlueROV from Blue Robotics [3] was used. During the autumn of 2016 another project continued on this work. Some basic modelling and controlling of the ROV has been implemented. By using a camera and artificial tags, functionality for positioning in a global environment also has been implemented. This year three ultrasonic senors will be used for positioning instead of a camera and artificial tags.

2.1 Purpose

The purpose of this project is to develop autonomous behaviors for the ROV, which include positioning in a known environment and trajectory following. With the new installation of the sensors, the model of the ROV also needs to be updated accordingly.

2.2 Goal

The goal with the project is to develop an autonomous ROV that can follow a given trajectory. Another goal is to develop a robust system to control the ROV and create autonomous behaviors in a pool environment.

The long term goal is to further develop the ROV so it can 3D-map an unknown environment or search for interesting objects. Therefore it is important that the ROV can easily be further developed after this project ends.

2.3 Deliverables

In the requirement specification [2], all requirements and documents that shall be completed and delivered to the customer are listed. Date for the final delivery to the customer is 2017-12-13. A technical report, poster, website, presentation film and post study will be delivered by 2017-12-18.

2.4 Exclusions

The system that is currently being used for development is designed to be used in a pool. The requirements for the ROV in this project is therefore set for use in a pool with calm and clear water. This means that the ROV is not expected to fulfill these requirements in water environments that are turbulent or have limited visibility.

3 Project Phases

The project is divided into three phases: before, during and after. This section briefly describes the structure of the project and the main activities.

3.1 Before

In the before phase, the project structure will be planned. A requirement specification will be written in collaboration with the orderer. Here, all requirements are stated that the product shall achieve. A project plan and a time plan will also be created. In the project plan it is described how the project shall be completed, how the group shall work, etc. All activities for the project are gathered in the time plan where the time for each activity and the order of the activities are specified. This phase ends with a decision point where the orderer decides if the before phase is approved and if the project should continue.

3.2 During

Next comes the main phase of the project. Here, a detailed design specification will be created on how the different modules of the product shall be designed. The ROV will then be developed based on this document. Tests will be performed continuously during this phase according to the test plan. There will also be a partial delivery of some selected functionalities. This phase ends with a decision point where the orderer decides if the project is ready for delivery to the customer.

3.3 After

In the after phase, the project will end by delivering the final product to the customer, including several documents. The project will be presented to other project groups in a project conference. The project group shall also write a reflection document.

4 Organization Plan

In this section, the organization structure and the project roles will be presented.

4.1 Organization Structure

In Figure 1, it is shown how the participants in the project is related. The project group has divided the different responsibilities into components. Each project member is responsible for one component. During the project, the project members will work with different components even though they have their assigned responsibility area.

4.2 Conditions for Cooperation in the Project Group

A group contract has been conceived that states how the members of the project group shall work together.

4.3 Definition of Project Roles and Responsibilities

There are several project roles in the group and their definitions are stated here.

- **Project manager:** The project manager leads the project. The project manager is responsible for reaching the goals of the project, planning the project and encouraging the rest of the project group to ensure the cooperation works as planned. The project manager is also responsible for gathering of meetings and where they will be held. The project manager is the project group's contact person with the orderer and customer.
- **Documentation manager:** The document manager plans the writing of the documents, including document templates, version management of the documents and making sure that the document will be completed in time. The document manager is also responsible for the quality of the documents.
- **Design manager:** The design manager creates guidelines on the system designs, to make sure that the assembling of all module goes smoothly. The design manager is also responsible for synchronizing the communication between different subsystems.
- **Test manager:** The test manager plans and synchronizes tests. The test managers responsibilities include the test plan, test protocols and when the tests shall be done. He is also responsible for booking of the bigger swimming pool in Ljungsbro.
- **Hardware manager:** The hardware manager leads the work with electronics and mechanics. He is also responsible for purchases of new hardware.
- **Software manager:** The software manager makes sure that the software follows predetermined coding standards, are correctly commented and has a functioning version control.
- **Modelling & simulation manager:** The model & simulation manager is responsible for the development of the simulation environment and for the necessary models.

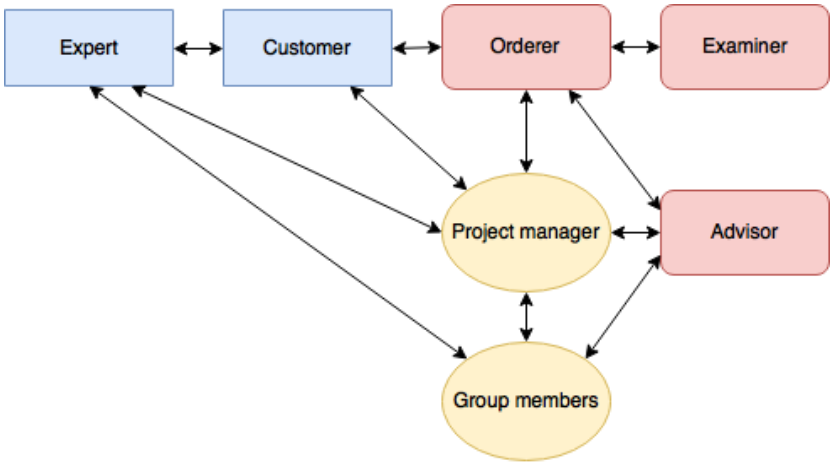

Figure 1: An overview of the organizational structure of the project. Red boxes is employees from Linköping University, blue boxes represents employees from Combine Control System AB and the yellow ellipsoids are students attending the course.

- **Information manager:** The information manager is responsible for creating a web page, a public movie, the project poster and all presentations.

5 Document Plan

The documents that shall be delivered during the project is stated in Table 1. For all documents, a short description, the target audience, final submission date and whom is responsible are stated. The documents are shared to all project group members through ShareLatex and Google Drive. The documents will also be uploaded to GitLab repository. All documents will be written in formal English. Before the final submission date, the documents will be iterated with the orderer or the supervisor. This means that a first draft of all documents will be sent to the orderer or the supervisor in good time before the final submission date. The group will then receive comments on what needs to be improved or changed in order for the document to be approved. After these changes have been made by the group, another version of the document will be sent to the orderer or the supervisor. These iterations will go on until the document has been approved.

Table 1: List of all documentations that will be carried out during the project.

Document	Responsible	Description	Target Audience	Date
Meeting protocols	MH	Protocols of what has been said at the meetings to ensure everyone is up to date with current position in the project.	Project group and Orderer	Weekly
Group contract	MH	The groups rules and expectations of the project stated as a ground for solving conflicts.	Project group	2017-09-11
Requirement specifications	MH	A list of requirements to achieve the goal for the project.	Project group, Orderer and Customer	2017-09-19
Project plan with time plan	MH	A plan of what activities should be carried out during the project, when and by whom.	Project group, Supervisor and Orderer	2017-09-19
Design specification	MH	A more detailed description of the system.	Project group and Orderer	2017-10-11
Test plan	AS	Describes how and when tests should be carried out to ensure accomplishment of the requirement specification.	Project group and Orderer	2017-10-11
Test protocol	AS	Protocol showing the results from the tests described in the Test Plan.	Project group, Supervisor and Orderer	2017-12-06
User manual	MH	A manual of how to operate the ROV in a secure way.	Project group, Supervisor, Customer and Orderer	2017-12-06
Technical report	MH	Description of the ROV system with technical details.	Project group, Orderer, Supervisor	2017-12-18
Poster	MM	Visual presentation of the ROV project that should appeal to the audience.	Customer and general audience	2017-12-18
Video presentation	MM	A video that shows the end product of the project and the reached goals.	Orderer, Customer and general audience	2017-12-18
Web page	MM	A web page that presents the project, the project members and the documentation.	Orderer, Customer and general audience	2017-12-18
Reflections	MH	Reflection of the entire project work.	Examiner	2017-12-11

6 Development Method

Since the project group consists of eight members, it is important to divide the work between all members. Many parts of the ROV is split up into different modules that can be worked on in parallel. It is therefore important to have a functioning communication in the group and have a clear plan on communication protocols between the different modules.

The group will use a kind of scrum board in order to keep track on ongoing activities and have an overview on how they are progressing.

7 Education Plan

All members of the project and the customer will require education during different phases of the project. The customer will receive education during the end of the project while the members of the project will require education at the beginning.

7.1 Education of the Project Members

The members of the project will receive a demonstration of the ROV to get acquainted with the systems and see what has been done to the ROV during previous projects. The project members should read through the MSc project [1] and the documentation from last year's project [4]. The project members should also read the parts that are relevant for each member of the documentation from earlier years.

7.2 Education of the Customer

At the end of the project the customer will receive a demonstration on what has been developed and implemented on the ROV. A user manual and documentation of the product will be delivered as well. The user manual and the documentation should contain all the details needed to operate the ROV and to use all of it's functionalities. All written code should be commented such that the customer easily can understand what each part of the code does.

8 Report Plan

All group members will report their working time each week and what activity they have spent that time on. Based on this, the time and project plan will be updated throughout the project by the project manager. A status report will be sent in each week to the orderer. That report will summarize the work the week before and also problems that have been encountered and solved.

9 Meeting Plan

The project group will have meetings every Thursday at 10.15-11.00 if nothing else was stated at the last meeting. All group members should also be available every Monday at 12.15-13.00 if one more meeting would be necessary. The project manager is responsible to

summon the meetings. The meetings will start with an update of all areas of responsibility. Ongoing and near-future activities will also be discussed as a conclusion at all meetings.

10 Resource Plan

This sections states the available resources during the project, such as time, materials, available facilities and purchases.

10.1 Project Group

The project groups consist of eight students from Linköping University. Everyone should contribute with 240 h each, that means a total of 1920 h that will be distributed over the projects total of 16 weeks. The project group has 40 h counselling and revision time with the supervisor from Linköping University.

10.2 Material

The available material for the project is the ROV from Blue Robotics with provided hardware and a PC with Linux as the workstation. There is also a car available for transportation to the swimming pool in Ljungsbro.

10.3 Facilities

At Linköping University a project room and a small pool is available. There is also possible to reserve a larger swimming pool in Ljungsbro when needed for performing the tests.

10.4 Economy

All purchases will be discussed with the customer Rikard Hagman at Combine Control Systems AB, that will cover the purchases.

11 Milestones and Decision Points

This section will mention the different milestones and decision points in the project.

11.1 Milestones

To measure the progress in the project, milestones are used and can be seen in Table 2.

11.2 Decision Points

During this project there are some decision points that have to be fulfilled to proceed with the project. Table 3 shows all decision points BP (Beslutspunkt in Swedish) that has to be approved by the orderer to proceed with the project.

Table 2: The milestones in the project.

Nr.	Description	Date
MI1	The ROV is tested waterproof in the small pool.	2017-10-04
MI2	Sonar sensor able to do measurement under water.	2017-10-11
MI3	First run with the ROV in the larger pool.	2017-10-30
MI4	The sensor fusion module can estimate linear- and angular velocities.	2017-10-31
MI5	A working simulation environment of the ROV shall exist.	2017-10-31
MI6	The sonar sensors are fully integrated. Mounted and can publish measurements to ROS topics.	2017-10-31
MI7	The ROV can receive a path plan from the GUI.	2017-10-31
MI8	The ROV can position itself in a known environment.	2017-10-31
MI9	The ROV can follow a reference trajectory.	2017-11-17
MI10	The project is ready for delivery.	2017-12-06

Table 3: All decision points for the project.

Decision	Description	Date
BP2	Requirement specification and project plan with time plan shall be approved by the orderer. A first draft of design specification shall also be presented.	2017-09-19
BP3	Design specification and test plan shall be approved by the orderer.	2017-10-11
BP4	The simulation environment shall be finished, the sonars shall be integrated, the requirements for estimation of linear and angular velocities shall be fulfilled and the requirements for route planning in known environment shall be fulfilled.	2017-11-10
BP5	All requirements with priority 1 shall be fulfilled. Test protocol, user manual and a presentation that shows that all requirements are fulfilled shall be approved by the orderer.	2017-12-06
Final delivery	A presentation shall be held for the customer to demonstrate that all requirements are fulfilled.	2017-12-13
BP6	A technical report, poster, website, presentation film and a post study that reflects the result and used time shall be approved by the orderer.	2017-12-18

12 Activities

This section will mention all activities for the project. The activities are divided into different subsections depending on what they are about.

12.1 General Activities

Table 4 shows the general activities that will be performed by the project group during the project. GE stands for General.

Table 4: The general activities.

Act. nr.	Activity	Description	Time (h)
GE1	Group meetings.	Weekly meetings with updates on the progress.	145
GE2	Create Poster.	Creating a presentation poster.	10
GE3	Reflection document.	Writing a reflection document.	8
GE4	Movie.	Making a presentation movie about the ROV.	10
GE5	Requirement specification.	Writing the requirement specification.	108
GE6	Delivery presentation.	Creating the delivery presentation	25
GE7	User Manual.	Writing the user manual.	30
GE8	Technical documentation.	Writing the technical documentation.	90
GE9	Test protocol.	Writing a test protocol.	15
GE10	Test plan.	Creating a test plan.	37
GE11	Design specification.	Writing the design specification.	173.2
GE12	Project plan with time plan.	Writing a project plan with a time plan.	70
GE13	Create Web page.	Creating a web page about the ROV.	10
GE14	Reserve time.	A pot of time that will be distributed when needed if non predictable trouble occurs.	125.6
GE15	Inspection of new code.	Inspection of new code to ensure that it follows the coding standards.	10

12.2 Hardware Activities

Table 5 shows all hardware activities throughout the project. HW stands for Hardware.

12.3 Graphical User Interface Activities

In Table 6, the different GUI activities are shown. GUI stands for Graphical User Interface.

Table 5: Hardware activities.

Act. nr.	Activity	Description	Time (h)
HW1	Sonar position.	Evaluating the sonar positions and orientation on the ROV.	2.2
HW2	Calibration of the sonar sensors.	Finding a method to calibrate the sonars.	6
HW3	Final testing of sonars.	Making tests of the sonars in air and water.	10
HW4	Waterproofing of the sonar sensors and cables.	Making the sonars and the wiring water resistance	16
HW5	Mounting of the sonar sensor.	Making fixtures for the sonars and mounting the sonars on the ROV.	22

Table 6: The GUI activities.

Act. nr.	Activity	Description	Time (h)
GUI1	Ability to set a reference trajectory.	Implementing functionality to send a reference trajectory to the ROV from the GUI.	15
GUI2	Graphical view of the ROV on a map.	Implementing functionality to show the ROV's position on the map.	30
GUI3	Add the map to GUI.	Creating functionality to show the map of the ROV's environment.	20
GUI4	Get familiar with the existing GUI.	Inspecting the GUI code and get familiar with the user interface on the workstation.	20

12.4 Control System Activities

The different control system activities are shown in Table 7. CO stands for control system.

Table 7: The control system activities.

Act. nr.	Activity	Description	Time (h)
CO1	Research control methods and earlier principles.	Research of control methods and principles used in the MSc project [1], last year's project [4] and previous years.	35
CO2	Propose possible strategies.	Proposing a control strategy which allows for control of the ROV in accordance with the functionality requirements specified in the requirements specification document.	31
CO3	Evaluate existing controllers.	Simulation and real world tests to compare position-, angle-, angular velocities- and linear velocities control performance to the demands mentioned in requirements specification document.	5
CO4	Implement the trajectory controller.	Implementing a trajectory controller based on control strategy proposition.	10
CO5	Evaluate and improve the trajectory controller.	Simulation and real world tests to compare trajectory control performance to the demands specified in the requirements specification document.	10
CO6	Integrate control methods.	Integration of the controllers in an overall structure to enable control of multiple states at the same time. Build and implement control modes including the reference signals combinations for each control mode.	20
CO7	Evaluation of integrated control.	Performing tests to determine if the implemented control modes are suitable for an operator.	10
CO8	Verify that the control module requirements are fulfilled.	Verifying that the control module requirements specified in the requirement specification are fulfilled.	5
CO9	Integrate with ROV.	Implementing the controllers (created in Simulink) in ROV.	10

12.5 Sensor Fusion Activities

The different sensor fusion activities in the project are shown in Table 8. SF stands for sensor fusion.

12.6 Modelling and Simulation Activities

All modelling and simulation activities are seen in Table 9. MS stands for modelling and simulation.

12.7 Administrative Activities

Table 10 shows the activities associated with administration. AM stands for administration.

12.8 Pathfinder Activities

Table 11 shows all activities associated with the pathfinder. PF stands for pathfinder.

Table 8: The sensor fusion activities.

Act. nr.	Activity	Description	Time (h)
SF1	Change motion model.	Instead of a constant velocity model the performance could be improved if a more complex model would be used.	20
SF2	Implement the positioning estimation.	Designing a suitable position estimation model and implement it in the code.	40
SF3	Test the moved sensor fusion module.	Running tests to make sure that the sensor fusion module works as planed when running on the Raspberry Pi.	4
SF4	Move sensor fusion module onto the Raspberry Pi.	Investigating if it is possible to, and then move the sensor fusion module onto the Raspberry Pi as a step to reach the long term goal of a fully autonomous ROV.	10
SF5	Understand current sensor fusion module code.	Getting a good knowledge about how the current sensor fusion is done and how it is implemented.	16
SF6	Research about filter implementations in ROS.	A new filter could be used to get a better position estimation. Research how different kinds of filters could be implemented with ROS.	10
SF7	Adopt sensor fusion to the new sonar measurements.	Extend the current sensor fusion functionality to use sonar measurements.	40
SF8	Update angle representation.	Update the angle representation from quaternions to Euler angles in the current sensor fusion module.	15

Table 9: The modelling and simulation activities.

Act. nr.	Activity	Description	Time (h)
MS1	Get familiar with existing models and simulation environment.	The modelling will be based on the work of the TSRT10 2016 project and therefore an understanding of the system is required to further improve it.	30
MS2	Evaluate and improve Simulink model.	The existing Simulink model needs to be upgraded with a working GUI and ROS communication.	35
MS3	Estimation of parameters.	Estimate the paramters in the ROV's dynamic model.	80
MS4	Validation of previous tests.	Validating the tests done in the previous project so that the model is correct.	15
MS5	Data collection and logging.	Running simulations and logging data for further evaluation of the model.	25
MS6	Implement the simulation with ROS.	To simplify the process of creating regulators the Simulink simulator will be able to get data direct from the ROV via ROS.	35
MS7	Telegraph signal generation.	Investigating which control signals that are suitable during parameter estimation.	40
MS8	Improvement of parameters.	Further testing and improvement of the ROV model.	80
MS9	Software in the loop.	Making hardware test with the Simulink-model implemented to validate and improve the model of the system	40
MS10	Validation of the model.	Performing tests to evaluate how the model differs from the ROV in reality.	40
MS11	Implement new simulation components.	Implement the ROV's sensors and known environment into the simulator.	40

Table 10: The administration activities.

Act. nr.	Activity	Description	Time (h)
AM1	Preparation of meetings.	Preparation for the meetings, create agenda etc.	16
AM2	Compile status report.	Summarize the work that have been made and update the time plan.	10
AM3	Other meetings.	Meetings with for example the customer and orderer.	50.5
AM4	Preparing for presentation.	Preparation for the different presentation during the project.	20
AM5	Group contract.	Write a group contract.	4.5

Table 11: The pathfinder activities.

Act. nr.	Activity	Description	Time (h)
PF1	Build map to implement in the pathfinder.	Creating a map of the known environment of the pool.	20
PF2	Develop the pathfinder node.	Create a new node for the pathfinder that can calculate a path between given points.	30
PF3	Implement the A* algorithm.	Implementing an A* algorithm for calculating the possible path between point A an B.	10

13 Time Plan

There is a separate document named *Time Plan* that specifies what activity each group member should work with, when to work with it and for how long. Based on the progress, the time plan will be updated throughout the project by the project manager. The different activities in Section 12 can be divided into the following categories:

General Activities that are more general for the project, such as meetings and different documents.

Hardware Activities that are related to the hardware. Three sonar sensors will be added to the ROV.

GUI Activities that are related to the development of the GUI. The GUI should be able to present a graphical view of the map and the ROV's estimated position.

Control system Activities related to the implementation and development of the control system.

Sensor fusion Activities related to the sensor fusion. The sensor fusion module will be moved to the on board computer and a new positioning filter will be implemented.

Modelling and simulation Activities related to modelling and simulation of the ROV.

Administrative Activities related to administrative work around the project, such as planning for meetings and compiling status reports.

Pathfinder Activities that are related to the pathfinder. The pathfinder should be able to plan a possible path for the ROV between a point A and B in a known environment.

14 Change Plan

During the project the requirement of the ROV might need to be changed. If a change is required, it has to be motivated to the orderer and the customer for approval. After the approval the requirement specification, timeplan and project plan can be updated.

15 Quality Plan

This section contains information about how the group will work to make sure the quality of the product will be as good as possible.

15.1 Reviews

All documents that are written throughout the project will be reviewed by at least one person before delivery. This will hopefully decrease the amount of errors.

15.2 Test Plan

A separate document named *Test Plan* will be written to make sure that each test is designed in such a way that it will be easy to see if a certain requirement has been satisfied after the test. The test plan will contain information about when and how all tests will be performed.

16 Risk Analysis

Different events that might affect the progress of the project have been identified and summarized below.

16.1 Indispensable Activities

The ongoing plan is to use the ultrasonic sensors to estimate the position and the velocity of the ROV. The project in its current form is enormously dependent on this goal. It will be difficult to measure the position and the velocities of the ROV if this idea proves to be difficult to implement. Simply, it will be hard to realize other activities without good estimations of positions, linear and angular velocities of the ROV. To make it possible to work without a good estimation, especially in the beginning of the project, it is important to create a simulation environment. Estimation of the linear and angular velocities can be simulated from there to develop the control system for the ROV.

16.2 Hardware Malfunction

It is possible that hardware malfunctions. In this case it would be good if there is a stock so the damaged parts can be replaced. If there is no stock for a damaged part the waiting time for a new part might delay the progress of the project.

16.3 Illness

It is always a risk that people could get ill. A meeting for renegotiation of the project requirements will be held if the illness remains for a big part of the project. Most of the activities are executed by at least two students to minimize the risk of a minor cold delaying the progress of the project. This also means that there always will be a deputy who can take over for the person that is responsible for an activity in case of absence.

16.4 Dependencies

Some parts of the ROV are independent while some are dependent on other parts or modules to be able to operate correctly. This applies to both hardware and software. The development can be affected if some activities are delayed or cancelled.

If the waterproofing of the sonar sensors fail or take longer than planned, it will affect the whole project since new decisions have to be made.

Some of the modelling activities are dependent on the sonar sensors while most of the sensor fusion activities are dependent on the sonar sensors to be installed. Some sensor fusion activities are also dependent of the GUI module.

Some of the control activities are dependent on the model activities and GUI activities since they require input from those modules.

To make sure that all activities works well together, a good communication will be established.

17 Priorities

The project will try to priorities all functionality that includes the ability for the ROV to follow a reference trajectory since this is one of the new main goals of this year's project.

Another priority is to write a clear and precise user manual to facilitate further use and continued improvements of the ROV.

18 Project Closing

When the orderer and the client have received and approved all deliveries the project can end. Before the project ends the ROV and the PC borrowed from Combine Control Systems AB have to be returned. All documentations and the movie will be available at the web page.

References

[1] Adam Aili and Erik Ekelund. *Model-Based Design, Development and Control of an Underwater Vehicle*. MSc Thesis - LiTH-ISY-EX–16/4979–SE, Sweden: Linköping University, 2016.

[2] Marcus Homelius. *Requirement Specification, Remotely Operated Underwater Vehicle*. 2017.

[3] Blue Robotics. BlueROV. https://www.bluerobotics.com/store/retired/bluerov-r1/. Accessed: 2017-09-20.

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