Requirement Specification

Remotely Operated Underwater Vehicle

Version 1.5

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Status

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Document History

Version	Date	Changes made	Sign	Reviewer(s)
0.1	2017-09-14	First draft.	All	AS, MH
0.2	2017-09-18	First revision.	All	AA, MH
0.3	2017-09-21	Second revision.	All	MJ
1.0	2017-09-21	First version.	FN	FN, MH
1.1	2017-10-02	Requirement 5 has been changed to make it possible to verify that the requirement is fulfilled. Requirement 62 has also been changed. Before the requirement was that the sensor fusion module would be able to run in real time.	FN, MH	FN, MH
1.2	2017-10-06	Requirement 48 has been updated so it refers to the right requirements. Requirement 14 has been changed. Now it is with respect to the state estimates instead of reality. New requirements regarding the pathfinder module have been added and two requirement on the GUI with respect to the pathfinder module has also been added.	AA, MH	AA, MH
1.3	2017-10-21	Requirement 51 has been changed to priority 2 and requirement 63 has been slightly modified.	FN	AA, FN
1.4	2017-12-01	Requirements 69 and 70 has been modified. Before the requirements were that the model would fit validation data to at least 85 %. Requirement 6 and 63 has been changed to priority 2. Requirement 5, 31-48, 56-58, 61 A and 62 has been changed to be performed in the simulator. Requirement 60 has been divided in to 60, 60 A and 60 B to get different requirements for x-, y- and z-direction.	AA, MH	AA

Version	Date	Changes made	Sign	Reviewer(s)
1.5	2017-12-08	Requirement 5 and 91 has been change to priority 2. In requirement 33, 38 and 42 the overshoot has been changed to 10%. In requirement 32 and 37 the rise time has been changed from 1 and 0.8 to 2 and 1.5, respectively. In requirement 39 and 43 the rise time has been changed from 2 and 3 to 3 and 5, respectively. Requirements 56 and 58 have been updated. In requirement 60 A the limits for the traveling speed have been changed from between 0.2 m/s and 0.3 m/s to between 0.15 m/s and 0.25 m/s. Requirement 61 has been changed. Now the estimates of angular velocity in yaw shall be performed in simulation and the estimate of angular velocity in roll and pitch shall be performed with an average speed between $60°/s$ and $80°/s$ in simulation. The purpose and goal have been updated.	MH, AA	MH, AA

Contents

Notations

DOF Degrees of Freedom

ESC Electronic Speed Controller

GUI Graphical User Interface

GCS Global Coordinate System

HIL Hardware In the Loop

IMU Inertial Measurement Unit

I/O Input/Output

LCS Local Coordinate System

PCS Pool Coordinate System

ROS Robot Operating System

ROV Remotely Operated Underwater Vehicle

SIL Software In the Loop

1 Introduction

Autonomous vehicles that can carry out missions at sea, in the air and on land without an operator are increasingly sought after in both civilian and military applications. Surveillance, rescue operations, mapping, repairs or tactical missions could be examples of tasks for such vehicles.

This project is a continued development of a remotely operated underwater vehicle (ROV). This document contains all requirements for both the project and the product.

1.1 Partners

The project group consists of eight student in the course TSRT10 Automatic Control Project Course at Linköping University. The 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.

1.2 Purpose

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

1.3 Goal

The goal with this project is to develop an autonomous ROV, and also to plan a reference trajtory in a known pool environment. Another goal is to develop a robust system to control the ROV and create autonomous behaviors in a pool environment.

The long time 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.

1.4 Use

When the project is finished, the result will be used to further develop the ROV. Ultimately, the goal is to have a fully autonomous vehicle. The ROV will also be used as a test platform for development of control systems for underwater vehicles.

1.5 Background Information

A MSc project [1] was performed during the spring 2016, where a BlueROV from Blue Robotics [2] 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 has also been implemented.

1.6 Requirement Definition

A requirement will be defined by a table with four columns. An example can be seen in Table 1. The first column is the number of the requirement. The second column describes to which version of the document the requirement was most recently updated in. Then there is a detailed description of the requirement. The final column sets the priority of the requirement, were 1 means that the ROV must fulfill the requirement while 2 means that this is a desired requirement.

Table 1: An example of a requirement table.

Req. nr.	Version	Description	Priority

2 System Overview

The ROV that was provided by Combine AB is BlueROV from Blue Robotics [2]. It comes assembled with a frame, watertight enclosure, thrusters and speed controllers. The thrusters are placed in such a way that it allows the ROV to have 6 degrees of freedom (DOF). On the ROV, an inertial measurement unit (IMU), two pressure sensors (one measuring the enclosed pressure and one measuring the water pressure), a magnetometer, a camera and three sonar sensors are mounted. All the mentioned sensors can be used to calculate the state estimates which can then be used to control the ROV. The computer controlling the ROV is a Raspberry Pi 2 model B, which runs many of the algorithms used to control the ROVs movements. The ROV is connected through a long Ethernet cable to a PC on land, later mentioned as the workstation. The workstation is for the sensor fusion module, the simulation module and the GUI module. An XBOX controller can also be connected to the workstation to allow manual control of the ROV with the controller.

2.1 Product Components

Along with the product, a technical documentation, a user manual, a website, a poster and a movie will be developed. The main development areas will be sensor fusion, simulation environment, control systems and navigation/planning.

2.2 Product Dependencies

A PC, called the workstation, connected with an ethernet cable to the ROV is always needed to be able to operate the ROV.

2.3 System Modules

The ROV system has been divided into multiple modules to make it easier to swap or remove some modules.

2.3.1 Hardware Module

The hardware consists of the ROV itself and all the components attached to it. It also includes the workstation and all other hardware around it.

2.3.2 Graphical User Interface Module

The graphical user interface will be running on the workstation. It will be used to operate and control the ROV with the help of a more user friendly environment.

2.3.3 Control Module

In the control module, multiple controllers will be designed. The input will come from the sensor fusion module and it will produce outputs to the ESCs which control the thrusters. The control module will be based on the on board computer.

2.3.4 Sensor Fusion Module

The sensor fusion module will consist of implementations of filters and state estimators. Its goal is to process raw sensor data and output a state estimate that the control module can work with. The sensor fusion module is at the moment based on the workstation, but the goal is to move it into the Raspberry Pi.

2.3.5 Simulation Module

The simulation module is a simulation environment, implemented in MATLAB/Simulink and used for development. The simulation module will be based on a computer that can run MATLAB.

2.4 Delimitations

The ROV is designed for a specific environment, a swimming pool. The performance requirement have been set to work in this environment, i.e. calm and clear water.

2.5 Design Philosophy

The software should also be module based to ease the swapping or removal of a module if necessary. It will also make it easier for the development team to work in parallel.

2.6 General Requirements

General requirements of the system can be seen in Table 2.

Table 2: General requirements of the system.

Req. nr.	Version	Description	Priority
Nr. 1	1.0	ROS will be used as the main framework for software and communication with the ROV.	1
Nr. 2	1.0	Raw sensor data, reference signals, control signals and state estimates should be logged for offline analysis.	1
Nr. 3	1.0	The ROV's thrusters should be able to be controlled by an XBOX controller.	1
Nr. 4	1.0	The ROV's attitude should be able to be controlled by an XBOX controller by outputting reference signals.	1
Nr. 5	1.5	The ROV shall be able to follow a reference trajectory in simulation.	2
Nr. 5 A	1.5	The ROV shall be able to follow a reference trajectory with a maximum deviation between references and estimates of 0.1 meters in position and 1 degree in attitude during simulation with simulated model errors.	2
Nr. 5 B	1.1	The ROV shall be able to follow a reference trajectory with a maximum deviation between reference and estimates of 0.05 m/s in linear velocity.	2
Nr. 6	1.4	There shall exist a hover mode, where the ROV will maintain position and attitude.	2

3 Graphical User Interface

The graphical user interface (GUI) runs on the workstation and contains information about the ROV, such as state estimates. The operator can also input references to the ROV via the GUI.

3.1 Interface

Table 3 lists the requirements on the GUI interface.

Table 3: Requirements on the GUI interface.

Req. nr.	Version	Description	Priority
Nr. 7	1.0	The GUI shall receive information from other modules by subscribing to ROS topics.	1
Nr. 8	1.0	The GUI shall send information to other modules by publishing to ROS topics.	1

3.2 Functional Requirements

Table 4 lists the requirements on the functionality of the GUI.

Table 4: Requirements on the GUI functionality.

Req. nr.	Version	Description	Priority
Nr. 9	1.0	There shall exist functionality in the GUI to manually input references in angles (roll, pitch, yaw), angular velocities (roll, pitch, yaw), position and linear velocity by using a script.	1
Nr. 10	1.0	There shall exist functionality in the GUI to present state estimates, references, control signals and active operating mode.	1
Nr. 11	1.0	There shall exist functionality in the GUI to present a graphical representation of the reference trajectory.	1
Nr. 12	1.2	There shall exist functionality in the GUI to set start and end points for the pathfinder module.	1
Nr. 13	1.0	There shall exist functionality in the GUI to present a graphical representation of the map and the ROV's position estimate.	1
Nr. 14	1.2	There shall exist functionality in the GUI to present a graphical representation of the ROV's attitude estimate.	2
Nr. 15	1.0	There shall exist functionality in the GUI to switch between operating modes.	1
Nr. 16	1.0	Parameters and settings for the modules on the ROV shall be adjustable from the GUI.	1

4 Software

There is software for controlling the ROV, its sensors, running the thrusters etc. The code must be well written in order to facilitate further improvements and work. Some design requirements on the code are therefore necessary.

4.1 Design Requirements

The requirements in Table 5 describes how the code will be written and formatted.

Table 5: Requirements for the code design.

Req. nr.	Version	Description	Priority
Nr. 17	1.0	The C++ source code written for ROS shall fulfill the ROS coding standard.	1
Nr. 18	1.0	Other written C++ code shall fulfill Google's coding standard.	1
Nr. 19	1.0	All written code shall be commented in English.	1
Nr. 20	1.0	The code shall be version controlled.	1

5 Control System

This section will list specifications and requirements for the control of the ROV. Furthermore, the interface for the ROV's control system will be outlined here.

5.1 Interface

The interface requirements for the control systems are presented in Table 6.

Table 6: Interface requirements for the control system.

Req. nr.	Version	Description	Priority
Nr. 21	1.0	The control system shall be able to receive reference signals to a trajectory by subscribing to a ROS topic.	1
Nr. 22	1.0	The control system shall be able to receive other reference signals for the attitude, position, linear- and angular velocities by subscribing to a ROS topic(s).	1
Nr. 23	1.0	The control system shall transmit control signals to the thrusters by publishing to a ROS topic.	1

5.2 Design Requirements

Table 7 presents the design requirements of the control system.

Table 7: Design requirements of the control system.

Req. nr.	Version	Description	Priority
Nr. 24	1.0	A controller shall be designed for control of the linear and angular velocity.	1
Nr. 25	1.0	A controller shall be designed for control of the attitude and position.	1
Nr. 26	1.0	A controller shall be designed for following a reference trajectory.	1

5.3 Functional Requirements

Table 8 shows the functionality requirements of the control system.

5.4 Performance Requirements

The performance requirements of the control system are divided into four tables. The requirements in Table 9 are related to the angles. Table 10 presents the requirements linked to angular velocities. Table 11 present a list of the performance requirements related to the position of the ROV. Table 12 presents the requirements related to the linear velocities. The pool coordinate system (PCL) is a coordinate system with origin in one of the pool corner and the x-y-axes along the sides of the pool.

Table 8: Functional requirements of the control system.

Req. nr.	Version	Description	Priority
Nr. 27	1.0	The ROV's attitude shall be controllable.	1
Nr. 28	1.0	The ROV's angular velocity shall be controllable.	1
Nr. 29	1.0	The ROV's linear velocity shall be controllable.	1
Nr. 30	1.0	The ROV's 3D-position shall be controllable.	1

Table 9: Performance requirements related to angles.

Req. nr.	Version	Description	Priority
Nr. 31	1.4	A step in roll, pitch and yaw from 0° to 30° shall have a maximum stationary error of 5% in simulation.	1
Nr. 32	1.5	A step in roll, pitch and yaw from 0° to 30° shall have a maximum rise time of 2 s in simulation.	1
Nr. 33	1.5	A step in roll, pitch and yaw from 0° to 30° shall have a maximum overshoot of 10% in simulation.	1
Nr. 34	1.4	A step in roll, pitch and yaw from 0° to 30° shall have a maximum settling time of 4.5 s with respect to an error band of 5% in simulation.	1
Nr. 35	1.4	A step in one of the degrees of freedom in simulation shall affect the other two rotational degrees of freedom with an maximum step amplitude of 1% after the settling time of the performed step is reached.	1

Table 10: Performance requirements related to angular velocities.

Req. nr.	Version	Description	Priority
Nr. 36	1.4	A step in angular velocity about LCS (Local Coordinate System)- axes from 0 rad/s to 0.5 rad/s shall have a maximum stationary error of 5% in simulation.	1
Nr. 37	1.5	A step in angular velocity about LCS- axes from 0 rad/s to 0.5 rad/s shall have a maximum rise time of 1.5 s in simulation.	1
Nr. 38	1.5	A step in angular velocity about LCS- axes from 0 rad/s to 0.5 rad/s shall have a maximum overshoot of 10% in simulation.	1
Nr. 39	1.5	A step in angular velocity about LCS- axes from 0 rad/s to 0.5 rad/s shall have a maximum settling time of 3 s with respect to an error band of 5% in simulation.	1

Table 11: Performance requirements related to the global position of the ROV.

Req. nr.	Version	Description	Priority
Nr. 40	1.4	A step in the ROV's position in any linear direction in PCS-axes by 1 m shall have a maximum stationary error of 5% in simulation.	1
Nr. 41	1.4	A step in the ROV's position in any linear direction along PCS-axes by 1 m shall have a maximum rise time of 5 s in simulation.	1
Nr. 42	1.5	A step in the ROV's position in any linear direction along PCS-axes by 1 m shall have a maximum overshoot of 10% in simulation.	1
Nr. 43	1.5	A step in the ROV's position in any linear direction along PCS-axes by 1 m shall have a maximum settling time of 7 s in simulation.	1

Table 12: Performance requirements related to linear velocities along LCS-axes.

Req. nr.	Version	Description	Priority
Nr. 44	1.4	A step in linear velocity from 0 m/s to 0.2 m/s shall have a maximum stationary error of 5% in simulation.	1
Nr. 45	1.4	A step in linear velocity from 0 m/s to 0.2 m/s shall have a maximum rise time of no of 2 s in simulation.	1
Nr. 46	1.4	A step in linear velocity from 0 m/s to 0.2 m/s shall have a maximum overshoot of 10% in simulation.	1
Nr. 47	1.4	A step in linear velocity from 0 m/s to 0.2 m/s shall have a maximum settling time of 3 s with respect to an error band of 5% in simulation.	1
Nr. 48	1.2	The step in the requirements 44-47 shall not effect the the pitch and roll angle more than 5%, and shall not effect the three rotational (degrees of freedom) velocities with more than $15°/s$, after the settling time is approached in simulation.	1

6 Sensor Fusion

The system is processing different data from sensors. These sensors are IMU (accelerometer and gyroscope), magnetometer, pressure sensor, barometer and three sonars. The data from these will be processed in the sensor fusion module.

6.1 Interface

Table 13 describes the requirements of sensor fusion modules interface with other modules.

Table 13: Interface requirements for the sensor fusion module.

Req. nr.	Version	Description	Priority
Nr. 49	1.0	The sensor fusion module shall be able to receive measurements from sensors by subscribing to ROS topics.	1
Nr. 50	1.0	The sensor fusion module shall be able to transmit the estimated states by publishing it to a ROS topic.	1

6.2 Design Requirements

The requirement on how the module shall be designed is described in Table 14.

Table 14: Design requirements on the sensor fusion module.

Req. nr.	Version	Description	Priority
Nr. 51	1.3	The sensor fusion module shall run on the Raspberry Pi.	2

6.3 Functional Requirements

The functional requirements in the sensor fusion module describes which functionality the module must be able to achieve. They are listed in Table 15.

Table 15: Functional requirements of the sensor fusion module.

Req. nr.	Version	Description	Priority
Nr. 52	1.0	The sensor fusion module shall be able to estimate the ROV's position in a known environment.	1
Nr. 53	1.0	The sensor fusion module shall be able to estimate the ROV's attitude.	1
Nr. 54	1.0	The sensor fusion module shall be able to estimate the ROV's linear velocities.	1
Nr. 55	1.0	The sensor fusion module shall be able to estimate the ROV's angular velocities.	1

6.4 Performance Requirements

How well the sensor fusion module shall perform is described as a number of performance requirements listed in Table 16.

Table 16: Performance requirements for the sensor fusion module.

Req. nr.	Version	Description	Priority
Nr. 56	1.5	The ROV shall be able to estimate its position in simulation, when the ROV is initialized with a maximum of 0.6 meters deviation of the true position.	1
Nr. 57	1.4	The ROV shall be able to estimate its attitude in simulation, when the ROV is initialized with a maximum of 15° deviation in each of the three angles.	1
Nr. 58	1.5	The estimation of the ROV's position in simulation shall be maintained within 0.3 meters of the true position, after the estimation has reach within this limit.	1
Nr. 59	1.0	The ROV shall be able to estimate its position and attitude when the position and attitude is initially unknown.	2
Nr. 60	1.4	The estimate of the linear velocity in x shall not have an error greater than 0.1 m/s, measured as an average velocity over 3 m, when traveling with a velocity between 0.3 m/s and 0.4 m/s for the whole distance.	1
Nr. 60 A	1.5	The estimate of the linear velocity in y shall not have an error greater than 0.1 m/s, measured as an average velocity over 3 m, when traveling with a velocity between 0.15 m/s and 0.25 m/s for the whole distance.	1
Nr. 60 B	1.4	The estimate of the linear velocity in z shall not have an error greater than 0.1 m/s, measured as an average velocity over 2 m, when traveling with a velocity between 0.2 m/s and 0.3 m/s for the whole distance.	1
Nr. 61	1.5	The estimate of the angular velocity in yaw shall not deviate more than $5°/s$ when rotating with an average speed between $35°/s$ and $45°/s$ in simulation.	1
Nr. 61 A	1.5	The estimate of the angular velocity in roll and pitch shall not deviate more than $8°/s$ when rolling in each direction with an average speed between $60°/s$ and $80°/s$ in simulation.	1
Nr. 62	1.4	The estimate of the attitude shall not deviate more then 1° from the true attitude in simulation.	1
Nr. 63	1.4	The sensor fusion module shall be able to produce state estimates with a maximum delay of 10 ms.	2

7 Modelling

A model of the system is necessary to be able to control the system with model based control strategies and to make simulations of the system. These requirements are just regarding the actual model. The model will be used and evaluated through the simulation environment.

7.1 Design Requirements

Table 17 contains design requirement of the modelling.

Table 17: Design requirement of modelling.

Req. nr.	Version	Description	Priority
Nr. 64	1.0	A mathematical model that describes the dynamic of the ROV shall be constructed.	1

7.2 Functional Requirements

In Table 18, the functional requirements of the ROV model is shown.

Table 18: Functional requirements of modelling.

Req. nr.	Version	Description	Priority
Nr. 65	1.0	The model shall describe the ROV's velocity along the x-, y-, z-axes in the LCS.	1
Nr. 66	1.0	The model shall describe the ROV's angular velocity around the x-, y-, z-axes in the LCS.	1
Nr. 67	1.0	The model shall describe the ROV's position along the x-, y-, z-axes in the PCS.	1
Nr. 68	1.0	The model shall describe the ROV's angle around the x-, y-, z-axes in the PCS.	1

7.3 Performance Requirements

In Table 19, the ROV's performance requirements is shown.

Table 19: Performance requirements of modelling.

Req. nr.	Version	Description	Priority
Nr. 69	1.4	When validating the model in one of the angular DOF's, the result in each DOF shall fit the data from relevant sensors, i.e. accelerometer and gyroscope, to at least 75 %. The data used for the validation, shall only excite the ROV in the DOF that shall be validated.	1
Nr. 70	1.4	When validating the model in one of the linear DOF's, the result in each DOF shall fit the data from relevant sensors, i.e. sonars, accelerometer and pressure sensor, to at least 80 %. The data used for the validation, shall only excite the ROV in the DOF that shall be validated.	1

8 Simulation

The simulation tool will be crucial for the successful implementation of the ultrasonic sensors to the system without having to operate the machine in the water. It will be built in Matlab/Simulink with both hardware and software in the loop capabilities. To be able to get direct input from the ROV during simulation an implementation to ROS must be functioning. This enables the simulated states to be calculated and regulated by the already existing regulators on the ROV.

8.1 Interface

The interface between the simulator in Matlab/Simulink and the ROV will be built as a ROS node, making it able to communicate both simulated sensor data to the sensor fusion node and simulated states to the on-board controllers. The interaction between user and simulation will be done via a GUI. During simulation, a 3D visualization of the ROV and its current states will be shown. In Table 20, the interface requirements are listed.

8.2 Design Requirements

With the simulator being able to do both pure software (SIL) and hardware in the loop (HIL) simulations, it needs to be robust enough to allow for differences between the real life system and of the mathematical model. To allow for further development of the now existing model it is important that the simulator is able to handle changes done in said model. In Table 21, the design requirements are shown.

8.3 Functional Requirements

In Table 22, the functional requirements of the simulation are listed.

Table 20: Interface requirements for the simulator.

Req. nr.	Version	Description	Priority
Nr. 71	1.0	A GUI for the simulation shall exist.	1
Nr. 72	1.0	The position and attitude of the ROV, in a known environment, should be updated in the GUI with a maximum delay of 100 ms.	1
Nr. 73	1.0	It shall be possible to specify the initial state of the ROV.	1
Nr. 74	1.0	The simulator shall be able to show angular velocities for the ROV.	1
Nr. 75	1.0	The simulator shall be able to show a 3D visualization of the ROV and its states.	1
Nr. 76	1.0	The simulator shall be able to show linear velocities for the ROV.	1
Nr. 77	1.0	The simulator shall be able to show the attitude of the ROV.	1

Table 21: Design requirements for the simulator.

Req. nr.	Version	Description	Priority
Nr. 78	1.0	The simulator shall be built in Matlab/Simulink.	1
Nr. 79	1.0	The simulation shall allow for changes being made in the model during testing.	1
Nr. 80	1.0	The mathematical model of the ROV can be used in the simulation.	1
Nr. 81	1.0	The known environment shall be implemented in the simulator and modeled with non visible bottom and surface.	1
Nr. 82	1.0	The sensors on the ROV shall be implemented in the simulator.	1

8.4 Performance Requirements

In Table 23, the performance requirements are listed.

Table 22: Functional requirements for the simulator.

Req. nr.	Version	Description	Priority
Nr. 83	1.0	The simulator shall be able to run SIL simulations.	1
Nr. 84	1.0	The simulator shall be able to run HIL simulations.	2
Nr. 85	1.0	When in HIL mode the simulator shall be able to switch between using simulated states and states calculated by the onboard sensor fusion module by simulating sensor data.	2
Nr. 86	1.0	While in HIL mode the simulation shall be able to handle user input with a maximum delay of 100 ms.	2
Nr. 87	1.0	The simulator will be able to log data from simulated runs.	1
Nr. 88	1.0	The simulator shall be able to import log data from real world measurements.	2
Nr. 89	1.0	The control module shall be possible to simulate in the simulator.	1
Nr. 90	1.0	The sensor fusion module shall be possible to simulate in the simulator.	1

Table 23: Performance requirements for the simulator.

Req. nr.	Version	Description	Priority
Nr. 91	1.0	The states produced by the simulation of the ROV, shall fit the estimated states from the sensor fusion module to at least 75 %, when validating with the same reference signals.	2

9 Hardware

This section contains the requirements for all hardware implementations that will be made during the project. The ROV is equipped with an IMU, a magnetometer, a barometer and a pressure sensor. These sensors can be used to stabilize the ROV and control its attitude. Three ultrasonic sensors (i.e. sonars) will be added to the ROV. This will create an opportunity for better estimation of position and velocity.

9.1 Interface

Table 24 contains requirements on the interface between the sensors and other components in the system.

9.2 Functional Requirements

Table 25 shows the different requirements on the functionality of the hardware.

Table 24: Requirements on the hardware interface.

Req. nr.	Version	Description	Priority
Nr. 92	1.0	The ultrasonic sensors shall be able to communicate with the I/O-module.	1
Nr. 93	1.0	The magnetometer shall be able to communicate with the I/O-module.	1
Nr. 94	1.0	The barometer shall be able to communicate with the I/O-module.	1
Nr. 95	1.0	The IMU shall be able to communicate with the I/O-module.	1
Nr. 96	1.0	The pressure sensor shall be able to communicate with the I/O-module.	1
Nr. 97	1.0	The I/O-module shall be able to publish sensor data on ROS topics.	1
Nr. 98	1.0	The I/O module shall be able to communicate with the ESC.	1
Nr. 99	1.0	The I/O-module shall be able to receive control signals by subscribing to ROS topics.	1

Table 25: Requirements on the functionality of the hardware.

Req. nr.	Version	Description	Priority
Nr. 100	1.0	The ROV shall be waterproof to a depth of 3.8 meters.	1
Nr. 101	1.0	It shall be possible to replace the battery of the ROV in less than 30 minutes.	1
Nr. 102	1.0	It shall be possible to access the control- and I/O-module of the ROV.	1
Nr. 103	1.0	The nuts on the ROV which acts as weights should be removed for a more aesthetic appearance.	2

10 Pathfinder

The ROV shall be able to find a possible path between a given start point, A, and a given end point, B, in a known environment. The path shall be planned to avoid known obstacles in the environment and to reach the final destination. This is made in the pathfinder module.

10.1 Interface

The interface requirements for the pathfinder module are shown in Table 26.

10.2 Functional Requirements

In Table 27, the functional requirements for the pathfinder module are shown.

Table 26: Requirements for the communication by the pathfinder module.

Req. nr.	Version	Description	Priority
Nr. 104	1.2	The pathfinder module shall be a ROS node.	1
Nr. 105	1.2	The pathfinder module shall be able to receive the estimated states from the sensor fusion model by subscribing to a ROS topic.	1
Nr. 106	1.2	The pathfinder module shall be able to receive the coordinates of the start point, A, and the end point, B, from the GUI by subscribing to a ROS topic.	1
Nr. 107	1.2	The pathfinder module shall be able to send the trajectory to the controller and the GUI by publishing to a ROS topic.	1

Table 27: Functional requirements of the pathfinder module.

Req. nr.	Version	Description	Priority
Nr. 108	1.2	The pathfinder module shall be able to plan a possible trajectory between point A and B in a known environment.	1
Nr. 109	1.2	The pathfinder module shall be able to plan a possible trajectory between a series of given points, A, B, C, etc. The path shall pass through each point.	2
Nr. 110	1.2	The ROV shall not collide with any obstacles or walls when it follows the planned path.	1

11 Possibilities to Upgrade

Since the result of the project will be used for further development and the ultimate goal is to make the ROV fully autonomous, it is necessary to have some requirements that make sure there are possibilities to upgrade. These requirements are listed in Table 28.

Table 28: Requirements that make sure there are possibilities to upgrade.

Req. nr.	Version	Description	Priority
Nr. 111	1.0	There shall exist a technical report.	1
Nr. 112	1.0	There shall exist a user manual.	1
Nr. 113	1.0	The system shall be module based.	1

12 Economy

In Table 29 the economical requirements are listed.

Table 29: Economy requirements.

Req. nr.	Version	Description	Priority
Nr. 114	1.0	Each member of the group shall spend 240 hours on the project. Accepted deviation is ± 10 %.	1

13 Security Requirements

In Table 30 some requirements are listed to promise security for developers and others that are around the product.

Table 30: Requirements to promise security.

Req. nr.	Version	Description	Priority
Nr. 115	1.0	The ROV shall detect if the connection with the workstation has been lost.	1
Nr. 116	1.0	All group members shall sign the document *Föreskrifter för användning av pool på innergård B25 till B27* before using the pool at LiU. This document regulates the terms and conditions for the pool. All activities in the project must comply with these terms and conditions.	1

14 Delivery

Table 31 contains the decision points and deliveries for the project.

Table 31: Required deliveries for the project.

Req. nr.	**Version**	**Description**	**Priority**
Nr. 117	1.0	BP2. 2017-09-19. Requirement specification, first draft of design specification, project plan and time plan shall be approved by the orderer.	1
Nr. 118	1.2	BP3. 2017-10-11. Design specification and test plan shall be approved by the orderer.	1
Nr. 119	1.2	BP4. 2017-11-10. 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 path planning in known environment shall be fulfilled.	1
Nr. 120	1.4	BP5. 2017-12-06. 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.	1
Nr. 121	1.4	Final delivery. 2017-12-13. A presentation shall be held for the customer to demonstrate that all requirements are fulfilled.	1
Nr. 122	1.0	BP6. 2017-12-18. A technical report, poster, website, presentation film and a post study that reflects the result and used time shall be approved by the orderer.	1

15 Documentation

During the project some documents have to be produced. Table 32 shows a description of each document and its target audience.

Table 32: List of all documentation required for the project.

Document	Description	Target Audience
Requirement specifications	A list of requirement to achieve the goal for the project.	Project group, Orderer and Customer
System overview	A brief technical presentation to show understanding of the system.	Project group, Supervisor and Orderer
Design specification	A more detailed technical description of the system and its modules that reflects the requirement specification.	Project group and Orderer
Project plan with time plan	A plan of which activities should be carried out during the project, when and of who.	Project group, Supervisor and Orderer
Test plan	Describe how and when tests should be carried out to ensure accomplishment of the requirement specifications.	Project group and Orderer
Test protocol	Protocol showing the results from the tests described in the Test Plan.	Project group, Supervisor and Orderer
Technical report	Description of the ROV system with technical details.	Project group, Orderer, Supervisor
User manual	A manual of how to operate the ROV in a secure way.	Project group, Supervisor, Customer and Orderer
Poster	Visual presentation of the ROV project that should appeal to the audience.	Customer and general audience
Video presentation	A video that shows the end product of the project and the reached goals.	Orderer, Customer and general audience
Web page	A web page that presents the project, the project member and the documentation.	Orderer, Customer and general audience
Presentation to client	Sales pitch and demonstration of the final project result.	Customer, Client and examiner
Group contract	The groups rules and expectation of the project stated as ground for solving conflicts.	Project group
Reflections	Reflection of the entire project work.	Examiner
Meeting protocol	Protocol of what had been said at the meetings to ensure everyone is up to date with current position in the project.	Project group and Orderer

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