Requirements Specification

Editor: Erik Bodin

Version 1.3

Status

Reviewed	Erik Bodin	2016-10-07
Approved	Martin Lindfors	2016-09-23

PROJECT IDENTITY

2016/HT, TIGER

Linköping Institute of Technology, ISY

Group members

Name	**Responsibility**	**Phone**	**E-mail**
Alfred Patriksson	Head of Software	076 210 94 30	alfpa324@student.liu.se
Axel Reizenstein	Head of Hardware	070 279 29 00	axere475@student.liu.se
Erik Bodin	Head of Documentation	076 241 11 32	eribo629@student.liu.se
Gustav Ling	Head of Testing	073 525 72 76	gusli621@student.liu.se
Henric Watz	Head of Information	076 817 57 75	henwa871@student.liu.se
Ingrid Sjöberg	Project Manager	070 652 14 01	ingsj090@student.liu.se
Joakim Mörhed	Head of Design	073 520 84 59	joamo950@student.liu.se

Group e-mail: tsrt10-balrog@googlegroups.com
Website: TBA

Customer: Saab Dynamics
Contact at customer: Torbjörn Crona, torbjorn.crona@saabgroup.com
Technical expert at customer: Erik Ekelund, erik.ekelund@saabgroup.com

Examiner: Daniel Axehill, daniel@isy.liu.se
Client: Martin Lindfors, martin.lindfors@liu.se
Supervisor: Per Boström, per.bostrom@liu.se

Contents

Document history

Version	Date	Changes	Changed by	Reviewed
0.1	2016-09-08	First draft	*	EB
0.2	2016-09-16	Second draft	*	EB
0.3	2016-09-19	Third draft	*	EB
0.4	2016-09-21	Fixed according to rest list	*	EB
1.0	2016-09-23	Approved	*	EB
1.1	2016-10-07	Removed times	*	EB
1.2	2016-11-22	Removal of outdoor requirements	IS	
1.3	2016-12-04	Changing size of test area, changing time of BP5	IS	

1 Introduction

The primary focus of this document is to enumerate the goals for this project, along with their relative importance. The document is broken down into sub-systems and their related requirements, along with the relative importance of each.

Each requirement has an importance rating, where level one requirements have to be fulfilled in order for the project to be approved. Level two requirements should be implemented and level three requirements are to be fulfilled if there is time. Each entry also specifies when the requirement was added to this document.

1.1 Involved parties

The project consists of the following parties:

- *Customer* Saab Dynamics represented by Torbjörn Crona
- *Client* Martin Lindfors at the department of Electrical Engineering (ISY), Linköping University
- *Technical advisor* Per Boström at ISY, Linköping University
- *Technical advisor* Erik Ekelund at Saab Dynamics
- *The project group* Consisting of seven engineering students at Linköping University

1.2 Goal

Req. #1	**Updated**	Delivery 2016-12-07.	**1**
Req. #2	**Original**	All tier 1 requirements fulfilled.	**1**
Req. #3	**Original**	All code will follow the relevant standards.	**1**
Req. #4	**Original**	All documentation will follow LIPS.	**1**

1.3 Usage

1.4 Background information

The project platform (Balrog) is provided by Saab Dynamics for student work at Linköping University. An HAL (Hardware Abstraction Layer) already exists and provides a unified MATLAB® interface for accessing sensor data and hardware state. This enables the project group to work solely in MATLAB® with compiled code running on Balrog.

This project is intended to provide precise positioning information for planning of routes and precise locating of mines. It is also necessary in order to guarantee a full mine detector coverage of a given area.

In addition to this basic functionality the platform is intended to implement higher level functionality such as SLAM and route planning, and serve as a further platform for cooperative development at LiU.

1.5 Definitions

- *Balrog* or *Platform* - The minesweeping vehicle that is used in this project.
- *The project group* - The group of students working on the project.
- *Position* - The center of the IMU unit placed on the platform which is also the center of rotation.
- *Obstacle position* - Position of the edges of the obstacle.
- *AprilTag* - A printable tag made by April Robotics Laboratory used to position the camera that looks at the tag. The tags will be used in the positioning of the platform.
- *Indoor test area* - A horizontal rectangular indoor area with dimensions 5x5 meters. The test area will be static over time. AprilTags will be placed in each corner of the test area.
- *Outdoor test area* - A horizontal rectangular indoor area with dimensions 20x20 meters. The test area will be static over time. AprilTags will be placed in each corner of the test area. Note: Outdoor testing has been removed. (2016-11-22)
- *Obstacle* - An object that the platform can not pass through. The obstacle shall have a rectangular solid profile and be 0.5 meters wide and 0.5 meters high.
- *Map* - A local made to scale representation of the indoor test area. It must at least contain position of the walls surrounding the test area. It may include selected obstacles.
- *Scanned area* - Area that the robot has driven over. The scan width is set to be 0.25 meters to each side parallel to the platform front area meaning it scans with a total width of 0.5 meters.
- *User* - The human who is controlling the platform. Either via the remote control or by adding waypoints to the navigation system.
- *Search area* - Area which the robot shall sweep for mines. The area is specified in width and length.
- *Test route* - A route defined by 4 waypoints placed in each corner of a square with side length 3 meters. The platform is placed with its center position over the first waypoint and its front facing the second waypoint. The platform shall have a map covering the test route and the required localization precision (specified under localization requirements) shall be met.

2 System Overview

The Balrog platform is an autonomous tracked vehicle equipped with sensors, GPS, and several single-board computers. It can be controlled remotely or programmed to navigate autonomously. A Raspberry Pi 3 model B+ running Raspbian is responsible for processing sensor data and performing calculations.

2.1 General description of the product

The product is separated into two parts, the platform Balrog and the higher level code implementing sensor fusion, optimal control and SLAM. Balrog is provided by Saab Dynamics.

2.2 Product components

The core component of this project is the robot Balrog.

The platform sensor suite includes LIDAR, ultrasonic rangefinders, GPS, IMU and a front-facing camera. In addition to the basic sensors the product will include a computer based graphical interface for visualization of maps and searched areas.

The primary software systems are positioning, mapping, navigation, and automatic control.

2.3 Subsystems

There are five software subsystems.

- Positioning - the core functionality. Its sole task is to estimate the current state vector.
- Mapping - local area map. It uses the ranging sensors to detect nearby obstacles.
- Navigation - path-finding and decision-making.
- Automatic control - route following and command execution.
- Graphical user interface. This displays maps and robot state.

2.4 System Dependencies

The positioning system only depends on the sensors. It then provides a state estimate for the mapping component. The mapping component combines the state estimate with the ranging sensors in order to build a map of the local area.

The routing system then builds off the map and state estimates in order to plan the next route. The routing system ultimately uses the automatic control systems to execute its plans.

Graphical GUI can be developed independently but depends on data from robot.

2.5 Delimitations

Making any changes to the provided hardware and related HAL is outside the scope of this project. This does not necessarily exclude hardware maintenance and repair.

2.6 Design philosophy

The purpose of this project is to provide a stable software platform for further development of automatic control and sophisticated decision-making. Therefore the primary goals are to provide stable and well documented core functionality.

The standards that this project follows are the LIPS model and the Google code standards.

2.7 General requirements

Req. #5	**Original**	The project will follow the LIPS standard.	**1**
Req. #6	**Original**	The platform can be remotely controlled by a human using the provided remote controller.	**1**
Req. #7	**Original**	There will be a dead mans switch, so the platform stops moving if the remote control loses connection.	**1**
Req. #8	**Original**	The project group will have meetings at least once a week.	**1**
Req. #9	**Original**	A group contract describing general conduct will be established.	**1**
Req. #10	**Original**	Each group member will agree with and follow the terms in the group contract, this will be confirmed by a signature from all members.	**1**

3 Positioning

There are a number of different sensors on the platform. These will be used to determine the state of the platform as accurately as possible.

3.1 Description

The criteria on positioning refer to the maximum difference between the current position and a 'ground truth' position.

3.2 Interface

The positioning module is responsible for providing a current state estimate to all other modules. It builds these from sensor data and has no other dependencies.

3.3 Design requirements

Req. #11	**Original**	There will be an internal model describing the robot's motion and state.	**1**
Req. #12	**Original**	The algorithm will take the statistical properties of all sensors into account.	**1**
Req. #13	**Original**	The robot shall store its current position each second.	**1**
Req. #14	**Original**	Positioning will be done in a local, two dimensional flat reference frame.	**1**
Req. #15	**Original**	Local reference frame should be mappable to global reference frame.	**2**

3.4 Functional requirements

Req. #16	**Original**	When navigating the *indoor test area*, the position will be estimated with an accuracy of:	**-**
Req. #16A	**Original**	0.1 meters.	**1**
Req. #16B	**Original**	0.05 meters.	**2**
Req. #16C	**Original**	0.01 meters.	**3**
Req. #17	**REMOVED**	When navigating an *outdoor test area*, the position will be estimated with an accuracy of:	**X**
Req. #17A	**REMOVED**	0.15 meters.	**X**
Req. #17B	**REMOVED**	0.10 meters.	**X**
Req. #17C	**REMOVED**	0.05 meters.	**X**
Req. #18	**Original**	The angular state of the robot will be estimated with an accuracy of:	**-**
Req. #18A	**Original**	10°when stationary.	**1**
Req. #18B	**Original**	1°when stationary.	**2**

4 Mapping

The mapping component will passively collate information from the sensors in order to provide a map of the area.

4.1 Description

The mapping unit's main purpose is to provide an estimation of the world state, primarily obstacles. The mapping unit will have to perform statistical analysis on the sensor results in order to filter out false negatives, and group measurements together.

4.2 Interface

The mapping component will be making use of the LIDAR and ultrasound sensors. It also needs the current state estimation provided by the positioning module in order to put these measurements into context. It then provides a map for the other modules to base decisions from.

The mapping component works passively, in the sense that it does not issue commands to control of the robot. It just passively collates the received information into the map.

4.3 Design requirements

Req. #19	**Original**	The platform will be provided with a predefined partial map of the test area.	**1**
Req. #20	**Original**	The platform explore all portions of the map that are reachable and not within 1 meter of an obstacle or the edges of the map.	**1**
Req. #21	**Original**	The map will indicate areas that have been searched. It will update the map every second.	**1**
Req. #22	**Original**	The platform should be able to detect obstacles (specified under Definitions) in front of it, closer than 10 m, which are not included in the predefined map using the LIDAR.	**1**
Req. #23	**Original**	Obstacles detected by the platform should be added to the map.	**1**
Req. #24	**Original**	The platform should be able to detect obstacles of the sides using the ultra-sound.	**2**
Req. #25	**Original**	The platform should implement computer vision and include this in the positioning calculations.	**1**
Req. #26	**Original**	The platform will be able to perform object recognition using the camera.	**3**
Req. #27	**Original**	The map should indicate where a mine has been detected.	**3**
Req. #28	**Original**	A stereo camera and 3D computer vision should be implemented.	**2**
Req. #29	**Updated**	The camera will be able to detect an AprilTag placed within 2 meters from the camera.	**1**

4.4 Functional requirements

Req. #30	**Original**	Detected obstacles and map elements which are not included in the predefined map shall be mapped within 15 seconds from detection.	**1**
Req. #31	**Original**	The platform will be able to detect obstacles in front of it at a range of 10 meters.	**1**
Req. #32	**Original**	The platform will be able to detect obstacles to the sides at a range of 1 meter.	**3**
Req. #33	**Original**	The camera will be able to recognize a predefined object at a distance of 5 meters.	**3**
Req. #34	**Updated**	When navigating the indoor test area with 3 obstacles spaced at least 2 meters apart, the obstacle position will be estimated with an accuracy of:	**-**
Req. #34A	**Original**	0.2 meters.	**1**
Req. #34B	**Original**	0.15 meters.	**2**
Req. #34C	**Original**	0.1 meters.	**3**
Req. #35	**Removed**	When navigating the outdoor test area with 5 obstacles spaced at least 5 meters apart, the obstacle position will be estimated with an accuracy of:	**X**
Req. #35A	**Original**	0.3 meters.	**X**
Req. #35B	**Original**	0.2 meters.	**X**
Req. #35C	**Original**	0.1 meters.	**X**

5 Navigation

The robot is intended to search large areas of land. It is possible to make large gains in efficiency and reliability by making the robot perform planning of the route autonomously.

5.1 Description

This is the place where the autonomous agent is implemented. It includes route-planning and decision-making. It should dynamically react to changes in the world map and state, to fulfill a given set of goals. Usually this goal will be to systematically cover an entire section of a map.

5.2 Interface

The route planning functionality uses the internal map provided by the mapping component and the state provided by the positioning component. It provides a target reference signal for the control module to follow.

5.3 Design requirements

Req. #36	**Original**	The user shall be able to manually add 10 waypoints with a minimum distance of 1 meter to each other to the predefined map as local coordinates.	**1**
Req. #37	**Original**	The navigation software will make the trajectory between the waypoints in a way that collision with mapped obstacles is avoided.	**1**
Req. #38	**Original**	The navigation software will update the trajectory if new obstacles appear.	**1**
Req. #39	**Original**	The navigation software should spline waypoints to provide a smooth reference trajectory for the control system.	**2**
Req. #40	**Original**	The user shall be able to specify a local search area in two dimensions. The area shall fit within the predefined map.	**2**
Req. #41	**Original**	The navigation software will plan a route in such way that the whole user defined search area is covered, except for obstacles.	**2**
Req. #42	**Original**	Planning should be done in real-time.	**1**

5.4 Functional requirements

Req. #43	**Original**	When navigating the indoor test area without obstacles, the algorithm should explore the entire map.	**1**
Req. #44	**REMOVED**	When navigating the outdoor test area without obstacles, the algorithm should explore the entire map.	**X**
Req. #45	**Original**	When navigating the indoor test area with 3 obstacles spaced at least 2 meters apart, the algorithm should explore all segments of the map more than:	**-**
Req. #45A	**Original**	0.5 meters from an obstacle.	**1**
Req. #45B	**Original**	0.2 meters from an obstacle.	**2**
Req. #45C	**Original**	0.1 meters from an obstacle.	**3**
Req. #46	**REMOVED**	When navigating the outdoor test area with 5 obstacles spaced at least 5 meters apart, the algorithm should explore all segments of the map more than:	**X**
Req. #46A	**REMOVED**	0.6 meters from an obstacle.	**X**
Req. #46B	**REMOVED**	0.4 meters from an obstacle.	**X**
Req. #46C	**REMOVED**	0.2 meters from an obstacle.	**X**

6 Automatic Control

6.1 Description

The automatic control module is a tool available to the navigation agent. In automatic mode the navigation agent uses the AC module to perform its search in a completely autonomous fashion. Without the AC module the navigation module can only give suggestions to a human operator who then has to perform them manually.

6.2 Interface

The automatic control module follows a trajectory provided by the navigation module. It also needs accurate state estimates that are provided by the positioning module. The output interface for the AC module is the wheel speeds.

6.3 Design requirements

Req. #47	**Original**	The control system use an externally provided reference signal.	**1**
Req. #48	**Original**	Route can be followed with variable speed.	**3**

6.4 Functional requirements

Req. #49	**Original**	The control system shall follow the defined test route (specified under Definitions) with a deviation of no more than 0.1 meters. It shall finish within a circle of radius 0.2 meters with its center in the initial waypoint.	**1**

7 Graphical User Interface

The GUI is intended to run on a laptop and communicate with the robot over a wireless connection.

The GUI is a tool to display Balrog state and sensor data. It will also show the current internal map. The goal is also to have it display some secondary statistics such as the wireless link load.

7.1 Interface

The GUI interfaces with Balrog over a 802.11n WLAN connection. The computer provides commands to change the robot operating state, toggle sensor data feeds on and off, as well as a link health update including the dead man's grip state.

7.2 Design requirements

Req. #50	**Original**	The GUI will be written in C++	**1**
Req. #51	**Original**	The software will use the gtkmm library.	**1**
Req. #52	**Original**	The GUI should log data for later analysis.	**1**
Req. #53	**Original**	The GUI should receive and render data in real time.	**2**
Req. #54	**Original**	The wireless connection will be encrypted.	**3**

7.3 Functional requirements

Req. #55	**Original**	The GUI will render the robot's position and internal map.	**1**
Req. #56	**REMOVED**	It will be possible to enable/disable the sensor data feeds, to prioritize important data.	**X**
Req. #57	**Original**	The GUI should display the wireless link performance.	**2**
Req. #58	**Original**	The GUI should display a real-time video feed from the robot	**3**

8 Upgrade Requirements

Because the project is intended to provide a suitable platform for further cooperative development between LiU and Saab Bofors Dynamics the primary requirements are to provide a well documented, stable and easily extended software interface.

Req. #59	**Original**	The project will be developed in such a way that new components are easy to implement	**1**

9 Economy

Req. #60	**Original**	All members will work 240h $\pm 10\%$ on the project.	**1**
Req. #61	**Original**	The project group will have access to 50 hours consulting from Martin Lindfors.	**1**
Req. #62	**Original**	The project group will have access to 50 hours consulting from Per Boström.	**1**
Req. #63	**Original**	The project group will have access to 40 hours of consulting from SAAB Bofors Dynamics.	**1**
Req. #64	**Original**	ISY will provide the project group with a room where the platform can be stored and work carried out.	**1**
Req. #65	**Original**	Any expenses shall be approved by and paid for by ISY or Saab.	**1**

10 Delivery Requirements

Req. #66	**Original**	A requirements specification shall be approved by the client no later than 2016-09-20	**1**
Req. #67	**Original**	A system draft shall be approved by the client no later than 2016-09-20	**1**
Req. #68	**Original**	A project plan containing a time plan shall be approved by the client no later than 2016-09-20	**1**
Req. #69	**Original**	A design specification shall be approved by the client no later than 2016-10-04	**1**
Req. #70	**Original**	A test plan shall be approved by the client no later than 2016-10-04	**1**
Req. #71	**Updated**	All functionality shall be approved by the client no later than 2016-12-05	**1**
Req. #72	**Updated**	The test protocol shall be approved by the client no later than 2016-12-05	**1**
Req. #73	**Updated**	The user guide shall be approved by the client no later than 2016-12-05	**1**
Req. #74	**Original**	A presentation showing that the requirements have been met shall be held no later than 2016-12-16	**1**
Req. #75	**Original**	The technical report shall be approved no later than 2016-12-16	**1**
Req. #76	**Original**	The after study containing a follow-up of the results and time used shall be approved no later than 2016-12-16	**1**
Req. #77	**Original**	The poster shall be approved no later than 2016-12-16	**1**
Req. #78	**Original**	The project video shall be approved no later than 2016-12-16	**1**
Req. #79	**Original**	A time report of each activity and person for the previous week will be sent to the client every monday morning.	**1**
Req. #80	**Original**	A status report shall be sent to the client and the customer every week.	**1**

11 Documentation

Req. #81	**Original**	The documentation produced in the project will follow the LIPS standard.	**1**
Req. #82	**Original**	All documents will be written in English	**1**

11.1 Webpage

Req. #83	**Original**	The project will have a web page describing the progress of the project.	**1**
Req. #84	**Original**	The web page will be up and running no later than 2016-12-19	**1**

11.2 Video

Req. #85	**Original**	A video that can be published as promotion for the project will be made.	**1**

11.3 Poster

Req. #86	**Original**	A poster describing the system will be produced.	**1**

11.4 Code

Req. #87	**Original**	Any C++ code produced in the project will conform to the Google code standard.	**1**
Req. #88	**Original**	MATLAB code produced in the project will conform to the standard defined in the project plan.	**1**

A Appendix

References

[1] *LIPS – nivå 1. Version 1.0.* Tomas Svensson och Christian Krysander. Kompendium, LiTH, 2002.