Requirement Specification

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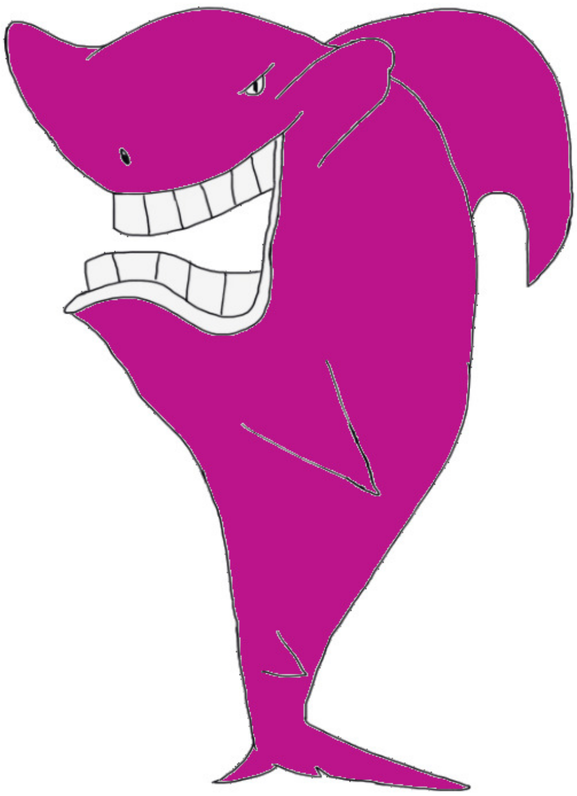
Version 1.0



Status

Reviewed	Axel Halldin	2015-09-09
Approved	Hanna Nyqvist	2015-xx-xx

PROJECT IDENTITY

2015/HT, Ross Haj
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Document history

Version	**Date**	**Changes**	**Sign**	**Reviewed**
0.1	2015-09-09	First draft.	all	AH, SG
0.2	2015-09-15	Second draft.	all	AH, SG
0.3	2015-09-17	Third draft.	all	AH, SG
0.4	2015-09-21	Fourth draft.	all	AH, SG
1.0	2015-09-22	Final version.	all	AH, HF

1 Introduction

This project concerns the continued development of Balrog, an autonomous mine-sweeping crawler. The project is a cooperation between Saab Bofors Dynamics and the Department of Electrical Engineering (ISY) at Linköping University.

This document holds an overview of the technical system and its subsystems and specifies requirements for said systems. The requirements are listed in tables, with a priority in the rightmost column. Priority 1 means the requirement has the highest priority and has to be satisfied. Priority 2 means it should be satisfied. Priority 3 means it should be satisfied if time allows it.

Apart from technical requirements, this document also holds requirements regarding project management, deliveries and constraints of resources.

1.1 Background information

Mine sweeping is a work both dangerous and time consuming. The machines used for clearing an area of mines are usually operated by a human, and detects mines by plunging metal chains into the ground to detonate the mines. The alternative today is to use a portable metal detector, operated by a human, but this is often deemed as too tedious.

If instead an autonomous machine could do the mine detection and mark the placements of mines on a map, both time and potential damages, to humans as well as to the environment, could be reduced.

A prototype platform for the autonomous mine sweeping system already exists, but has to be improved in a number of different areas. The main focus is to improve the navigation/localization.

1.2 Involved parties

The project organization consists of

- The Customer contact at Saab Bofors Dynamics: Torbjörn Crona
- The Client at ISY, Linköping University: Hanna Nyqvist
- The Advisor at ISY, Linköping University: Martin Lindfors
- The Technical Advisors at Saab Bofors Dynamics: Stefan Thorstenson, Björn Johnsson and Carl Nordheim
- The Project Leader: Axel Halldin
- The project group consists of (Project Leader included) seven engineering students, of which six study Applied Physics and Electrical Engineering and one study Industrial Engineering and Management.

1.3 Objects

The objects this years are to

1. Improve the estimation of the crawler's navigation/localization
2. Add a new sensor with IMU, magnetometer and barometer capability to Balrog
3. Thoroughly document the performance of every sensor connected to the crawler
4. Implement and document a navigation filter
5. Develop an algorithm detecting when a sensor is reliable/unreliable

1.4 Usage

The resulting product is to be used by Saab Bofors Dynamics and ISY at Linköping University for further research and educational purposes.

1.5 Definition of terms

Balrog - The autonomous moving vehicle (crawler) that will be navigating.
Hand Controller - A remote Xbox hand controller used to control Balrog manually.
Main Control Unit - The main computer on Balrog.
Base Station - The computer containing the GUI from which Balrog receives orders and to which Balrog sends mapping information.
Balrog's position - The geometrical center of Balrog's IMU-unit.
Operator - The person operating Balrog.
Demonstration - A demonstration is when Balrog is driven in a search area to demonstrate its capabilities. Balrog is manually driven by the operator inside the area, avoiding any obstacles. The operator shall drive Balrog forwards and make turns, and Balrog may be stationary for some time of the demonstration. Balrog must travel a total distance of at least 4 meters during the demonstration. During indoor demonstrations, Balrog must never be farther then 4 meters away from an obstacle or a wall.
Search Area - The area where the system will work. This area must be rectangular and its sides must be longer then 6 meters and shorter then 30 meters. Balrog must be able to travel from any point in the search area to any other point in the search area, if non of these points are blocked by an obstacle.
Obstacle - Any object that Balrog can't travel over/through.

2 Overview of the system

In the following section, the system will be roughly described.

2.1 Description of the system

The system is comprised by Balrog including its Main Control Unit, the Hand Controller and the Base Station. The Hand Controller is used when Balrog is operated manually and the base station is used when Balrog operates autonomously.

2.2 Product components

- Balrog
  - Laser scanner
  - Ultrasonic sensor
  - Inertial measurement unit (IMU)
  - Odometers
  - Magnetometer
  - WiFi communications
  - Barometer
- Hand Controller
- Base Station
  - Computer
  - WiFi communications

2.3 Dependency to other systems

In order to determine the absolute position of Balrog, GPS coverage is needed. Without GPS coverage, only a relative position can be determined.

2.4 Design philosophy

The system is to be considered as a foundation for future project and shall be developed with that in mind. The code shall be very well commented so that it can be reused in future project, and the algorithms shall be as general as possible. Likewise, this project is using previous year's project as foundation and as much code and design from previous years as possible shall be reused.

2.5 Limitations

Only the navigation/localization problem is considered in this project, so the mine searching aspects of Balrog will not be covered. The project aims to make the positioning of Balrog great during manual driving and Balrog acting autonomously will not be considered. All walls and obstacles used for positioning are assumed to be time invariant. All obstacles are assumed to be detectable by Balrog's laser scanner and ultra sonic sensor (eg. no holes or low barriers).

The communication between Balrog, the Base Station and the Hand Controller is assumed to be robust and reliable, cases contradicting to this statement will not be considered. The stereo camera previously present on Balrog will not be considered in this project.

3 Administration

In the following section, the administration requirements of the project is specified.

Req. 1	**Original**	The project group shall have weekly meetings	**1**
Req. 2	**Original**	The Project Leader should have meetings with the Client at least every 14 days	**1**
Req. 3	**Original**	The project work shall follow the LIPS model	**1**

4 Sensors and sensor diagnosis

Some of the sensors will occasionally deliver unreliable measurements (for example, the GPS might not work well indoors, laser measurements might be unreliable outdoors, etc.). It is desirable to know which sensors delivers bad measurements, so that high level algorithms using sensor values don't use bad input. Therefore, a sensor diagnostics subssytem will be added to Balrog. This subssystem will also handle the sensor models and conversions to correct units. Furthermore, a new sensor measuring altitude is to be added to Balrog.

4.1 Requirements for sensors and sensor diagnosis

Req. 4	**Original**	The old IMU/magnetometer unit on Balrog shall be replaced with a new IMU/magnetometer/barometer unit	**1**
Req. 5	**Original**	The performance of each sensor shall be documented (accuracy, errors)	**1**
Req. 6	**Original**	Each sensor shall be modelled and the model shall be documented	**1**
Req. 7	**Original**	The raw input from each sensor shall be logged together with a timestamp by Balrog	**1**
Req. 8	**Original**	There shall be a sensor diagnosis subsystem	**1**
Req. 9	**Original**	The sensor diagnosis subsystem shall convert the sensor output to SI units	**1**

Req. 10	**Original**	The sensor diagnosis subsystem shall flag any sensor data as unreliable when it lies outside the confidence interval of the expected sensor value. The confidence interval is calculated from the Balrog position estimate and uncertainty (see Req. 17 and 18)	**1**
Req. 11	**Original**	The confidence level of the confidence interval in Req. 10 is sensor-specific and it is set as a design parameter in the sensor diagnosis system	**1**
Req. 12	**Original**	If data from any sensor is outside the confidence interval with a certain frequency, the sensor shall be flagged as inaccurate.	**1**
Req. 13	**Original**	The frequency in Req. 12 is sensor-specific and it is set as a design parameter in the sensor diagnosis system	**1**
Req. 14	**Original**	It shall be possible to manually set the diagnosis system to flag any sensor as inaccurate	**1**
Req. 15	**Original**	The GUI shall show all sensors flagged as inaccurate	**1**
Req. 16	**Original**	All data from sensors flagged as inaccurate shall be flagged as unreliable	**1**

5 Positioning and navigation

It is crucial that Balrog can determine its position with a high degree of certainty, in order to avoid incorrect positioning of mines. Therefore, a filter will be developed that uses sensor data, Balrog's previous position estimates and a map of the Search Area (known or estimated) to estimate its current position. Positioning with a known map has been given higher priority than the harder SLAM problem.

5.1 Requirements for positioning and navigation

Req. 17	**Original**	The navigation/localization of Balrog shall be estimated with a navigation filter	**1**
Req. 18	**Original**	The navigation filter shall estimate the uncertainty in the navigation/localization estimate	**1**
Req. 19	**Original**	The navigation filter shall be based on a 2D motion model of Balrog	**1**
Req. 20	**Original**	The navigation filter shall be based on a 3D motion model of Balrog	**3**
Req. 21	**Original**	The navigation filter shall use all sensor data that is not flagged as unreliable	**1**
Req. 22	**Original**	The navigation filter shall be able to use a predefined map to improve Balrog's navigation	**1**
Req. 23	**Original**	The navigation filter shall be able to map the enviroment of Balrog to improve navigation (SLAM)	**3**
Req. 24	**Original**	Balrog shall keep track of its previous positions with uncertainties	**1**
Req. 25	**Original**	It shall be possible to run the navigation filter off-line with logged or simulated sensor data	**1**
Req. 26	**Original**	During a 1 minute demonstration with a known map in an indoor environment, Balrog shall be able to determine its position relative to the ground truth with a maximum error of...	
Req. 26A	**Original**	...less than 0.15 meters	**1**
Req. 26B	**Original**	...less than 0.1 meters	**2**
Req. 26C	**Original**	...less than 0.05 meters	**3**
Req. 27	**Original**	During a 1 minute demonstration with a known map in an outdoor environment, Balrog shall be able to determine its position relative to the ground truth with a maximum error of...	
Req. 27A	**Original**	...less than 0.4 meters	**1**
Req. 27B	**Original**	...less than 0.2 meters	**2**
Req. 27C	**Original**	...less than 0.1 meters	**3**
Req. 28	**Original**	During a 1 minute demonstration with no map in an outdoor environment, Balrog shall be able to determine its position relative to the starting point with an maximum error less then 0.5 meters	**1**

Req. 29	**Original**	During a 1 minute demonstration with a known map in an indoor environment, Balrog shall be able to determine its current heading relative to its starting position with a maximum error of 20 degrees	**1**
Req. 30	**Original**	During a 1 minute demonstration with a known map in an outdoor environment, Balrog shall be able to determine its current heading relative to its starting position with a maximum error of 30 degrees	**1**

6 Economy

Req. 31	**Original**	Each member of the group shall work 240 hours $\pm 10\%$ with the project	**1**
Req. 32	**Original**	All extra purchases due to needs in the project shall be approved and payed by the Customer or the Client at ISY	**1**

7 Deliveries

Req. 33	**Original**	A requirement specification shall be approved by the Client no later than 2015-09-22	**1**
Req. 34	**Original**	A system draft shall be approved by the Client no later than 2015-09-22	**1**
Req. 35	**Original**	A project plan shall be approved by the Client no later than 2015-09-22	**1**
Req. 36	**Original**	A design specification shall be approved by the Client no later than 2015-10-13	**1**
Req. 37	**Original**	A test plan shall be approved no later than 2015-10-13	**1**
Req. 38	**Original**	Two sensor models shall be presented to the client (part of requirement 10) no later than 2015-11-10	**2**
Req. 39	**Original**	The sensor diagnosis subsystem shall be able to disable a sensor that is unreliable (requirement 9). This will be presented to the client no later than 2015-11-10	**2**
Req. 40	**Original**	A test protocol shall be approved by the client no later than 2015-11-23	**1**
Req. 41	**Original**	A user manual shall be approved by the client no later than 2015-11-23	**1**
Req. 42	**Original**	A presentation for the client to demonstrate that all requirements are fulfilled no later than 2015-11-23	**1**
Req. 43	**Original**	The final product shall be delivered to the customer no later than 2015-12-01	**1**
Req. 44	**Original**	A technical report shall be approved by the client no later than 2015-12-10	**1**
Req. 45	**Original**	A project evaluation document shall be approved by the client no later than 2015-12-10	**1**
Req. 46	**Original**	A time report shall be delivered on a weekly basis	**1**
Req. 47	**Original**	A short status report shall be delivered on a weekly basis	**1**
Req. 48	**Original**	The group shall attend the project conference on 2015-12-14	**1**

8 Documentation

Req. 49	**Original**	Written language in all documents must be English	**1**
Req. 50	**Original**	Each official meeting must result in a meeting protocol	**1**
Req. 51	**Original**	All produced plots and graphs shall be vectorized if possible	**1**

8.1 Web page

Req. 52	**Original**	The project must have a web page demonstrating the progress of the project	**1**
Req. 53	**Original**	The web page shall be up and running no later than 2015-09-28	**1**

8.2 Video

Req. 54	**Original**	A video, presenting and demonstrating the system, shall be posted on www.youtube.com no later than 2015-12-10	**1**

8.3 Poster

Req. 55	**Original**	A poster, describing the project, shall be produced no later than 2015-12-10	**1**

8.4 Code

Req. 56	**Original**	New source code shall be well commented and follow the guidelines specified by Google, Google style guide	**1**
Req. 57	**Original**	All the source code shall be well commented and follow the guidelines specified by Google, Google style guide	**3**
Req. 58	**Original**	New source code shall be documented in Doxygen	**1**
Req. 59	**Original**	All source code shall be documented in Doxygen	**3**

9 Requirements for further development

Req. 60	**Original**	The project must be developed such that new components are easy to implement in the future	**1**

A Appendix

References

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