Project Plan
Minesweeper

Version 1.0

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Status

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Project Identity

Linköping University, Department of Electrical Engineering (ISY)
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Contents

Document History

Version	Date	Changes made	Sign	Reviewer
0.1	12/9 2017	First draft.	-	EN
0.2	14/9 2017	First revision	-	EN
0.3	17/9 2017	Second revision	-	EN
0.4	21/9 2017	Third revision	-	EN
1.0	21/9-17	First approved version	-	EN

1 Customer

The customer is Saab Dynamics represented by Torbjörn Crona. The client is Martin Lindfors from the department of Electrical Engineering at Linköping University.

2 Project Overview

This document describes a continuation of an existing project developed by Linköping University and Saab Dynamics. The long-term goal of the project is to create an autonomous minesweeper which intends to explore and clear areas from landmines. This task requires a high accuracy and confidence in its position. As a research project, conducted by students, this task has been simplified with regards to operating environment and interacting objects. What is new for this year is that the tracked vehicle which intends to search for mines on the ground now will cooperate with an UAV (Unmanned Aerial Vehicle) in the air for navigation and tracking purposes.

2.1 Purpose & Goals

The minesweeper project is conducted as a CDIO (Conceive Design Implement Operate) project as a part of the course TSRT10 at Linköping University. The course goal is for the students to practice theoretical skills in a realistic project conducted in close collaboration with a company.

The aim of this project is to further develop already implemented algorithms of a robot platform (referenced to as "Balrog"). The vehicle should be able to search and map an area and detect landmines. The route which the Balrog intends to follow shall be planned with regards to different optimization criteria. A UAV (referenced to as "Sauron") is introduced to the project and should be implemented in such a way that it supports the robot platform on its mission. The long term goal is to extend the system with hardware and software, so it can detect mines autonomously.

2.2 Deliveries

The deliveries for the project is seen in the table below.

Delivery	**Tollgate**	**Date**
Requirement specification	2	18/9 2017
Project plan including a time plan	2	18/9 2017
System draft	2	18/9 2017
Design specification	3	04/10 2017
Test plan	3	04/10 2017
Mapping based on rotational LIDAR	4	07/11 2017
Test protocol to prove the above functionality	4	07/11 2017
Test protocol proving requirements	5	01/12 2017
Demonstration focused on functionality	5	01/12 2017
User manual	5	01/12 2017
System delivery to customer	5+	TBA
Technical report	6	15/12 2017
Project evaluation	6	15/12 2017
Poster	6	15/12 2017
Website	6	15/12 2017
Demonstration film	6	15/12 2017
Installation manual	6	15/12 2017
Time report to client delivered by PM		Weekly
Status report to client and customer delivered by PM		Weekly

2.3 Scope

Software for Balrog and Sauron will mostly be developed from existing code. The hardware will be delivered by Saab Dynamics and will not be revised within the project. Demonstration and testing areas will be located inside although the final goal is outdoor usage. Detailed descriptions of the requirements set for the project are available in the Requirements specification [1].

3 Project Phases

3.1 Before

Before any actual technical development, the following documentation will be presented. These documents will form the basis for the decision of initiating the development process of the project.

- Requirements specification
- System draft
- Project plan
- Time plan

However, the requirements specification will be revised as more in-going knowledge of the system is obtained. Here information from the earlier projects is examined and a basic plan for the new system is developed.

3.2 During

The following documentation will be written during the development process:

- User manual
- Test protocol

During this phase, most of the development process will be conducted. The development process will be inspired by *SCRUM*. In the beginning of this phase, most resources will be focused on getting the new sensors to work with the existing robot platform. When the robot is working (barely, when no fine-tuning is done), the next step of this phase is to be initiated.

When a working system is achieved, more subsystems can be developed to further improve the functionality of the robot platform. For instance, the functionality of the UAV can be implemented. Every subsystem should be tested and the functionality verified before it is integrated into the robot platform.

3.3 After

The last phase of the project will result in the following documentation:

- Technical report
- Poster
- Video presentation
- Website with project information
- Evaluation of project

Furthermore, a presentation of the results of the project will be conducted in front of a live audience.

4 Project Organization

All members of the project group have a certain role (see section Group Members). For a graphical structure, see Figure 1, where external personnel is displayed in light blue and members of the group in darker blue. Further there are two people responsible for bigger areas (SLAM, Route Planning & Navigation) which are in contact with both testing, hardware and design. Each person is also member of a subgroup, SLAM, Route Planning & Navigation or UAV. See the Time Plan for the distribution of people.

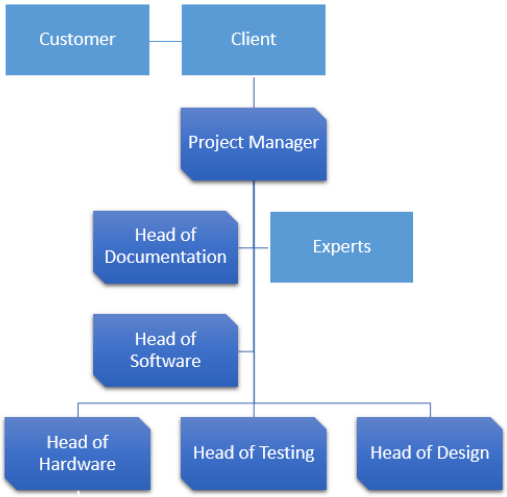

Figure 1: Project organization

4.1 Definition of responsibilities for each role

4.1.1 Project Manager (PM)

The project manager is responsible for communicating with the customer and client. This includes representing the other participants in the project and raising their questions. The PM is also responsible for that the goals of the project are accomplished within the specified time. This includes planning and follow up on time spent in different phases and steps in the development process.

The project manager should also encourage the other participants to conduct their work effectively and should help to resolve any internal conflicts that may arise.

In addition, the PM is responsible for:

- Setting up and preparing meetings with the project group
- Updating the client with time reports on a weekly basis
- Delegating responsibilities for individuals if necessary
- Updating the calender with deadlines, meetings etc.

4.1.2 Head of Documentation

The responsibilities for the Head of Documentation are:

- Setting up templates for all documents
- Ensuring a consistent structure in all documents
- Ensuring proof-reading is conducted
- Storing and backing up all documentation
- Handing in documents and doing so on time
- Documenting meetings or delegating the task to another. Ensuring that the meeting protocols are made available for all other project members
- Making sure all relevant documents are uploaded into the Gitlab repository

4.1.3 Head of Testing

The responsibilities for the Head of Testing are:

- Setting up a test plan
- Ensuring that tests are synchronized with each other
- Making sure that testing is well documented in reports as well as in test protocols
- Design tests (or assist others when designing tests) where specific requirements are evaluated

4.1.4 Head of Design

The responsibilities for the Head of Design are:

- Coordinating the design (development) process between the subgroups.
- Ensuring that the requirements regarding the design is fulfilled at the end of the project
- Ensuring that a user manual is made

4.1.5 Head of Hardware

The responsibilities for the Head of Hardware are:

- Reporting and resolving hardware malfunctions as quickly as possible
- Ensuring that the hardware is securely locked inside the project room when not in use
- Making sure that the batteries in all hardware are fully charged when needed

4.1.6 Head of SLAM

The responsibilities for the Head of SLAM are:

- Ensuring all requirements regarding SLAM are fulfilled at the end of the project
- Making sure that the development work concerning SLAM is well documented

4.1.7 Head of Route Planning and Navigation

The responsibilities for the Head of Route planning and Navigation are:

- Making sure requirements regarding route planning and navigation are fulfilled at the end of the project
- Making sure that the development work concerning route planning and navigation is well documented

4.1.8 Head of Software

The responsibilities for the Head of Software are:

- Ensuring that all code is written according to the standard and is well commented
- Making sure all code is uploaded to the GIT repository
- Creating a backup of new releases
- Making sure old versions of the code is accessible

5 Document Plan

The documents and media that will be made and approved during the project is seen below. Meeting protocols should also be available online during the process.

Delivery	**Approved by**	**Purpose**	**Date**
Requirement specification	ML	A document defining what requirements the system shall fulfill.	18/9 2017
Project plan	ML	A plan of how the project will be conducted. A time plan is included.	18/9 2017
Design specification	ML, PB	A thought-out plan for how the system will be designed.	04/10 2017
Test plan	ML, PB	A document describing the testing of the system.	04/10 2017
Test protocol mapping	ML, PB	Proves the functionality of mapping using rotational LIDAR.	07/11 2017
Test protocol	ML	Describes the results of testing the system and if the functional requirements are fulfilled.	01/12 2017
User manual	ML	Describing how to use all subsystems.	01/12 2017
Technical report	ML, PB	A report on how the product works along with the theory behind it.	15/12 2017
Project evaluation	ML	A paper where the members evaluate how the project has worked.	15/12 2017
Poster	ML	A visual method to present the project in smaller groups.	15/12 2017
Website	ML	A website for promoting the project.	15/12 2017
Demonstration film	ML	A video showing the system.	15/12 2017
Installation manual	ML	A text describing how to start and install the system.	15/12 2017
Time report	ML	Documentation about how much time all the project members have spent during the week.	Weekly
Status report	ML	What has been done in the project.	Weekly

6 Development Method

The project is to be broken down into smaller parts with people assigned to each part (subgroup). Since the project group is small, a desire to redistribute resources can easily be communicated and rapidly performed. Documentation and code from previous CDIO projects are stored in LiU's Gitlab repository which is to be used and updated by this years CDIO group.

Documentation will be done continuously during the project. The Head of Documentation and the Head of Software are responsible for files to follow the appropriate standards. With this year's implementation of a UAV, the Head of Design will be responsible for ensuring that the development of Sauron and Balrog are in alignment.

The project will be conducted with inspiration from SCRUM. This means a continuous development process based on a functional system will be used. At the beginning of the project, focus will be put on getting the basic functionality implemented according to the requirements specification. Once these requirements are fulfilled, resources will be put to either further enhancing the existing functionality and/or developing other functionality to improve the overall system. A functional platform should always be presentable throughout the project.

7 Training Plan

For a good development, training will be done within the group and with the customer.

7.1 By Project Group

The Head of Documentation will give a brief introduction to documentation standards. The Head of Software will provide some documentation/examples as well as give a short presentation about code standards.

When the subgroups have been set and each subgroup has had an appropriate amount of time to read more about their task, each group will present it to the others in short. By doing this, more members of the project will have more knowledge of all subsystems, so that all members can assist all subgroups if deemed necessary.

7.2 By Customer

Saab Dynamics will give a demonstration of the hardware and software.

8 Status & Time Report

The responsibility to ensure that the client and customer are up to date with the project falls on the project manager. The project manager will ensure that the following documents are delivered to their recipients:

- **Status report:** This document contains the progress of the project for each week. That includes, for example, if any goals have been achieved, problems have occurred etc. This document shall be delivered to both the customer and the client before each weekly meeting (every Friday).
- **Time report:** The time report contains how many hours everyone has spent on the project as well as how they have been spent. It also contains the total hours spent for the group altogether. The time report is submitted to the client before each Friday.

Both documents regard the previous week. The project manager will meet the client in person to briefly update the client on the project status. If the client or customer feel the need for a more thorough update, a meeting will be set up.

9 Meeting Plan

One meeting is held Monday every week 12.30 - 13.00. Meetings with the technical advisor, client and/or customer will be held if necessary.

10 Resource Plan

The resources available during the project are presented here.

10.1 Personnel

The project group consists of eight students on their final year for a Master of Science in Engineering at Linköping University. Six of the students are from the Mechanical Engineering program and two from the Applied physics and Electrical Engineering program.

The external resources are Per Boström-Rost at the department of Electrical engineering (ISY) at Linköping and Erik Ekelund and Axel Reizenstein at the customer Saab Dynamics. Per is at disposal for 40 hours and Erik and Axel for 40 hours in total.

10.2 Equipment

All material that is necessary for the project is provided by Saab Dynamics. This includes the ground vehicle (Balrog) , a 3DR x8+ UAV (Sauron) and a laptop for running the control software. Balrog is equipped with multiple sensors from previous projects: IMU, odometers, ultrasonic range sensors and a camera. A new 360 degrees LIDAR is provided by the customer. The software developed in previous projects is also at disposal.

10.3 Project Room & Test Area

For working, a group room in the B-building at LiU Campus Valla is available throughout the entire project. For testing, the new area "Visionen" is accessed by making a reservation via the client or supervisor at ISY.

10.4 Economy

The time budget for each member of the project is 240 hours and should not be exceeded by more than 10%. This gives a total of 1920 hours to spend according the time plan. If there is need of any purchases, Saab Dynamics is contacted.

11 Milestones & Tollgates

11.1 Milestones

Here are the milestones for both Balrog and Sauron listed.

11.1.1 Balrog

No	Description	Date
1	Balrog can be programmed to run forward for two seconds and then stop.	25/9 2017
2	A SLAM algorithm only utilizing the scanning LIDAR is implemented. The resulting map can be visualized on a base station computer running ROS.	25/9 2017
3	The Balrog laptop can send a map and an estimated robot pose to the Balrog Raspberry Pi. The Raspberry Pi can send odometry sensor data to the laptop.	02/10 2017
4	A SLAM algorithm utilizing both the scanning LIDAR and odometry sensor data sent from the Balrog Raspberry Pi is implemented.	05/10 2017
5	Balrog can be *manually* controlled to map the test area with desired accuracy.	12/10 2017
6	The complete communication protocol between the Balrog laptop and the Balrog Raspberry Pi is implemented.	30/10 2017
7	A navigation algorithm that explores an area free from obstacles is implemented.	02/11 2017
8	A navigation algorithm that explores the entire test area is implemented.	20/11 2017
9	An integrated GUI for all visualization functionality is implemented.	20/11 2017

11.1.2 Sauron

No	Description	Date
10	Sauron can be manually operated indoors.	25/09 2017
11	A video feed from Sauron can be visualized on a base station computer running ROS.	13/10 2017
12	Communication between PixHawk and the Raspberry Pi on Sauron is implemented.	13/10 2017
13	Detection of known objects during manual flight is implemented and the detection result can be visualized on a base station computer running ROS.	06/11 2017
14	Relative position estimations based on detection of known objects is implemented and the estimate can be displayed on a base station computer running ROS.	13/11 2017
15	An integrated GUI for all visualization functionality is implemented.	20/11 2017

11.2 Tollgates

The following tollgates are defined in the project:

No	Delivery	Date
2	To initialize the project, the requirement specification, project-plan and time-plan must be approved by the client.	18/9 2017
3	To continue the development process, the design-specification and the test-plan must be approved by the client	04/10 2017
4	Mapping based on the scanning LIDAR and odometry will be presented along with a test-protocol proving the above functionality.	07/11 2017
5	The system functionality, test protocols, a user manual and a presentation (that shows that all requirements are fulfilled according to the requirements specification) are finished.	01/12 2017
6	For the project to be approved, a technical report, project evaluation, a poster, a web-page, a film and an installation guide will be compiled and presented on the project conference.	15/12 2017

12 Activities

This section contains all identified activities in the project. Each activity is listed together with a short description and an estimate of how many hours the activity will require to complete.

12.1 General

General project activities are listed in the table below.

No	Activity	Description	Time
1	Lectures.	During the project course, a series of lectures will be given. Part of the project includes attending these.	16
2	Research ROS	Research implementation of Robot Operating System (ROS) software.	50
3	Final testing	Test the functionality of the complete minesweeping system.	50

12.2 Documentation

Activities related to the writing of all project documents are listed in the table below.

No	Activity	Description	Time
4	Requirements specification.	Write a requirements specification.	100
5	Project plan	Write a project plan.	30
6	Time plan	Write a time plan.	25
7	Design specification	Write a design specification.	120
8	Test plan	Write a test plan.	25
9	Test protocols	Write test protocols.	10
10	User manual	Write a user manual.	15
11	Technical report	Write a technical report	150
12	Project evaluation	Write a project evaluation.	12
13	Poster	Create a poster presenting the project.	20
14	Website	Create a website.	16
15	Presentation.	Create an oral presentation.	20
16	Demonstration film.	Shoot and edit a demonstration film.	30

12.3 Balrog

This section contains all activities related to the tracked robot Balrog. The activities are mainly categorized according to the software subsystems defined in the requirements specification.

12.3.1 General

No	Activity	Description	Time
17	Platform assembly.	Mount the scanning LIDAR sensor and the laptop on Balrog. Connect the LIDAR sensor to the laptop.	8
18	Setup ROS.	Install ROS on the Balrog laptop and the base station computer. Implement and test basic communication over WiFi.	8
19	Essential communication.	Implement a protocol for sending a map and an estimated robot pose from the Balrog laptop to the Balrog Raspberry Pi. Implement a protocol for sending odometry sensor data from the Rasperry Pi to the laptop.	35
20	Full communication.	Complete the communication protocol between the Balrog laptop and the Balrog Raspberry Pi for transmission of sensor data, manual commands etc.	45
21	Setup test area.	Design and setup the test area as described in the requirements specification.	10
22	Final Balrog testing.	Test the functionality of the complete Balrog subsystem.	40

12.3.2 SLAM

No	Activity	Description	Time
23	Research SLAM.	Research LIDAR based SLAM and available ROS SLAM packages.	35
24	LIDAR setup, basic SLAM.	Implement a SLAM algoritm only utilizing the scanning LIDAR and visualize the resulting map on a base station computer running ROS.	20
25	Full SLAM implementation.	Implement a SLAM algorithm utilizing both the scanning LIDAR and odometry sensor data sent from the Balrog Raspberry Pi.	20
26	Manual mapping.	Test and modify the SLAM implementation such that the test area can be mapped with desired accuracy when Balrog is *manually* controlled.	70
27	Autonomous mapping.	Test and modify the SLAM implementation such that the test area can be mapped with desired accuracy when Balrog is *autonomously* controlled.	40

12.3.3 Navigation

No	Activity	Description	Time
28	Prestudy	Look into the previous project's navigation solution and implementation.	15
29	Research	Research different navigation strategies and optimization strategies.	20
30	Obstacles	Evaluate chosen strategies with obstacles in mind. Iterate if needed.	10
31	Implementation	Write code. When fed a map and current position, make an algorithm that finds the goal position and its route.	60
32	Output	Given the route to the goal node, translate it to continuous outputs for the control module.	10
33	Further development	Fine tune the navigation with regards to different objectives.	50
34	Testing	Test the navigation algorithm.	90

12.3.4 Control

No	Activity	Description	Time
35	Examine the current control module.	Understand the current control module implementation and its interface with the navigation module. Research alternative implementations.	15
36	Evaluate the current control module.	Evaluate the performance of the current control module implementation and its impact on the overall system performance.	20
37	Improve the control module.	If found necessary, implement and evaluate an alternative control module design.	10

12.3.5 GUI

No	Activity	Description	Time
38	Implement GUI functionality.	Visualize the created map, relevant sensor data etc. in separate windows using ROS.	30
39	Integrate GUI.	Integrate all visualization and user input functionality into one unified GUI. Test final functionality.	50

12.4 Sauron

This section contains all activities related to the UAV Sauron. The activities are categorized according to the software subsystems defined in the requirements specification.

12.4.1 Detection

No	Activity	Description	Time
40	Mount Raspberry Pi	Attach the Raspberry Pi with camera to Sauron.	2
41	Video stream re.	Research how to live stream video from the Raspberry Pi camera to the base station.	6
42	AprilTag re.	Research how to detect AprilTags and estimate Sauron's position based on detection information.	10
43	Video stream imp.	Implement live-stream video from Sauron to base station.	8
44	AprilTag detection imp.	Implement detection of AprilTags and position generation for Sauron.	50
45	Communication test	Test communication between Raspberry Pi and base station.	4
46	Video feed test	Make sure camera feed is satisfactory.	4
47	Multi tag test	Test that one and several different AprilTags can be detected by Sauron.	20
48	Sauron detection test	Test and confirm Saurons position based on estimated position from AprilTag detection.	30

12.4.2 Tracking and Control

No	Activity	Description	Time
49	Manual flight re.	Research manual flight of Sauron without GPS.	6
50	Manual flight imp.	Implement manual flight without GPS.	10
51	Manual flight test	Test manual flight of Sauron outdoors and indoors.	2
52	Pi-PixHawk re.	Research how to connect the Raspberry Pi to PixHawk.	4
53	Connect Pi-PixHawk	Connect the Raspberry Pi to PixHawk.	2
54	Pi-PixHawk interaction re.	Research how to interact with PixHawk software using Raspberry Pi.	30
55	Hold stationary tag imp.	Implement position holding over a stationary AprilTag.	50
56	Following tag imp.	Implement constant position holding over a moving AprilTag.	10
57	Balrog tracking imp.	Implement tracking of AprilTags on the moving Balrog.	10
58	Pi-PixHawk communication test	Test communication between Raspberry Pi and PixHawk.	6
59	Autonomous tag tracking test	Test autonomous tracking of AprilTags.	18

12.4.3 GUI

No	Activity	Description	Time
60	GUI-Pi connection imp.	Establish wireless connection between GUI station and Raspberry Pi on Sauron.	8
61	GUI design	Design GUI.	20
62	GUI functionality imp.	Implement GUI functionality.	50
63	GUI-Sauron communication test	Test that communication between GUI and Sauron works.	8
64	GUI functionality test	Test GUI functionality.	15

13 Time Plan

For the time plan of the project, see separate document: Time Plan.

14 Adjustment Plan

Any changes made to the requirements specification requires a discussion with the client to renegotiate and get an approval. Therefore, if a potential change in the requirements plan is indicated, the client will be notified in order to simplify potential negotiations. Changes to the project and time plan will be discussed and approved by the client. Any changes to internal documents will be discussed and managed within the project group.

15 Quality Plan

To ensure that the project has a high quality when delivered to the customer, some of the members of the project group have certain responsibilities.

15.1 Reviews

The Head of Software is responsible for ensuring that all new code is reviewed in order for it to follow the set standards and be well documented. Similarly, the Head of Documentation is responsible for ensuring that all documents are reviewed in order for them to have a clear and consistent structure.

15.2 Testing

A test plan shall be created by the Head of Test together with the project group. This will make sure that the project lives up to the functionality and requirements described in the Requirement specification [1].

16 Risk Analysis

This section is to describe potential events that would delay the project.

16.1 General

16.1.1 Hardware Malfunction

If hardware on the provided vehicles or computer will malfunction in a critical way, the project could be delayed. If such a malfunction is to occur the part will be replaced by the owner (most likely Saab Dynamics). If the part can not be replaced within an appropriate time frame the project will be renegotiated.

16.1.2 Theft

Theft is to be prevented by keeping any hardware inside the locked project area.
If any hardware is stolen it will either be replaced or the project renegotiated.

16.1.3 Data Loss

Data loss could set the project back majorly. All code will be stored on LiU's GitLab and any documentation will be stored in the project group's ShareLatex user.
To prevent code loss Git is used which ensures that a local copy of the complete code for the project is stored on each project member's computer as well as on the GitLab server.
To prevent documents from being lost the Head of Documentation is to keep a backup of any completed document as well as keeping a copy in the Git repository.

16.1.4 Loss of Project Member

If, for any reason, a project member would leave the project, the project would have to be renegotiated.

16.2 Sauron Specific

16.2.1 Laws

UAV's are quite a new concept for the general population and with the increasing interest from both private consumers as well as companies. UAV's have had fluctuating regulatory conditions. If any restriction appears, preventing our testing with Sauron the project might be set back. This is out of the groups control but if such a restriction is implemented the project might have to be renegotiated. Today there is a prohibit against flying in Linköping and its surroundings due to the two airports.

17 Priorities

Different goals of what must have to be completed are clearly stated in the requirements specification. Their relative priority is stated with the number one, two or three with priority decreasing in ascending order. All goals that have the priority one must be completed no later than the date of delivery of the final product. A level two priority should be completed while level three priorities defines goals that are not necessary to achieve due to time limitation. They can be seen as a starting point for further development.

References

[1] E. Näsholm F. Gustafsson F. Tormod H. Andersson J. Jerner M. Andreasson A. Hägglund, A. Lundgren. Requirement specification minesweeper. Unpublished technical document, 2017.