



AALBORG UNIVERSITY
STUDENT REPORT

P5 Project Report - Autumn 2015

??¹

Group ??²

¹FiXme Note: Input project title

²FiXme Note: Input group number

Title:

??³

Theme:

Digital and Analog Systems
Interacting with the Surroundings

Project Period:

P5, Autumn 2015
02/09/2015 - 17/12/2015

Project Group:

??⁴

Synopsis

Participants:

Amalie V. Petersen
Julien Brehin
Mads Gotthardsen
Niels Skov Vestergaard
Romaric Destremau
Thomas Rasmussen

??⁹

Supervisor:

??⁵

Prints: ??⁶

Pages: ??⁷

Appendices: ??⁸

Concluded 17/12/2015

Preface

Preface Here¹⁰

Text by:

Amalie V. Petersen

Julien Brehin

Mads Gotthardsen

Niels Skov Vestergaard

Romaric Destremau

Thomas Rasmussen

¹⁰FiXme Note: Write preface

Contents

I	Introduction	1
1	Introduction	2
1.1	Robotic lawn mowers	2
1.2	Problems with existing robotic lawn mowers	4
1.3	The Games on Track (GoT) system	4
1.4	Satellite based positioning systems vs GoT	5
1.5	Potential consumer expectations	5
II	Design & implementation	7
2	Design Consideration	8
2.1	Use-case design	8
2.2	Prototype Constraints	9
3	Something	12
3.1	Hardware and software choices	12
4	Chapter	13
5	Chapter	14
6	Chapter	15
7	Chapter	16
8	Chapter	17
9	Chapter	18
A	Appendix	I
B	Appendix	II
C	Appendix	III
D	Appendix	IV
E	Appendix	V

F Appendix**VI****G Appendix****VII****H Appendix****VIII**

Part I

Introduction

Introduction 1

More and more robots appear in everyday life. Automatic vacuum cleaners and floor washers are getting widespread, as the technology is becoming cheaper and better. The vacuum cleaners have matured to a level, where they are been considered for saving man-hours in the elderly care sector.

Outside the walls of our homes lays the next weekly hurdle: Mowing the lawn. A known way to handle this, is to pay the neighbour's teenager to do it. Unfortunately they grow up and move out, leaving the lawns in the residential neighbourhoods behind.

Luckily engineers have stepped in, and provided a more long-term solution: Robotic lawn mowers.

1.1 Robotic lawn mowers

Several manufacturers of electrical gardening machines have started selling robotic lawn mowers in the recent years. In general they use one of two strategies when cutting the lawn:

- Random direction mowers
- Parallel line mowers

Mowers using the random direction strategy will drive in a straight line until a guard wire or an obstacle is detected. They will then turn in a random direction, and continue. See [figure ??](#)

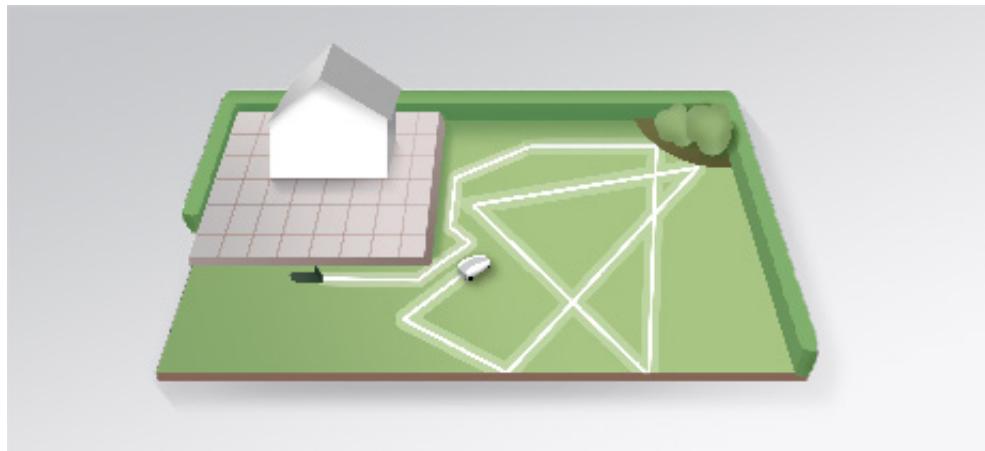


Figure 1.1: Random cut system [source:Bosch]

When the battery is nearly discharged, the mower will follow the guard wire back to the base station for recharging.

Parallel line mowers use a more intelligent control algorithm to optimize the mowing. After an initial learning run, following the guard wire around the lawn to be mowed, it will map the lawn, and cut in parallel lines, see [figure ??](#). The advantage of this strategy efficiency, as the lawn mower will not run over the same spots more than once. According to Bosch, a given lawn can be mowed up to 30% faster with their Logicut system.

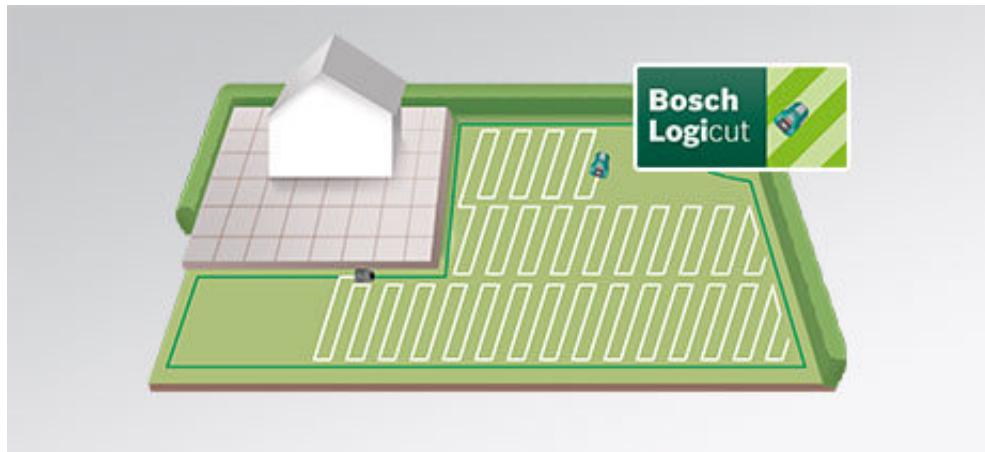


Figure 1.2: Bosch Logicut system [source:Bosch]

Common for both systems is the guard wire, which has to be placed around the lawn and anywhere the lawn mower is not allowed to go, like flower beds, swimming pools, etc.

This brings us to the problem with existing products.

1.2 Problems with existing robotic lawn mowers

All commercially available robotic lawn mowers require a guard wire placed around the lawn. This can either be placed at the surface, and be held in place by pegs, or dug down below the surface. The guard wire must be routed around flower beds, etc. as well, see [figure ??](#)

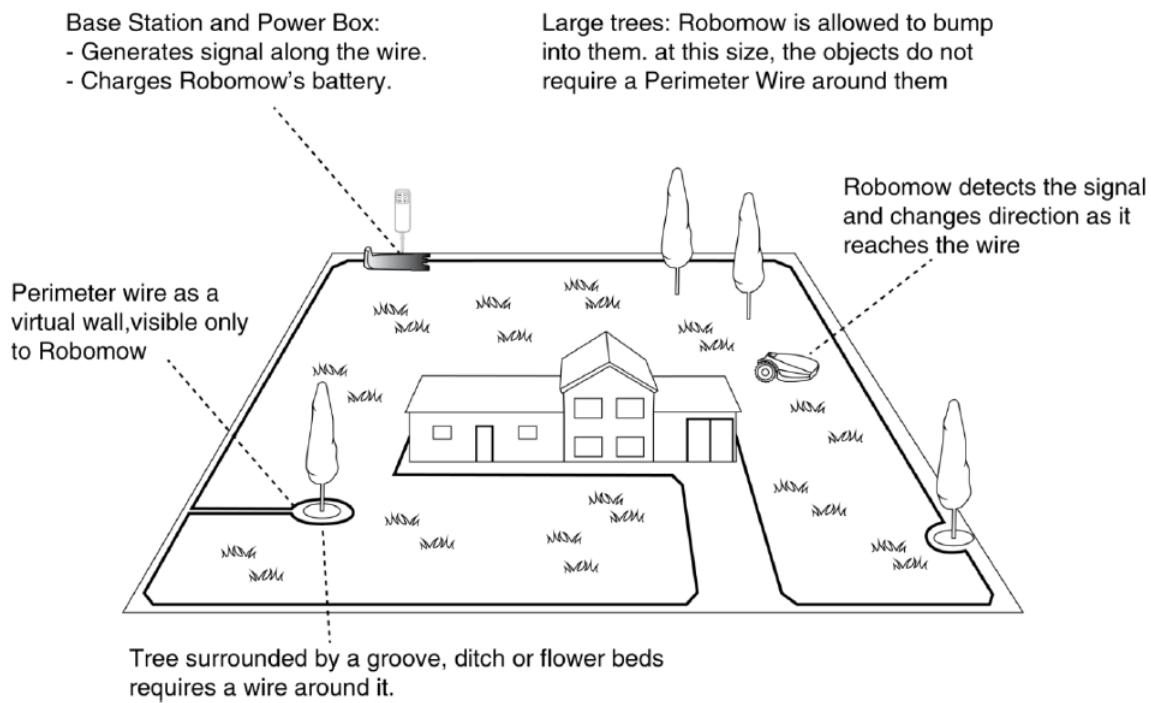


Figure 1.3: Guard wire installation [source:Robomow]

The use of the guard wire for guiding the mower back to the charging station presents another potential problem: in a garden with many restricted areas, the guard wire could get very long. This could therefore make the journey home long, compared to a more direct route. This again uses more battery power, that instead could have been used for actually mowing the lawn.

This will be the motivation for the project: to avoid the work routing a wire around the garden, and as a bonus get more work done on a battery charge, by not wasting power following the wire home.

Then, the question is: What other solutions could be used to get the lawn mower to go where it has to go?

One first step could be to keep track of where it is in real-time.

1.3 The Games on Track (GoT) system

We were provided with the *Games on Track GT-Position* system as a start to be able to determine the lawn mower's position in space.

It is composed of four different parts both hardware and software :

- A tracked module, which emits ultra-sound waves. It should be placed on the lawn mower itself while taking care, that the emitting cell is not obstructed by anything.
- Beacons or receivers, placed around the area the lawn mower will move in. Depending on the terrain, anywhere from 2¹ to more than 20 of these can be used: The more is placed, the more accuracy can be obtained to fight against any ambient noise.
- The central system, which calculates the distance of the tracked module to each beacon, and transmits it to the computer via USB in regular intervals.
- The GoT software aggregates the received positions throughout time, and can be used to draw a map of the terrain (the lawn), and to determine the absolute position of the tracked module.

GoT was originally designed for train modelling, but it is easily adaptable for any use of position tracking and seems a good choice, at first, for our autonomous lawn mower.

But, why not use a satellite based positioning system ?

1.4 Satellite based positioning systems vs GoT

² The reasons why satellite positioning system won't be used in our project are mainly related to accuracy and energy consumption.³

Indeed, these kinds of system like GPS or GLONASS would require a dedicated chip to put on the final system. The problem then would be the lack of precision under a few meters (around 2 or 3 meters in ideal situations for the best chips).⁴

Moreover, this kind of system implies slow communications with different distant satellites at the same time.⁵ Therefore, the energy consumption would quickly rise,⁶ thus reducing the lawn mower autonomy, which is not desirable.

1.5 Potential consumer expectations

The design of a product has no real value if no one is interested in using it. Thus, choices made during this project have to be made in accordance with the final user's

¹FiXme Note: is two enough?

²FiXme Warning: Wrong reasons for GPS vs GoT, elaborated below

³FiXme Note: GPS uses very little power

⁴FiXme Note: Only applies to cheap solutions, differential GPS can go to mm level, but is extremely expensive. This is what we are trying to replace with GoT, as it is a lot cheaper than diff-GPS

⁵FiXme Note: GPS is one-way communication

⁶FiXme Note: nope, it's just a radio receiver, uses almost no power

expectations.

For instance, the autonomy of the vehicle (both in energy and for the navigation), and the overall cost should be considered ⁷. Even though the GoT system itself has a cost beyond anything a normal customer would pay for a lawn mower, it appears, at first, as a good solution for us in terms of accuracy and energy consumption compared to GPS-like systems which are also quite expensive ⁸.

For an improvement, we could consider replacing it with a similar solution as it is only a simple brick of the whole system. ⁹

These are the types of preliminary considerations that will influence this design process for an autonomous lawn mower.

⁷FiXme Warning: insert price approximation here

⁸FiXme Warning: insert price approximation here - not so true actually

⁹FiXme Note: This sentence should be perhaps moved to a dedicated part of the report

Part II

Design & implementation

Design Consideration 2

In this chapter the system is designed with a top-down approach. First a use-case of the functionalities in the system is described, in order to give an overall view of what the system must be able to do. Hereafter, constraints set by time limitations as well as a focus on the main scope of the project, in regards to the prototype, is considered. Based on the use-case description and the prototype constraints the requirements for the systems prototype are listed.

2.1 Use-case design

To give an overall view of what the system should be able to do, a UML use-case diagram is used to consider and describe the main functionalities and operators in the system, see **figure 2.1**.

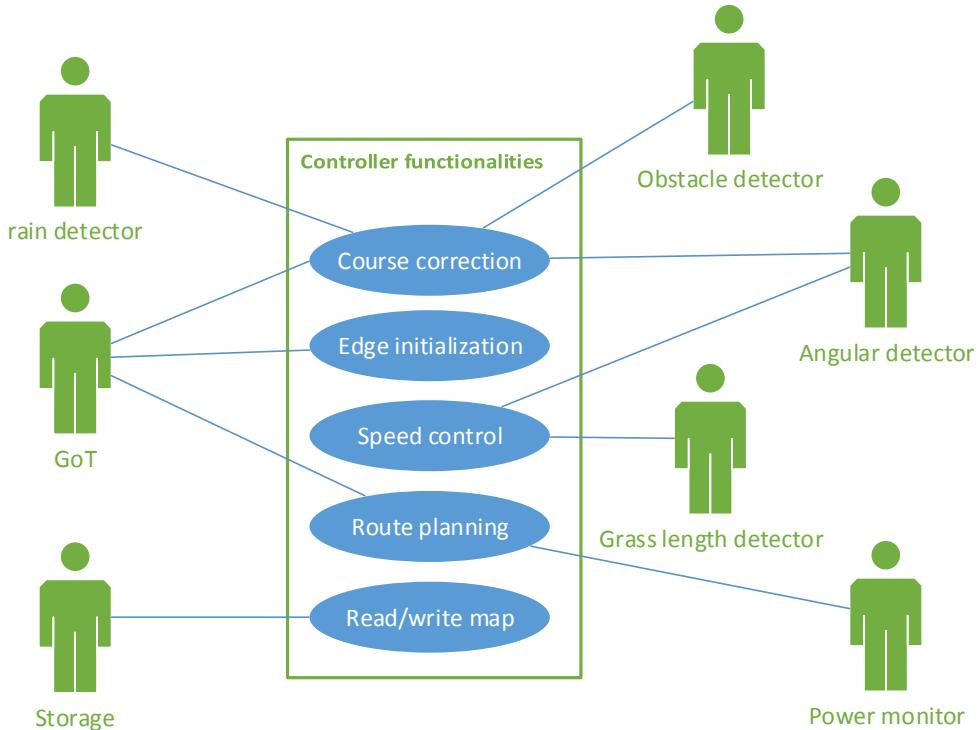


Figure 2.1: Use-Case Diagram

The main purpose of the system is to automatically navigate in a specific area which is confined by the *edge initialization* functionality. This functionality handles the marking of the areas edges. The functionality is only used in the initialization process of the system. The concept is to only use the functionality after the GoT system has been positioned in the area. The consumer then takes the system around the edges of the grass, while the GoT system tracks its positions. It is therefore only necessary to reinitialize the system, if the GoT satellites has been moved. While the edge is being tracked, the *edge initialization* uses the *read/write map* functionality to store the information collected, in storage.

The route in which the lawn mower is to navigate, in the specified area, is provided by the functionality *route planning*. *Route planning* uses the information, about the specific area, which is collected from the storage, to plan the most optimal route. Furthermore the *route planning* needs information about the systems power level to insure the functionality is considering if the system needs charging and therefore have to return to the charging station at some point on the route.

The *read/write map* functionality as described earlier, handles the communication with storage. Hence it stores information, received from the *edge initialization* and collects information from storage when the functionality *route planning* needs it.

To insure the system is moving with a desired speed (in a straight line and in a turn) or a speed which is fitted to the height of the grass, detected with the *grass length detector*, a *speed control* functionality is necessary in the system to control the motors. To insure the *speed control* can deliver the desired speed an *angular sensor* is utilized.

The last functionality, *course correction* is used when the system strays of the path calculated by *route planning* or if the path gets blocked. The obstacle which is blocking the route is detected by the sensor *obstacle detector*. Furthermore the GoT system and the *angular detector* will detect if the system is not on the desired path, or if the system starts to slip. Also, if it starts to rain, which is detected by the *rain detector*, the system has to return to the charging station. Finally, the *course correction* sends the calculated data to the functionality *speed control*.

The overall functionalities of what the system must be able to do has been described. Now the different constraints on the system will be considered and the project prototype should be established.

2.2 Prototype Constraints

Before the prototype can be established, some considerations has to be made in respect to the time limitations and the main scope of this semester. The aim of the project is to create a functional proof of concept prototype of an automated lawn mower. The following section includes a brief description of the technology on which the prototype is constructed, along with argumentation for eliminated functionalities.

2.2.1 Technology Base

The technology which has been provided for the prototype is a tracked vehicle, seen on [figure 2.2](#). The vehicle comes with a brushed DC motor which provides power for rotation of the wheels, connected with the belts, and a servo motor which utilize breaks, connected to the wheels, to control the ratio of the differential steering. Furthermore the tracked vehicle includes two hall sensors, one by each belt, which keeps track of the speed, of the belts, by measuring pulses from magnets mounted on the front wheels. The testing will take place in Aalborg University Vicon Room, where the GoT system is installed and calibrated with the appurtenant transmitter, which is mounted on the tracked vehicle during test.

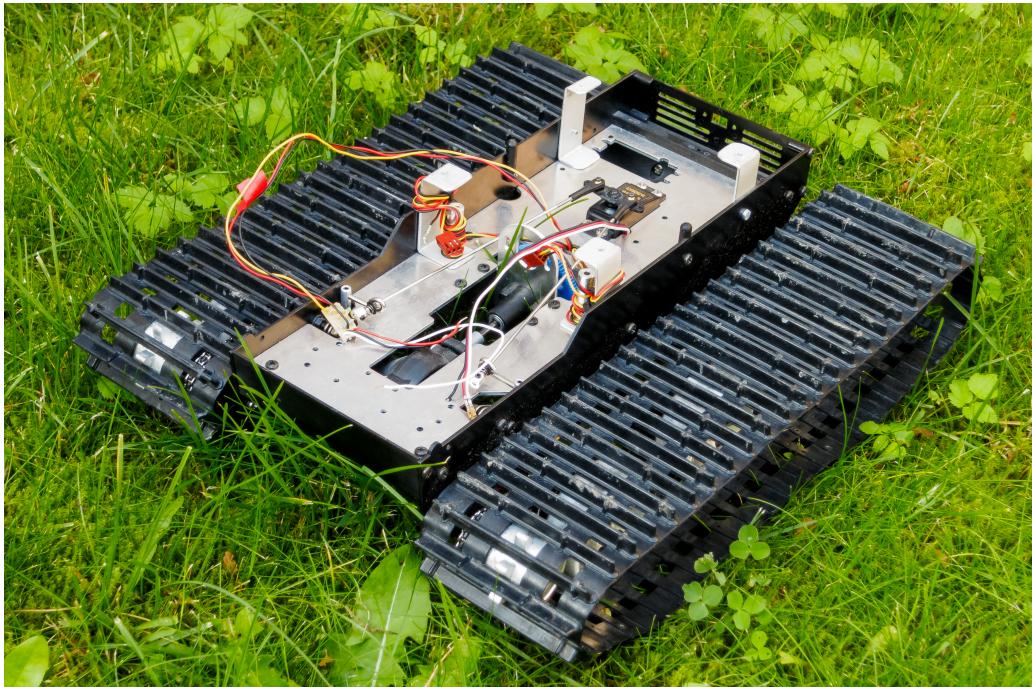


Figure 2.2: The provided belt vehicle

[1](#)

2.2.2 Grass Length Detection

Detection of the grass length to control the speed of the lawn mower thus ensuring an evenly cut lawn, is a submodule which can be added at any time. Since it is not fatal for a working system and might even be unnecessary depending on time between each mowing of the lawn, it is decided to exclude this functionality from the initial design.

2.2.3 Rain Sensor

As the lawn mower is supposed to work outside, it is important to consider that it may be raining, and that an electronic device can be affected by those environmental

¹FiXme Note: datasheet of the vehicle

issues. Even if the electrical part is waterproofed, there is a mechanical threat, a rain sensor could then warn the system to order the vehicle to get back in time. It is possible to build the vehicle aware of those issues and add mechanical modules to secure it. However, the prototype will only be tested indoor, so this type of sensor will not be necessary in a prototype design.

2.2.4 Obstacle Avoidance

The lawn movers path might not always be clear, there could be some garden tools, tables or chairs, or people walking in it. The vehicle should be aware of what is in front of it at any time, to correct its path and get around the obstacle if necessary. To avoid this the sensor could be a pushing button to detect a solid strong object, or an ultrasound detector if the object is breakable. As the aim of the project is to control the path of the vehicle by using angular positioning sensors, a proximity sensor will not be included. Static objects could be registered on the map to avoid these issues.

Furthermore the edge mapping functionality will not be included in the project which instead will focus on a quadratic map predefined in the test room.

2.2.5 Power Monitoring

Power monitoring could be implemented by measuring the voltage across the batteries, to ensure that the lawn mower is not running out of power, and to ensure the vehicles calculated route passes the charging station before the power runs too low. This and the charging station will not be in the prototype, since it is beyond the scope of the project this semester and is not crucial for a working prototype.

2.2.6 Prototype

(to be continued)

Something 3

3.1 Hardware and software choices

Processor

Operating system

Chapter 4

Chapter 5

Chapter 6

Chapter 7

Chapter 8

Chapter 9

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Appendix F

Appendix G

Appendix H

Glossary

List of Corrections

Note: Input project title	1
Note: Input group number	1
Note: Input project title	i
Note: Input group number	i
Note: Input supervisor	i
Note: Input number of prints	i
Note: Input number of pages	i
Note: Input number of appendices	i
Note: Write synopsis	i
Note: Write preface	iii
Note: is two enough?	5
Warning: Wrong reasons for GPS vs GoT, elaborated below	5
Note: GPS uses very little power	5
Note: Only applies to cheap solutions, differential GPS can go to mm level, but is extremely expensive. This is what we are trying to replace with GoT, as it is a lot cheaper than diff-GPS	5
Note: GPS is one-way communication	5
Note: nope, it's just a radio receiver, uses almost no power	5
Warning: insert price approximation here	6
Warning: insert price approximation here - not so true actually	6
Note: This sentence should be perhaps moved to a dedicated part of the report	6
Note: datasheet of the vehicle	10