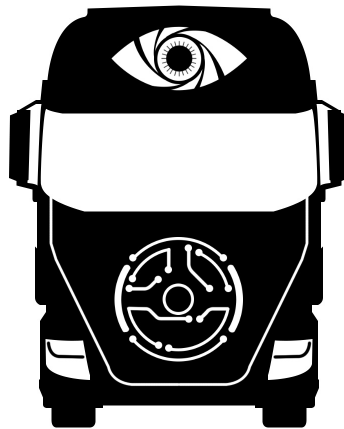


Project Plan

Autonomous Truck With a Trailer

November 9, 2020

Version 2.0



Status

Reviewed	Filip Jussila	2020-11-09
Approved	Carl Hynén	2020-11-10

Project Identity

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DOCUMENT HISTORY

Version	Date	Changes made	Made by	Reviewer
0.1	2020-09-17	First draft	Project Group	Ofa Ismail
0.2	2020-09-21	Clarified activities and made new time estimations	Project Group	Filip Jussila
1.0	2020-10-01	Small changes made on behalf of the orderer	Project Group	Filip Jussila
2.0	2020-11-09	Final draft	Project Group	Filip Jussila

1 GENERAL DESCRIPTION OF THE PROJECT

In this section the project purpose and goals are described as well as the deliveries throughout the course of the project.

1.1 Definitions

Below are some terms and abbreviations defined and explained.

- **APPAS** – The name of the product developed during the project. It stands for Autonomous Path Planning & Parking Assistance System.
- **Git** – Distributed version control system used for software.
- **MPC** – Model Predictive Control, optimization based control method used to control a process while satisfying a set of constraints.
- **QualiSys** – Positioning system used in Visionen.
- **ROS** – Robotic Operative System, an open source software library which simplifies writing modular code for robotic applications.
- **RPi** – Raspberry Pi, a small single-board computer.
- **TG** – Tollgate.
- **Visionen** – A research arena for robotics applications at Linköping University.

1.2 Background and purpose

The increasing number of autonomous applications in our society give rise to the need of a good research and teaching platform for autonomous vehicles [1]. A relevant research object would be an autonomous truck with a trailer capable of following a path, forward and backwards. The main reason for this choice is because of the difficult task of reversing a truck with a trailer.

The project group from the previous year created a reversing aid system for the autonomous LEGO truck with a trailer. The purpose of this year's project is to improve the already existing reversing aid system with an implementation of an MPC controller which will communicate with the LEGO EV3 unit using an RPi. The autonomous LEGO truck is a system which displays the possibilities with automatic control for students at Linköping University. It is therefore important that the visualization of the system is done properly.

1.3 Project goal

The long-term goal of the Autonomous Truck project is to create a platform for research and teaching on autonomous vehicles at Linköping University.

This year, the focus is to implement an MPC controller to the already existing system to improve its control and robust performance when driving forward and backward. Also an installation of an RPi on the LEGO truck will be conducted which will enable the truck to operate without an external computer.

1.4 Deliverables

In Table 1 are all the deliveries that are needed for the project listed.

Table 1: Mandatory deliveries during the project.

Date	Delivery	Version
2020-09-23	Requirement specification	Final version
2020-09-23	Project plan	Final version
2020-09-23	Time plan	Final version
2020-09-23	Design specification	First draft
2020-09-23	Oral presentation of the system	
2020-10-06	Design specification	Final version
2020-10-06	Test plan	Final version
2020-10-29	All subsystems individually tested	
2020-12-01	Fully functional system	
2020-12-01	Test protocol	Final version
2020-12-01	User manual	Final version
2020-12-01	Presentation of all fulfilled requirements	
2020-12-14	Technical report	Final version
2020-12-14	After study	Final version
2020-12-14	Poster presentation	
2020-12-14	Movie and website of the project	

2 PLAN FOR THE PROJECT PHASES

In this section are all the phases during this project described.

2.1 Before start

In this phase, it is decided how the project should be carried out. A requirement specification and project plan is written. The activities are written so that the requirements listed in the requirement specification can be fulfilled. They're also written in a way that makes it easy to distribute time between the requirements.

2.2 During the project

In this phase, most of the activities listed in this document are performed. As many of the requirements listed in the requirement specification as possible should be fulfilled. The requirements that are not fulfilled must be renegotiated with the orderer.

2.3 After the project

The result of the project will be presented both orally and written via a presentation, project conference, technical documentation and a user manual. Furthermore, results are also presented on a web page created by the project group. An after study will also be made by each student.

3 ORGANIZATION PLAN

This section will describe the different roles within the organization associated to this project.

3.1 Organization plan for each project phase

In Figure 1 is a schematic picture of how all parts in the project will communicate with each other presented.

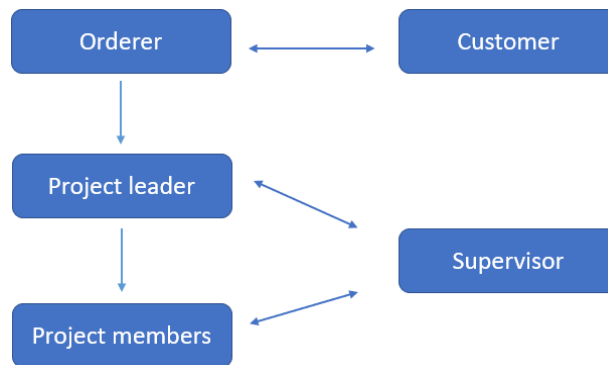


Figure 1: Organization of the project.

3.2 The project group

The different roles within this project and which responsibilities they each have is described in this section.

3.2.1 Project leader

The project leader (PL) is responsible to assure that the project’s goals are reached. The communication between the project group and the orderer as well as with the customer is also done through the PL. The PL also ensures that the project is moving forward according to the project plan. Finally the PL is responsible for that the project meetings have an agenda and will also lead these meetings.

3.2.2 Document manager

The document manager is responsible for that all the required documents are available for the whole project group and that these will be produced in time for all deadlines. Furthermore, the document manager should also ensure that the documents produced are version controlled.

3.2.3 Information manager

The information manager is in charge of that the website, the short movie and poster is executed correctly according to the project plan.

3.2.4 *Design manager*

The design manager is responsible for the overall design of the system and is therefore the person who is in charge of making the major decisions made about the design. The design manager should also set up guidelines for the design and communicate with the persons responsible for each component.

3.2.5 *Software architect*

The software architect is responsible that the new implemented code follows the defined standard which the project uses and that the version control is used efficiently.

3.2.6 *Test leader*

The test leader is responsible for planning all the tests that will be performed and is also responsible for test protocol and test plan.

4 DOCUMENT PLAN

Table 2 lists all documents that shall be produced during the project, where the different targets for these documents are the project group (PG), orderer (O) and customer (C).

Table 2: Documents to be produced during the course of the project.

Document	Language	Aim	Target	Ready
Project plan	English	Formulates how the work during the project is organized, including milestones and deliveries.	PG, O	2020-09-22
Requirement specification	English	Describes the different requirements of the product which has to be fulfilled by the project group.	PG, O, C	2020-09-22
Time plan	English	Specifies how the resources shall be distributed between the activities.	PG, O	2020-09-22
Design specification	English	It will contain an thorough overview of the whole system and also of the three subsystems.	PG, O	2020-10-06
Test plan	English	Describes the tests that are supposed to be performed and the requirements they are suppose to fulfill.	O	2020-10-06
Test protocol	English	A protocol which present a list of all the tests which were made and the requirement they fulfilled.	O	2020-12-01
User manual	English	Describes how the end product should be used.	C	2020-12-01
Technical documentation	English	A documentation that will contain all the technical results during the project.	O	2020-12-14
After study	English	A reflection of what went well during the project and what could be improved in future work.	O	2020-12-14
Poster presentation	English	A poster which will summarize the whole project, mainly the results and conclusion.	C	2020-12-14
Web page	English	A web page that will present the project and contain all the relevant documents.	C	2020-12-14
Movie	English	A short movie presenting the final system and how it works.	C	2020-12-14
Meeting minutes	English	The agenda of each meeting which also contains the notes during the meeting.	PG, O	Continues reported
Time report	Swedish	An accurate time report which will present how much time each project member has spent on the different activities each week.	PG, O	Continues reported
Status report	Swedish	Report of what each member have done during the week.	O, PG, C	Continues reported

5 DEVELOPMENT METHOD

The project group will be divided into smaller groups which will be responsible for a certain subsystem. Each group will choose one person to be the component manager which is responsible for the communication with the design manager to ensure that the group's work is aligned with the design plan.

6 REPORT PLAN

Every Sunday at 18.00, the project manager shall send the time report to the orderer. The time report shall contain all the hours that were spent during the week from each group member and also specify at which certain activities the time were spent.

7 MEETING PLAN

There is one mandatory meeting for the whole group each Monday at 15.15-17.00. The PL will set the agenda for the meeting and publish it on Microsoft Teams at least one night before the meeting. The group members are supposed to read the agenda of the meeting and be well prepared for the meeting. The secretary shall rotate between each meeting in alphabetical order. Since the meetings are mandatory the individual that is not able to attend in person must attend via a digital portal. The agenda and notes that were taken during the meeting will be stored in Microsoft Teams. If an additional meeting has to be held the PL invites all the group members through the communication channel in Slack.

8 RESOURCE PLAN

The resources available in this project are 2640 hours of work, the hardware, software and the different work rooms. These resources are described below in the following subsections.

8.1 Persons

The project group consist of eleven students, seven with background in electrical engineering and four with background in mechanical engineering. Each student is supposed to spend 240 hours of work during this project. The group is also entitled to 40 hours of guidance from a supervisor.

8.2 Material

The different types of hardware that will be used during this project are the following:

- LEGO EV3 unit
- LEGO truck
- Linux computer running ROS
- Raspberry Pi
- Projector for map visualization
- A battery pack for powering the RPi

8.3 Work rooms

The project group is entitled to a closed project room which only the project group has access to during the project. The project group has also access to Visionen to perform their tests.

9 MILESTONES AND TOLLGATES

During the project the project group will present results at specific dates in form of tollgates. To achieve this, several milestones have been decided upon as guidance.

9.1 Milestones

The project group have decided on several milestones listed in Table 3.

Table 3: Milestones of the project.

Milestone	Description	Date
1	ROS hosted on RPi.	2020-10-09
2	All subsystems should be able to communicate with each other.	2020-11-06
3	The truck should be able to complete a mission generated by the motion planner in the simulation environment.	2020-11-10
4	The truck should be able to complete a mission generated by the motion planner in Visionen.	2020-11-27

9.2 Tollgates

In Table 4 are the tollgates together with delivery dates presented.

Table 4: Tollgates of the project.

No	Description	Approved by	Date
1	Approval of the requirement specification, decision to start the preparation phase.	Orderer	2020-09-01
2	Approval of the project planning and the requirement specification, decision to start the execution phase.	Orderer	2020-09-22
3	Approval of the design specification and the test plan, decision to continue the execution phase.	Orderer	2020-10-06
4	All subsystems should be individually tested in simulation or in Visionen.	Orderer	2020-10-29
5	Fully functional system, user manual, test protocol and a presentation where it is shown that the requirements are fulfilled.	Orderer	2020-12-01
6	Approval of the technical report, after study, movie, poster presentation and a website describing the project.	Orderer	2020-12-14

10 ACTIVITIES

The activities will have the format shown in Table 5. Each activity will have a unique number followed by the name of the activity. It will have a short description and be denoted with a dependency if it is dependent on another activity. The time is estimated and displayed in hours.

Table 5: Example of activities.

No	Activity	Description	Dep.	Time
X	Activity name 1	Description of activity 1.		50 h
X2	Activity name 2	Description of activity 2.	X	25 h

10.1 General activities

General activities for the project are listed in Table 6.

Table 6: General activities.

No	Activity	Description	Dep.	Time
1	Requirement specification	Establish a requirement specification.		60 h
2	Project plan	Establish a project plan.	2	50 h
3	Time plan	Establish a time plan.		20 h
4	Design specification	Establish a design specification.		100 h
5	Test Plan	Establish a test plan.		30 h
6	Test Protocol	Establish a test protocol.		20 h
7	User Manual	Produce a user manual.		30 h
8	Technical Documentation	Establish a technical documentation.		80 h
9	After Study	Conduct an after study.		22 h
10	Poster	Create a poster.		20 h
11	Web Page	Create a web page.		30 h
12	Movie	Produce a movie showing the final product.		15 h
13	Deliveries	TG delivery meetings.		55 h
14	Meetings	Meetings held by the project group.		326 h
15	Administration	General administrative work.		30 h
16	ROS research	Research and learning ROS.		60 h
17	Understand the implemented code	Go through and read the already implemented code.		100 h
18	Test last year implementation	Try last year's code and see how it behaves.		40 h
19	Learn basic Git	Learn cloning, pulling, committing, pushing and reviewing code using Git.		20 h
20	Test mounted sensors	Make sure the already mounted sensors are tested and produces reasonable data.		8 h
21	Testing	Conduct the tests specified in the test plan.		110 h

10.2 Controller system

Activities related to the MPC controller system are listed in Table 7.

Table 7: Activities for the controller system.

No	Activity	Description	Dep.	Time
22	MPC Research	Gather information about MPC and how it can be implemented and which extensions that is appropriate.		150 h
23	Send and receive data	Make sure that the MPC controller can send and receive data from affected subsystems.		50 h
24	Calibration on startup	Construct a calibration system that corrects the steering angle of the wheels at the start of a mission.		40 h
25	Basic MPC	Implement a general MPC on the RPi.	22	150 h
26	Interface	Implement a simple development interface for easy handling of the MPC parameters.	25	32h
27	MPC extensions	Improve the MPC with extensions.	25	190 h

10.3 Communications system

Activities related to the communications system are listed in Table 8.

Table 8: Activities for the communications system.

No	Activity	Description	Dep.	Time
28	Sketch the ROS structure	Sketch the communication between files in the ROS structure.		10 h
29	Install required start-up software	Download and install software required for booting up the RPi on a SD-card.		2 h
30	Install ROS software on the RPi	Download and install software that is required for running ROS on the RPi.	29	3 h
31	Migrate already existing master node	Migrate and compile the master node from the already existing ROS project.	30	3 h
32	Migrate already existing motion planner node	Migrate and compile the motion planner node from the already existing ROS project.	30	3 h
33	Test ROS system	Make sure connection is established between systems.	31	5 h
34	Test mounted sensors on ROS	Make sure connection is established between sensors and ROS interface and that it produces reasonable data.	31	8 h
35	Establish a start-up script	Establish a script which start the ROS system when the RPi is connected to a power supply.	29	2 h
36	Establish SSH connection to RPi	Enable an SSH connection between RPi and laptop.	29	2 h
37	Optimize already existing code	Optimize existing code on ROS nodes.		40 h
38	Model holder for RPi and power supply	Model a holder which can attach the RPi and the power supply to the truck.		10 h

10.4 Visualization system

Activities related to the visualization system are listed in Table 9.

Table 9: Activities for the visualization system.

No	Activity	Description	Dep.	Time
39	Computer - projector connection	Establish a connection between the projector and the computer in Visionen.		1 h
40	RPi - computer connection	Establish a Wifi connection between the RPi and the computer in Visionen.		40 h
41	Receive truck and obstacle position	Investigate current visualization signals.	40	20 h
42	Calibration	Make sure displayed position and real position of truck is the same.	41	20 h
43	Receive motion plan from RPi	Receiving the planned path at the start of the mission.	40	40 h
44	Display motion plan	Display the offline calculated motion plan.	43	160 h
45	Display driven path	Continuously display the path driven by the truck.	40	60 h
46	Display online improvements	Continuously displaying the improvements of the motion plan.	40	40 h

10.5 Simulation system

Activities related to the simulation system are listed in Table 10.

Table 10: Activities for the simulation system.

No	Activity	Description	Dep.	Time
47	Display obstacles	Implement the software for showing the obstacles.		20 h
48	Connect the planner	Implement the needed software to connect the simulator with the planner.		30 h
49	Display planned trajectory	Implement the software for showing the planned trajectory.		40 h
50	Simulate movement	Implement software for simulating the movements of the truck according to the controller.		30 h
51	Display simulated trajectory	Implement the software for showing the simulated trajectory of the truck.	50	40 h
52	Improve simulation	Improve the already implemented simulation program.	50	48 h

10.6 Buffer time

Remaining time used for unplanned activities. 11.

Table 11: Buffer time.

No	Activity	Description	Dep.	Time
53	Buffer time	Buffer time		165 h

11 TIMETABLE

The time plan describes when and by who each activity should be performed by. It also states how long time an activity should take. The time plan is appended in an Excel document. The time plan can be modified as the project proceeds.

12 QUALITY PLAN

To maintain a high quality and a sense of consistency in the product, a test plan will be conducted and all developed software will be reviewed before published.

12.1 Reviews

The project group will use Git when developing the software. It will follow the formatting that is already used by the previous project groups and no new code will be developed in the master branch. The formatting used before complies with the Google code standard for **C++** and **Python**. All code will be published through a merge request and reviewed by another group member before merged into the master branch.

12.2 Test plan

A test plan will be established that will describe the tests needed for testing each subsystem independently and the complete system. The tests will be designed to ensure that all requirements in the requirement specification are fulfilled to be able to pass.

13 RISK ANALYSIS

During this project there are no real risks of physical injuries connected to the project. However during the prevailing circumstances (Covid-19), some measures will be taken to reduce the amount of physical meetings which will be replaced with meetings through different digital portals.

14 PRIORITIES

The requirements on level 1 and 2 will be prioritized. If there is a risk that a requirement will not be achieved, this will be renegotiated with the orderer. The project group will work on requirements on level 3 if time is available.

15 PROJECT CLOSING

A decision whether the project can be closed is taken on TG6. At this point, all requirements have to be fulfilled, except the ones that have been renegotiated with the orderer. At TG6, the poster, movie and all the documents will be delivered and published on the website. Furthermore, a week before TG6, the poster should be ready for printing and an after study should be made.

REFERENCES

- [1] K. Stubbs, P. J. Hinds, and D. Wettergreen, "Autonomy and common ground in human-robot interaction: A field study," *IEEE Intelligent Systems*, vol. 22, no. 2, pp. 42–50, 2007, [Online accessed: 21 September 2020].