Requirement specification

Autonomous Reversing Truck

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Version 1.2

TRUCKVISION

Status

Reviewed	2019-12-06	Theodor Westny
Approved	2019-12-06	Oskar Ljungkvist

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DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
0.1	2019-09-12	First draft.	Ludvig Junler	Ludvig Junler
0.2	2019-09-16	More specific requirements.	Theodor Westny	Theodor Westny
0.3	2019-09-17	Clarification of requirements as well as grammatical error fixes.	Oskar Lind Jonsson	Oskar Lind Jonsson
1.0	2019-09-18	Changed the date of BP4.	Ludvig Junler	Ludvig Junler
1.1	2019-12-05	Updated req. 8 and 22 after negotiation.	Theodor Westny	Theodor Westny
1.2	2019-12-06	Updated req. 14 after negotiation.	Alexander Källström	Alexander Källström

1 INTRODUCTION

This is the requirement specification for the project *Autonomous Reversing Truck* in the CDIO project course TSRT10 at Linköping University, fall 2019.

The project has been running for several years, and the main goals of this years project are to evaluate and implement external sensor-based tracking techniques, improved state estimation and optimization-based motion planning. The purpose of this document is to specify the requirements for the final results of the project.

1.1 Partners

The following parties are involved in this years project:

- The project group, which consists of six students studying applied physics and electrical engineering or mechanical engineering at Linköping University
- The orderer Oskar Ljungqvist, department of automatic control at Linköping University
- The customer and examiner Daniel Axehill, department of automatic control at Linköping University
- The advisor Daniel Arnström, department of automatic control at Linköping University

1.2 Definitions

- **ROS** - Robotic Operative System, an open source software library which simplifies writing modular code for robotic applications
- **Visionen** - A research arena for robotics applications at Linköping University
- **QualiSys** - Positioning system used in Visionen

1.3 Aims and goals

The aims of the Autonomous Truck project is to create a platform for research and teaching on autonomous vehicles at Linköping University. Last year, the platform was integrated within Visionen's QualiSys positioning system. A graph search-based motion planner and a path-following controller was also implemented.

This year, the focus is on autonomously driving the truck to a loading bay. To improve the positioning of the trailer, different sensor-based tracking techniques should be implemented and evaluated. A state-observer should be implemented to fuse measurements from the different available sensors. The motion planning should also be improved by implementing a more efficient search heuristic and including a post-optimization step of the motion plan.

1.4 Use

The final product will be used in both research and teaching courses in advanced control theory at Linköping University. If the results of using external sensors to track the trailer are promising, this technology might be further investigated for use on real trucks.

1.5 Background information

Autonomous vehicles is currently a large topic in both research and industry. A challenging maneuver such as reversing a truck with a trailer could be simplified by introducing autonomy and advanced driver-assistance systems. However, the reliance on sensors placed on the trailer limits the practical applicability of the technology, as the trailers are often interchanged during daily operation. A more promising solution would be to place additional sensors on the loading bay to estimate the trailer position and orientation.

1.6 Requirement specification

Requirements will be specified in the format shown below. A requirement might be an original requirement, or renegotiated in a later version of this document. Each requirement will be given a priority from 1-3. Requirements with priority 1 have to be fulfilled upon delivery of the project, while priority 2 and 3 will be fulfilled if there is excess time and interest.

Requirement	Revising	Description	Priority
§ X		Description of requirement X	1/2/3
XA	DD/MM - YY	Revision A of requirement X	1/2/3

2 SYSTEM OVERVIEW

The main system consists of a LEGO EV3 truck and trailer system. The operation of the system is aided by a positioning system installed in Visionen, as well as an external tracking sensor mounted on the loading bay. The goal of the system is to perform an autonomous reversing maneuver to place the trailer at a loading bay. This can be divided into two different phases, which are described in the following sections. General requirements for the system are described below.

Requirement	Revising	Description	Priority
1	Original	Requirements that the project group are unable to fulfill should be renegotiated with the orderer well before the deadline	1
2	Original	The obstacles should be able to be placed arbitrary	1
3	Original	The construction of the truck should be improved, the camber angle of the front wheels should be reduced	1
4	Original	All sensor values should be able to be visualized	1

2.1 Approach phase

In the approach phase, the system should navigate to a suitable position where the trailer can be tracked by the sensor on the loading bay, while avoiding obstacles on the way. This phase uses the motion planner of the truck together with onboard sensors as well as the Visionen positioning system. In a real world scenario, this phase could also be performed manually by the truck driver. The approach phase is shown in Figure 1.

2.2 Reversing phase

In the reversing phase, the truck should perform a precise reversing maneuver which places the trailer at a reference position at the loading bay. It is aided by onboard sensors as well as an external tracking sensor, mounted on the loading bay. The reversing phase is shown in Figure 2.

2.3 Included sub-systems

The total system consists of four major subsystems which have different purposes. An overview of the different systems is shown in Figure 3. The QualiSys computer handles connection to the QualiSys system and publishes

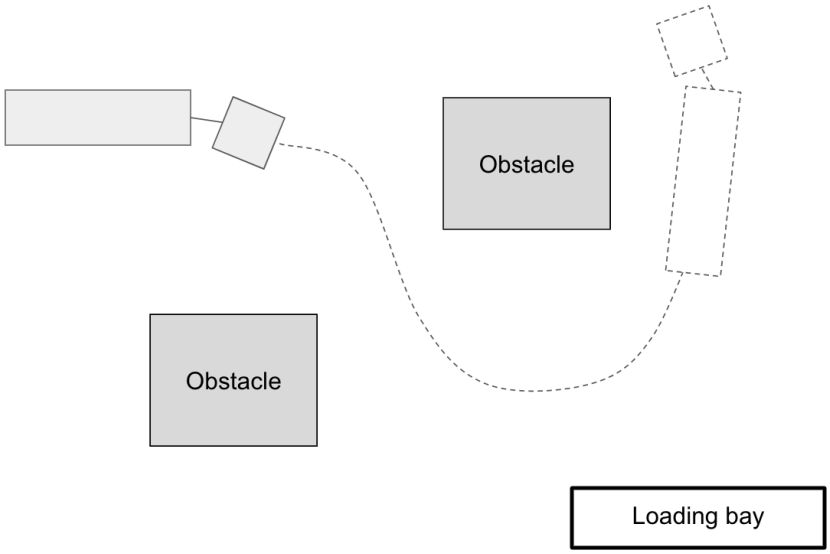

Figure 1: Approach phase

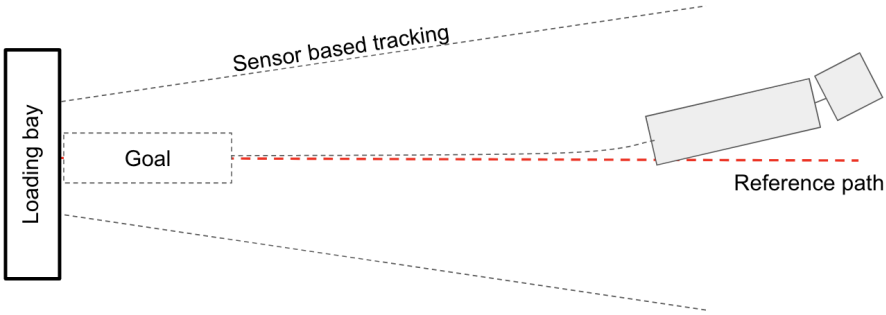

Figure 2: Reversing phase

position estimates on a ROS topic. The ROS computer runs the ROS master node and handles calculation of motion plans which are sent to the LEGO Truck. The tracking system handles tracking and estimation of the trailer position and publishes this information for use in the state observer. The LEGO truck computer handles the logic for path-following control based on the recieved motion plan as well as a nonlinear observer used for state estimation.

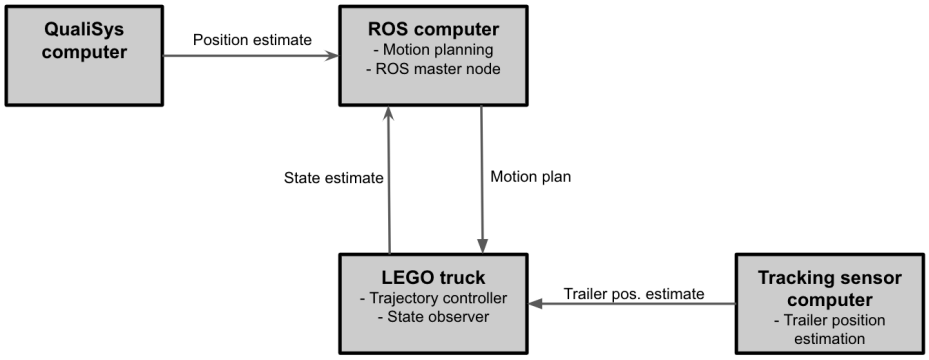

Figure 3: The final product will consist of four sub modules

2.4 Limitations

To be able to fulfill all requirements there are some limitations on the project:

- All obstacles are static
- The truck moves on a flat surface
- The velocity of the truck is always low enough to justify the use of a kinematic vehicle model
- The true dimensions of the trailer is known beforehand

3 TRAILER TRACKING SYSTEM

The trailer tracking system is responsible to aid the truck with position and orientation estimates of the trailer when reversing towards the loading bay. The trailer tracking system is to be mounted on the loading bay. The requirements for the trailer tracking system are listed below.

Requirement	Revising	Description	Priority
5	Original	There should exist one computing unit for sensor data collection and computation	1
6	Original	There should exist one or two sensors in the trailer tracking system	1
7	Original	The sensor(s) should be able to estimate the position of the trailer when in field of view with an error of no more than 2 cm	1

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Requirement	Revising	Description	Priority
8	Renegotiated 1.1	The sensor(s) should be able to estimate the trailer angle with respect to the loading bay (when in field of view) with an error of no more than 5°	1
9	Original	Estimated position and orientation should be published through a ROS node	1

4 STATE OBSERVER

The state observer is responsible for estimating the states of the truck and trailer using data from a number of different sensors. The requirements on the state observer are listed below.

Requirement	Revising	Description	Priority
10	Original	A motion model of the vehicle should be used within the state observer	1
11	Original	The state observer should use data from the inertial sensors on the truck	1
12	Original	The state observer should handle measurements from QualiSys	1
13	Original	The state observer should handle measurements from the trailer tracking system	1
14	Renegotiated 1.2	The state observer should handle measurements that are asynchronous.	1
15	Original	All raw sensor values should be published through a ROS node	1
16	Original	The state observer should be able to estimate the position of the trailer with a maximum error that is 50 % of the maximum error from sensors, excluding the trailer tracking system	1
17	Original	Estimated states should be published through a ROS node	1
18	Original	The state observer should estimate the initial heading of the system, i.e. the yaw angles of the dolly, trailer and truck, with a maximum error of 5°	2
19	Original	The trailer position and orientation should be estimated without the use of QualiSys. The estimate should be with a maximum error that is 80 % of the maximum error from the inertial sensors, i.e. the gyroscope and odometer	2

5 MOTION PLANNER

The motion planning module is responsible for planning a feasible path which the truck and trailer system can follow from a starting state to a goal state. Currently, the motion planner is a lattice-based motion planner which uses A* grid search with a euclidean distance heuristic. In this years project the motion planner will be improved by implementing a heuristic look-up table and an optimization-based improvement step in the lattice planner. The requirements on motion planning are listed below.

Requirement	Revising	Description	Priority
20	Original	Graph search using the heuristic look-up table should on average be at least 10 time faster than using the euclidean distance	1
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Requirement	Revising	Description	Priority
21	Original	The lattice planner should be able to find a solution to the goal (given any start and end point) in the Visionen arena in less than 1 second	1
22	Renegotiated 1.1	The resulting end position of the trailer at the loading bay should be no more than 5 cm off the reference position	1
23	Original	The motion planner should receive the estimated states from the state observer	1
24	Original	The motion planning module should be able to handle other starting configurations than all angles equal to zero	2
25	Original	Optimal path planning should be done in receeding horizon fashion with a fix frequency of 1 Hz	2

6 SOFTWARE QUALITY

Requirements regarding the standard and format of produced software are listed below.

Requirement	Revising	Description	Priority
26	Original	Code written by the group should comply to the Google code standard (https://google.github.io/styleguide/cppguide.html)	1
27	Original	Any new modules should be based on ROS	1

7 ECONOMY

Requirements regarding the available resources of the project are listed below.

Requirement	Revising	Description	Priority
28	Original	Each group member shall spend 240 hours on the project	1
29	Original	The group shall recieve a total of 40 hours of tutoring time	1
30	Original	The group shall be provided with a project room	1
31	Original	Necessary hardware for the project shall be provided by the customer	1

8 DELIVERY

Requirements regarding the necessary deliveries are listed below.

Requirement	Revising	Description	Priority
32	Original	BP2: By 2019-09-24 the following shall be delivered: Requirement specification, project plan including timeplan, a draft of the design specification and a verbal presentation of the system	1
33	Original	BP3: By 2019-10-01 the following shall be delivered: Finalized design specification and test plan	1
34	Original	BP4: By 2019-11-13 the following shall be delivered: All separate modules tested in simulation or visionen	1
35	Original	BP5: By 2019-11-28 the following shall be delivered: Full functionality of the system, a presentation which shows that the requirements have been fulfilled, test protocol, user manual	1
36	Original	BP6: By 2019-12-16 the following shall be delivered: Technical report, after study, poster presentation, a website and movie presenting the project	1

9 DOCUMENTATION

A list of the required documents for the project is given below. Targets of the different documents are either the project group (PG), orderer (O), customer (C) or course responsible (CR).

Document	Language	Purpose	Target	Format
Requirement specification	English	Formulates which requirements should be fulfilled by the project based on the project directive.	PG, O, C	Electronic/PDF
Project plan	English	Describes how the work of the project group should be organized. It lists major milestones and deliveries as well as responsibilities of the project members.	PG, O	Electronic/PDF
Time plan	English	Lists all activities to be performed during the project in chronological order, with allocated time and responsible project member.	PG, O	Electronic/Excel
Design specification	English	The design specification should give a thorough overview of the construction and implementation of all different parts of the system.	PG, O	Electronic/PDF
Test plan	English	Describes which test should be performed and which requirements they are supposed to verify	PG, O	Electronic/PDF
Test protocol	English	Lists the results of performing test and which requirements where fulfilled	O	Electronic/PDF
Technical documentation	English	A thorough documentation of the technical results of the project.	O	Electronic/PDF
User guide	English	Describes how the final system should be used.	C	Electronic/PDF
After study	English	Reflection of what went well and what could be improved during the project as well as actually used time.	O, CR	Electronic/PDF

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Document	Language	Purpose	Target	Format
Poster presentation	English	A poster summarizing the results of the project and its features	C	Poster
Movie	English	A movie demonstrating the final system	C	Electronic/Video
Web page	English	A web page which presents the project as well as relevant documents	C	Electronic/HTML
Meeting protocol	Swedish	A protocol over what was discussed during each weeks meeting together with a status report	PG, O	Electronic/Email
Time report	English	A report over how much time each project member has spent on different activities each week	PG, O	Electronic/Email