Requirement specification

AGV Control Machine Learning

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Version 1.1

Status

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AGV Control Machine Learning
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DOCUMENT HISTORY

Version	Date	Changes	Made By	Reviewed
0.1	2021-09-13	Preliminary requirements	All	Rasmus Björk
0.2	2021-09-20	Refining the requirements	All	Rasmus Björk
0.3	2021-09-23	Refining the requirements	K.B., R.B.,	Rasmus Björk
1.1	2021-12-14	Final version	All	Mahdi Najafi

1 INTRODUCTION

This section will explain the purpose, goals and background of the project. The goal of the report is to create a feasibility study, which means that showing something is not possible or very hard to execute should be viewed as a success. Therefore some of the requirements in this report are made to be optimistic since they can be renegotiated with the orderer if shown impossible to fulfill. This does especially apply to the requirements regarding the performance of the different components.

1.1 Definitions

AGV: Automatic guided vehicle
ML: Machine learning

1.2 Stakeholders

There are three stakeholders in the project. Toyota Material Handling (Toyota M.H.), Linköping University and the project group. Toyota M.H. is the end customer and the ones who will make use of the project post-completion. Toyota M.H. is represented by Oskar Bergkvist, who acts as the customer. The project is part of a course at the department of electrical engineering (ISY) at Linköping University; Daniel Axehill (ISY) acts as examiner for the project, Anton Kullberg (ISY) as orderer, and Hamed Haghshenas (ISY) as supervisor for the project group.

1.3 Purpose and goal

The purpose of the project is to make a feasibility study for automating the fine tuning of controllers for Toyota M.H. vehicles. The goal of the project is to evaluate at least two different machine learning methods. Different machine learning techniques will be evaluated to a varying degree depending on the potential perceived by the project group. To be able to evaluate the different solutions a simulator of an AVG (automated guided vehicle) will have to be develop. Alternatively updating a simulator created in a previous thesis could also be an option.

1.4 Usage

The report will be used as a basis in a decision for further development at Toyota M.H.

1.5 Background information

Toyota M.H. have recently launched their fully autonomous vehicles after having previously used autonomous systems on the existing trucks. The control system for the new AGV is developed by an external company but Toyota M.H. have the ambition to, in the future, develop the controls for the vehicle in house. Based on a Master's thesis work [1] it has become apparent that tweaking the control system for different environments is excessively time consuming. As the simulated working environment is sub-optimal to the actual working environment, the final tuning will be finished on a customer to customer basis. Previously, the control system from the simulation has been tuned to an estimated 90% of the desired controller. The goal of this project is to increase the controller's performance to 95%. Therefore,

Toyota M.H. in cooperation with Linköping University created this project to explore the possibilities of automating the process by using machine learning to tune the controllers.

2 SYSTEM DESCRIPTION

The system consists of an AGV which in this project is a differential drive robot. The AGV has four wheels, two of which are driven separately located on each side and two caster wheels placed on the front and back of the robot. The purpose of the caster wheels are to increase balance and enable smooth turning. Each wheel is configured via an encoder and a 2D LIDAR is used for positioning. The guidance of the system is handled by a software platform developed by Toyota M.H. Readable data of the system is wheel speed for each of the wheels and positioning in x,y coordinates as well as heading. A picture of the AGV is listed below.

Figure 1: Image of the AGV [1]

2.1 Requirements for the whole system

Below are the requirements for the system.

Requirement	Version	Description	Priority
1	1.0	The system shall have a simulator	Base
2	1.0	The project shall evaluate at least two machine learning methods	Base
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Requirement	Version	Description	Priority
3	1.0	At least one machine learning method shall be used to build an auto-tuner	Base
4	1.0	Proper documentation shall be produced.	Base
5	1.0	A program will be built to easily access the variable values in the log files	Extra

3 AUTO TUNER

The function of the auto tuner is to tune the controller parameters. The auto tuner in this project will be based on machine learning.

3.1 Requirements for auto tuner

Below are the requirements for the auto tuner.

Requirement	Version	Description	Priority
6	1.0	The auto tuner shall be compatible with the simulator	Base
7	1.0	The auto tuner shall be based on MATLAB or Python	Base
8	1.0	One auto tuner shall be based on reinforcement learning	Base
9	1.0	The ML algorithms must be capable to solve the continuous control problem	Base
10	1.0	The auto controller should be able to function in a different environment, i.e. a different path and different errors	Base

4 SIMULATOR

The purpose of the simulator is to create simulated data describing the state of the AGV given a model for its dynamics, an implementation of a controller and a description of the initial states of the AGV. Since it is important that the simulated data corresponds to how the physical AGV would behave given the same conditions, a comparison between the simulated data and data collected from the physical AGV should be produced.

4.1 Description of simulator

The simulator uses data from an AGV to construct a map of the mission and an interface to evaluate the model's performance. The simulator uses simulated performance disturbances to aid the development of the auto tuner.

4.2 Requirements for the simulator

Below are the requirements for the simulator.

Requirement	Version	Description	Priority
11	1.0	A model of the AGV should be produced that describes its dynamics.	Base
12	1.0	A system should be implemented that simulates the AGV according to some model of its dynamics.	Base
13	1.0	The simulator shall be able to simulate delays in the controller	Base
14	1.0	The simulator shall be able to simulate errors in the IMU or the robot's orientation	Base
15	1.0	The simulator shall be able to simulate errors in the LIDAR or the robot's positioning	Base
16	1.0	The simulator shall be able to simulate errors in the odometer	Extra
17	1.0	The simulator shall be able to simulate variations in the load distribution of the AGV	Extra
18	1.0	The simulator shall produce relevant data (e.g. track deviation) for the evaluation of the auto tuner performance	Base
19	2.0	The simulator shall be constructed in MATLAB or Python	Base
20	1.0	The simulator can measure the time/performance required to auto-tune	Extra
21	1.0	The learning process of the auto tuner will be visualized	Base
22	1.0	The simulator will have a GUI to start and end the learning process	Base
23	1.0	The GUI in the simulator will display the performance of the controller	Extra

5 PERFORMANCE

To evaluate the usefulness of the machine learning techniques for auto tuners, the results from the methods are compared to the results from the graduate thesis. The robot is evaluated on efficiency: the robot should not accelerate and decelerate rapidly.

5.1 Requirements for the system performance

Below are the requirements for the performance of the ML methods.

Requirement	Version	Description	Priority
24	1.0	The auto tuner performs better than the thesis controller	Extra
25	1.0	The system learns the control parameters faster than one hour	Extra
26	1.0	One of the auto tuners should be able to tune the controller to have a maximum position error of 20 mm	Base
27	1.0	One of the auto tuners should be able to tune the controller to have a maximum orientation error of 2.5°	Base

6 ECONOMY

The course workload shall be in relation to the course specifications.

6.1 Economy requirements

Below are the listed requirements for the economy.

Requirement	Version	Description	Priority
28	1.0	The project workload shall not exceed 240 hours per individual	Base

7 DELIVERIES

By course requirements and customer wishes a set of delivery dates have been determined.

7.1 Delivery requirements

The following dates have been determined for the deliveries.

Requirement	Version	Description	Priority
29	1.0	21 september (BP2): Requirement specification, project plan, time plan, and a draft of the design specification	Base
30	1.0	TBD (BP3): Design specification and test plan	Base
31	1.0	TBD (BP4): First draft of simulator and protocol for evaluating the requirements	Base
32	1.0	30 november (BP5): Demonstration of base and extra requirements, evaluation protocol, and user manual	Base

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Requirement	Version	Description	Priority
33	1.0	13 december (BP6): Technical report, post-study, poster presentation, project website, presentation of the system (video), installation guide	Base

8 DOCUMENTS

To structure the working process a set of documents will be produced alongside the system.

8.1 Table of documents

Below are the documents that shall be produced.

Table 7: Table of documents

Document	Language	Purpose	Target	Format
Requirement specification	English	Requirements of the project	Customer	PDF
Project plan	English	Specifications of when parts of the project will be completed	Customer	Excel spreadsheet
Time plan	English	Estimate of how long each sub-task will take to complete	Customer	Excel spreadsheet
Design specification	English	A description of the system	Customer, supervisor	PDF
Test plan	English	A plan of how the test's will be conducted	Customer	PDF
Technical report	English	A technical report of the system	Customer, supervisor	PDF
User manual	English	A guide to use the system	Customer	PDF
Post-study	English	Assessment of the system and project continuation	Customer	PDF

9 EDUCATION

To complete the project, the group needs to accumulate significant knowledge within their project area. Additionally, the project leader will be educated in project management.

9.1 Education requirements

The requirements for the self-study of the group participants are listed below.

Requirement	Version	Description	Priority
34	1.0	Self-study within respective project area	Base
35	1.0	Project management tutorship for the project leader	Base

10 QUALITY

To attain a satisfactory level of quality, a list of quality requirements have been created.

10.1 Quality requirements

The project will adhere to the quality requirements listed below.

Requirement	Version	Description	Priority
36	1.0	The code shall adhere to Google's code standard where applicable	Base

11 MAINTAINABILITY

To easily maintain the system, certain features will be implemented.

11.1 Maintainability requirements

Below are the listed maintainability requirements.

Requirement	Version	Description	Priority
37	1.0	The interface between the simulator and the auto-tuner should be specified in the documentation (see section 8).	Base
38	1.0	The simulator and the auto-tuner should be constructed in a modular way.	Base

REFERENCES

[1] A. Holgersson and J. Gustafsson, “Trajectory tracking for automated guided vehicle,” 2021.