Obstacle detection for moving and static objects in driving environments - a proposal

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***Abstract*—Development of autonomous vehicles is an important safety and energy issue. One of the most crucial and challenging parts of the development is to detect obstacles with sensors. The sensors proposed in this proposal are ultra-sonic, LIDAR, radar and cameras. To distinguish which of the sensors is most suitable, an experiment is proposed. The performance of each sensor will be measured in accuracy, precision and recall.**

INTRODUCTION

The development of autonomous cars has become more and more popular. Big companies have come far in the development and self-driving cars will soon drive on the roads [2]. An autonomous car needs a lot of different advanced functions to work properly. E.g. functions to avoid collisions. One of the things needed to avoid collisions is to detect both moving and stationary obstacles. There are many different object detectors out there, used with different complex algorithms that can, more or less, tell the system to steer or brake to avoid a collision.

The MDH Solar Team has an idea of making their car autonomous. One of the functions they are missing is an obstacle detector. This gave the authors an idea of writing a proposal, primary aimed for the MDH Solar Team, of an experiment to investigate what method of obstacle detection is most suitable for their car. It is important to state what its driving environment will look like, as different environments might give different results. This study will hopefully give the MDH Solar Team a good obstacle detector and also put more research in the topic.

Aims and objectives

The aim of this research is to find the most suitable sensor for obstacle detection as this is an important step in making the solar car self-driven. There are several objectives to achieve these goals. Research has to be done on the different available sensors. Also, suitable algorithms for each sensor has to be found. Then a controlled experiment will be made on a race track to determine the performance of each sensor. Finally, the performance has to be evaluated to establish which one of the sensors that performs the best.

Research question

With those aims and ideas, one research question was established. That is:
RQ1: *Which sensor attached to the solar car performs the best at detecting obstacles on a race track?*

RELATED WORK

There are multiple ways to detect obstacles for an autonomous car. Studying related papers gave that the most commonly used obstacle detectors are:

1) Ultra-sonic
2) Light Detection and Ranging (LIDAR)
3) Radio Detection and Ranging (Radar)
4) Cameras

Cameras can be further categorized as stereo vision camera and monocular camera [9].

Characteristics

The sensors are all good at different areas. The main difference between them is the range they are operating in. An ultra-sonic sensor is one of a kind regarding the distance detection. It is very good up to a distance of about 2.5 meters [3]. In this short range it does operate good, even at night or in bad weather conditions. Regarding the operating distance, the LIDAR and the cameras are similar. The LIDAR has a very good angular resolution at a range up to about 50 meters, where the camera is good up to about 30 meters. [5]

Meaning that they are good to classify certain objects in a short range. This can be compared to a radar which can detect objects much further away, but its angular resolution is not as good as the others [10]. On the other hand, the radar can instantly say that an object is moving, which could help the classification of that object. Furthermore the radar still has a good reliability during night or when the weather condition is bad. The LIDAR and the cameras are both affected negatively by the weather. However, during night the LIDAR performs even better [6] and thus has an advantage over the cameras, as it needs light to operate [5]. Another difficulty with cameras is that it needs processing of the image to classify objects [1] [7]. This means that a good object detector, using a camera, does not only need a good camera, but also a good algorithm to process and correctly classify possible obstacles in the image.

Driving environment

The environment of the road will most likely have an impact of which obstacle detector to use [5]. E.g. in cities or on crowded roads, where the speed of the vehicle is low, the angular resolution to correctly classify objects could be more important than to have a long distance obstacle detector. On the other hand, in environments where the speed is high, like high-ways, the distance to detect objects could be more important than to have a good angular resolution on short range. On the other hand there will always be outliers in this statement. E.g. animals or even humans could appear on a high-way. The same goes to fast-driving cars in the city, where the driver takes no account of the speed limit.

Placing of an obstacle detector

The placing of an obstacle detection equipment could have an impact on the reliability. A high placed obstacle detector will help the determination of the height of objects on the road [4]. This helps the classification of smaller objects that can be ignored by the car. A low placed obstacle detector could, in worst case, tell the car to break when it doesn't need to.

Research Methodology

An experiment is suitable for this project because the data is easily compared and quantifiable. Different setups of the test environments can used to compare sensor performance. Experiments are a good match for comparisons, especially if the data generated is similar in nature. An experiment is also superior if everything can be controlled and measured. In this case the test environments is easily controlled, and sensor performance are by its very nature easy to measure. Another research method could have been a simulation. However, as the solar car actually exists and the authors want to have a final product at the end of the study, an experiment is more suitable for this study.

Goals

The main goal for this experiment is to find which obstacle detector works best for obstacle detection on a race track.

Environment

The experiment will be conducted on Gröndal Motorstadium in Eskilstuna. The track is supposed to represent a low populated suburban road. The track will be modified with different obstacles to represent the corresponding conditions.

Experimental material

The objects selected in this study are the various sensors: LIDAR, ultra-sonic, radar, stereo vision and monocular camera. Based on the related work study, these sensors are often used in obstacle detection in driving environments.

Hypotheses, parameters and variables

Based on the research question, one null hypothesis and five alternative hypotheses were addressed as:

H_{011} : *There will be no difference in accuracy between the various sensors.*

H_{111} : *Using LIDAR will give the highest accuracy.*

H_{112} : *Using radar will give the highest accuracy.*

H_{113} : *Using ultra-sonic will give the highest accuracy.*

H_{114} : *Using stereo vision will give the highest accuracy.*

H_{115} : *Using monocular camera will give the highest accuracy.*

The independent variable in this experiment is the obstacle. The dependent variables are measurements in how accurately each sensor can detect an obstacle, these will be measured in accuracy, precision and recall. The independent variable will change between being a pedestrian standing still on the road, a pedestrian walking across the road, a car standing still on the road and a car moving on the road.

Design

There will be two factors to take into account. The first factor is the speed of the vehicle. The other is the different obstacles that will be tested. Furthermore, the subject is the environment (the race track) to which the independent variables and treatments are subjected to. The environment will be subjected with the treatments of static and dynamic objects such as pedestrians and cars. Table 1 shows the factorial design to use for each of the five objects.

TABLE 1
DESIGN TYPE FOR EACH OBJECT

		Obstacles			
		Static		Moving	
		car	pedestrian	car	pedestrian
speed	0				
(km/h)	20				

Procedure

The solar car will be taken to the race track and the various sensors will be attached to it, one at a time. The track will then be modified with the current treatment. The different treatments will be static pedestrian, moving pedestrian, static car and moving car. The solar car will both be standing still and moving at a pace of 20 km/h. The race track will be staged with the different obstacles one at a time and the performance of the sensors will be measured using a computer program. All sensor data will be saved and later analyzed.

Analysis procedure

When all experiments are finished and data has been generated, the data need to be examined. This is done by using descriptive statistics. By examine the data with math and visualize it in graphs, one could informally interpret the data. [8] This will give a better understanding of the experiment's actual results. After an informal interpretation of the data it should be clear if some data can be excluded or redacted. Only data relevant to the current scope should be included in the analysis of the experiment. When one is satisfied with the data set, further statistical analysis could give a deeper understanding of the data and enable an in-depth interpretation. Results will be based on how accurate the object detector is in accuracy, precision and recall. A final value between 0 and 1 will represent how good the detector is, where a 1 represents a flawless test. The conclusions based on the experimentation results should be tested against the hypothesis. In this way one can test if the hypothesis could be rejected. Further studies can be proposed based on the analysis.

Treats to Validity

1) Construct Validity: When constructing and setting up the experiments in this case one should take care to choose many different scenarios and situations. This is important since the experiment claims to measure "the best sensor". What the characteristics of a good sensor is should be based on discussions among the researchers and related works. The reasoning behind this should also be stated in the article.

2) Internal Validity: Internal Validity is extremely important to any experiment. First of all, any experiment should be randomized if possible. This is done to avoid certain situations being favorable to some objects. Also, some kind of control group must be constructed. Any instruments used in the measurements need to be calibrated correctly. When analyzing the data, the researchers should (if possible) not know which sensor produced which result. Furthermore, when conducting the experiment and analyzing the data multiple observers should be present.

3) External Validity: The experiments in this case can be easily replicated. Sensors should be tested in laboratory environments and multiple different sensors should be used to maximize generalization.

1) Mock data

Table 2 illustrates mock data of a possible analysis of this study.

TABLE 2
ANALYSIS OF A LIDAR (MOCK DATA)

LIDAR		Obstacles			
		Static		Moving	
		car	pedestrian	car	pedestrian
speed	0	0.91	0.85	0.82	0.76
(km/h)	20	0.85	0.79	0.70	0.62

EXPECTED OUTCOMES

When this project is finished the best suited obstacle detection sensor has been found for the solar car. The sensor is going to be used in a demonstration of the solar cars self driving capabilities on the same track as the experiment has been conducted on. In future works the sensor could be tested with several different algorithms for object detection to find the most suitable for the solar car.

Time and activity plan

Delivery times for the sensors can be delayed and thus the sensor testing will be delayed. Sensor testing should be done before the experiment so the experiment can go through as planned. The experiment execution is planned over a period of five days to counter the risk of bad weather and delivery times.

If the equipment doesn't arrive on time the study cannot really proceed. The sensors can still be further researched. So if the delivery passes its deadline further research on each sensor will be done to speed up the later testing and understanding of each sensor.

If the data from the experiment for some reason is not sufficient then firstly more testing can be done in a laboratory during the analysis phase. Secondly another day on the race-track can be scheduled during the analysis phase if crucial data is missing.

TABLE 3
TIMEPLAN

Task Name	Duration	Start	Finish
Research	**28 Days**	**Mon 19-01-21**	**Wed 19-02-27**
State of the art	5 days	Mon 19-01-21	Fri 19-01-25
Sensor Research	5 Days	Mon 19-01-28	Fri 19-02-01
Algorithm research	5 days	Mon 19-02-04	Fri 19-02-08
Solar Car Funciton	3 days	Mon 19-02-11	Wed 19-02-13
Sensor acquisition	5 days	Thu 19-02-14	Wed 19-02-20
Sensor testing	5 days	Thu 19-02-21	Wed 19-02-27
Experiment	**10 days**	**Thu 19-02-28**	**Wed 19-03-13**
Preparation	3 days	Thu 19-02-28	Mon 19-03-04
Execution	5 days	Tue 19-03-05	Mon 19-03-11
Equipment recovery	2 days	Tue 19-03-12	Wed 19-03-13
Analysis	**30 days**	**Thu 19-03-14**	**Wed 19-04-24**
Sort and label data	7 days	Thu 19-03-14	Fri 19-03-22
Analyse data	12 days	Mon 19-03-25	Tue 19-04-09
Visualize data	11 days	Wed 19-04-10	Wed 19-04-24
Report	**32 days**	**Thu 19-04-25**	**Fri 19-06-07**
Finalize report	15 days	Thu 19-04-25	Wed 19-05-15
Feedback	3 days	Thu 19-05-16	Mon 19-05-20
Refine report	3 days	Tue 19-05-21	Thu 19-05-23
Presentation	11 days	Fri 19-05-24	Fri 19-06-07

Risk management

The major risks for this study is that equipment can fail, for example, if the car collides with an obstacle and something gets damaged. This can be avoided by being careful when conducting the experiment and proceed with caution at every step. If the necessary equipment is not available the proposed experiment needs to be modified. For example, if a LIDAR can't be obtained, that part of the experiment is going to be postponed or scraped completely.

Furthermore, weather conditions need to be satisfactory and not change during the experiment. This to correctly measure each of the sensors at its best as this study is not taking into account different weather conditions.

Additionally, caution needs to be considered when handling the collected data so it is labeled and stored correctly. Otherwise valuable information can be lost and the experiment has to be remade.

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