TME202 VTS

Active Safety Assignment

Group number: 20

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1. Introduction

In the last few years, a trend of rising bicycle usage has been observed [1]. One of the reasons for this trend is that the number one mean of transportations, cars, comes with multiple downsides such as pollution, traffic jams and congestion. Another reason is that the usage of bicycles comes with different advantages such as cost, health benefits and being environmentally friendly, which may be affected by the rising awareness for the climate change and individual health.

Many of the most severe cycling injuries are the result of crashes with motorized vehicles, most of them being overtaking maneuvers. While the motorized vehicles have a surrounding protection in the form of the vehicle itself, bicyclists have no protection other than helmets. Therefore, it is of special interest to understand the causation of crashes which involve bicyclists and vehicles and find ways to stop them, for example by adding active safety functions to vehicles. To get the best results and adaptation of such functions it is crucial to understand how the drivers behave and which factors affect their decision making.

One of the most important factors for the driver behavior is the assessment of drivers' comfort zone boundaries, which is already used in active safety functions in different ways. To describe the safety distances between the bicyclist and the driver, quantified comfort zone boundaries can be used as a metric. Therefore, means to quantify this metric are needed.

To find the best way to study the comfort zone boundaries, a pilot test was set-up involving a bicyclist driving on public roads with a fixed distance to edge of his lane. A LIDAR system was used to measure the distances of the overtaking vehicles over time. The aim of this report is to study if and how the positioning of the LIDAR system affects the overtaking distances and, therefore, the comfort zone boundaries of the driver.

2. Literature Review

2.1 Research on cars overtaking cyclists

The paper "Drivers overtaking bicyclists" by Ian Walker explores the different factors regarding bicyclists that affect the distance at which drivers overtake them, as well as factors related to the drivers [2]. The paper found correlations between the gender of the rider, the distance of the bicycle to the shoulder of the road, the use of helmet, the type of vehicle passing by and how these different parameters affected the overtaking distance between vehicles and a bicycle.

First, most drivers gave more passing distance when thinking the bicycle rider was a female when compared to male. The drivers also had an increased distance when passing the cyclist closer to the shoulder of the road when compared to the cyclist riding in the middle of the lane. The use of helmet also inflicted changes, as drivers would be more careful when the rider did not have a helmet on, with increased distances for overtaking, but with the helmet on the drivers would be passing closer to the bicycle. Different vehicles also inferred differences, with cars, SUV's and light commercial vehicles presenting similar results with larger distances when compared to the likes of heavy commercial vehicles and busses.

The drivers were going through a risk assessment situation, where they would evaluate aspects about the bicycle rider and the position of the bicycle in the lane in order to decide at which distance to pass the rider. However, it seems that this relation was different for bigger vehicles, as although the risk of serious injury is likely higher when a heavy vehicle hits a cyclist, the distances were bigger probably as it is harder for these drivers to accurately picture the position of the cyclist during the overtaking maneuver due to the longer time taken to effectively complete the overtake. So a subconscious analysis of the bicycle rider profile as well as its position in a lane weren't the only factors influencing the passing distance, there were also aspects regarding vehicle type and not the driver type.

The main difference of this experiment when compared to the experiment provided was the equipment used. In the experiment from Ian Walker's paper, the bicycle was equipped with an ultrasonic distance sensor to measure the distance between the bike and the passing vehicles as well as a hidden camera on the handlebar. There was also a laser that helped keeping the bike in a relatively fixed distance to the edge of the road. In the provided experiment, a LIDAR sensor was used, which is much more precise and would probably recreate even the smallest details of how the vehicles were passing, which could present an even more accurate depiction of driver behavior, as the maneuvers done by the overtaking drivers can be evaluated other than only the distance between bike and vehicle.

2.2 Comfort Zone Boundaries

The paper from Mikael Ljung Aust is about outlining a general framework on the evaluation of active safety systems and specify their requirements in a generic manner [3]. The author points out that while for passive safety Haddon provided such a framework with the Haddon Matrix and the Energy Transfer Modell such a framework does not exist for active safety.

One of the biggest factors for this is the limited data and research and that there are no agreed-upon concepts and principles in the active safety function evaluation for the use of field data to define evaluation scenarios and performance metrics. While the first factor might be resolved soon with large scale investigations of crash causation, the second factor is to be tackled in the paper by proposing a conceptual framework for the translation of accident data into generally applicable evaluation scenarios, defining of evaluation hypothesis and a selection of performance metrics and criteria.

The central concept is what the author calls situational control. Control is the ability to direct and maintain the development of a chain of events and is a joint property of the driver-vehicle system. Situational control "represents the degree of control jointly exerted by driver and vehicle (the JDVS) in a specific traffic situation within a traffic scenario" (Aust and Engström, 2011). Driving is seen as a control task which aims to fulfil a goal by continuous adaptation to the ever-changing environment. The extended control model (ECOM) extends this concept by explaining how goals on different levels interact with each other. This doesn't address how the goal states are selected. Therefore, the author implements the zero-risk theory and the "comfort through satisficing" model.

Briefly speaking, the zero-risk theory states that the driver wants to maintain a state of zero risk and is driven by motivation – the inhibitory forces- which are balanced by excitatory forces. Inhibitory forces are based on experience of subjective risk. The "comfort through satisficing" model states that maintaining control requires effort and that humans will trade of optimal performance to avoid spending effort - taking corrective actions – if the driver is in his comfort zone.

Gibson and Crooks (1938) stated that the selection of reference values is based in a space of driver, vehicle and environment parameters with the goal of keeping a field of safe travel which is used for assessing the adaptive behavior [4]. For this, a concept of safety zone, comfort zone and safety margins between the DVE are defined. Those are defined by the vehicle speed and the friction between the vehicle and the road, see Figure 1.

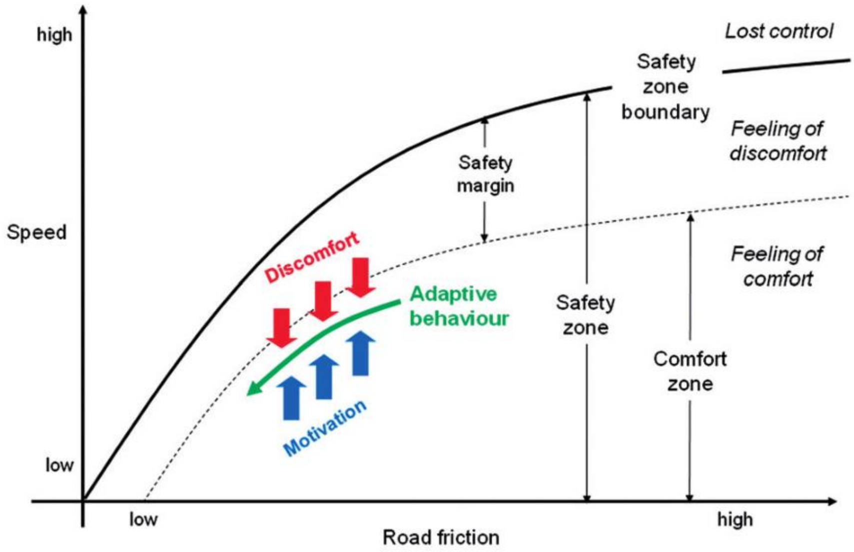

Figure 1: Concept of safety zone, comfort zone and safety margins between the DVE

The comfort zone is defined by the speed and friction combination for which the driver doesn't feel discomfort. The safety zone boundary is defined by those parameters which lead to loss of control. Between those two is the safety margin. Defining factors are dependent on the environment as well as the experience and skill the driver has and those define the limits of the boundaries. Research leads to several factors.

Active safety functions focus on preventing the loss of control or mitigating the consequences if there is a loss of control. For this active safety functions focus on crash scenarios which can be divided into multiple pre-crash situations.

1. The comfort zone boundaries are not crossed yet and the driver doesn't experience any discomfort
2. The comfort zones boundaries have been crossed and the driver feels discomfort but is still able to recover
3. A crash is inevitable because the safety zone boundaries has been crossed
4. The trajectory of the vehicle is outside of the safety zone boundaries

This definition is used as a baseline in specification and evaluation of active safety functions. For the application of the framework the author proposes two steps with three sub-steps.

1. Requirement specifications
    a. Identify traffic scenario
    b. Define active safety use case
    c. Specify requirements of functions enhancement
2. Evaluation
    a. Generating a hypothesis that defines the effects tested for
    b. Recreation of the active safety use case in a controlled environment
    c. Definition of performance metrics and criteria to define positive/negative change

3. Methodology

The basic idea for the pilot test was to ride a bicycle on public roads and collect data from the vehicles overtaking it. For this purpose, the front of the bicycle was equipped with a data acquisition system including an inertial measurement unit, a GPS sensor as well as a forward-facing camera. On the back of the bicycle a backward facing camera and a LIDAR system, facing side-ways or backwards, were mounted.

The collected data is being used to identify overtaking maneuvers, acquire the least distance perpendicular to the direction of movement as well as the type of vehicle. The type of vehicle is based on the vehicle length measured. To evaluate the LIDAR data the software UrgBenriPlus is used, which is a software capable of recording, viewing and replaying data captured by devices using the SCIP2.x communication protocol. The extracted data is written into an Excel-file and then analyzed and interpreted. A statistical significance test in the form of an independent t-test is performed using the IBM SPSS statistical software, which provides functions for statistical analysis. The t-test assumes that the data has multiple properties which are being tested.

4. Results

4.1 Data from the LIDAR

Table 1: Result of evaluating the experiment data

Position	Cases	Mean	Min	Max	Standard deviation
Rear	23	1839.695652	1144	2677	501.2620971
Side	26	1692.166327	860	3900	643.6967936

After going over the recorded data and filling the Excel file, we found that the mean distance in which the bicycle was overtaken to be lower for the side mounted LIDAR in comparison to the rear mounted LIDAR. As we noticed from the previous readings, it seems that physical aspects about the bicycle as well as the rider affect the distance in which they were passed by the drivers, so the different layouts did present a difference in the passing distances, but it did not go according to our expectations. We thought that the different layout for the side mounted LIDAR would get more attention from the drivers and that they would maybe overtake the bicycles with a bigger gap between them. Perhaps as the bicycle became wider, the drivers had to be more careful about the overtake, waiting for lesser traffic in the incoming lane and using more space for the maneuver.

The minimum overtaking distance was 860 mm for the side mounted LIDAR for the and 1144 mm for the rear mounted LIDAR, where the smaller distance might have been due to the smaller overtaking space a car would have to stay in lane, and it happened when a passenger vehicle was passing and not a larger vehicle, as it is expected for the smaller distance according to the paper from Ian Walker. Still, all the larger vehicles recorded were overtaking the bicycle in a less than average distance. Moreover, the standard deviation was larger for the side mount in comparison to the rear mount, which agrees with the bigger range of distances found the case and perhaps indicates that the drivers passing the bicycle with the rear mounted LIDAR presented a more similar behavior.

While looking into the LIDAR files, the side mounted system makes it easier to spot the passing vehicles as well as to identify their size and distance to the bicycle. Also, as the LIDAR offers 180-degree view from the side of the bicycle, we can also see how the vehicles approach, overtake and even their behavior after passing. In this sense we noticed the rear LIDAR to be more limited than the side mounted one, as this set up provides a good view of the rear of the bicycle but is limited on how far it detects the passing car, only up until a perpendicular line to where the sensor is mounted, or around 90 degrees. This makes it better to visualize how the passing vehicles are approaching the bicycle, but not while or after passing it. Also, since the range of angles to which the vehicles are detected is smaller, the vehicles are exposed to the sensor for less time, making them harder to spot, and their size is harder to calculate. Overall, we believe that the side mounted lidar system provides better information for each overtaking event, not only being clearer to notice the passing vehicles but also providing a better overview of the entire overtaking maneuver.

4.2 T-test

Table 2: Output of SPSS Statistics performing the independent t-test

	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower 95% Confidence Interval of the Difference	Upper 95% Confidence Interval of the Difference
Equal variances assumed	1,022	0,318	0,935	44	0,355	142,30435	152,12405	-164,28146	448,89016
Equal variances not assumed			0,935	43,993	0,355	142,30435	152,12405	-164,28291	448,89161

The assumptions of the t-test are that the data samples are measured on a continuous scale, come from a random sampling, are normally distributed and have homogenous variances. The first assumption is correct since the way the data is sampled is known and continuous. It is difficult to prove that the samples are random but there is no obvious bias to observe. To determine if the samples are normally distributed, they are being plotted and a normality test is done using a Q-Q plot. The Q-Q plot is a visual test. A line represents the normal distribution, and the points are plotted as well. If the data points are close to the line, they are the distribution is approximately normal which is the case for both data sets.

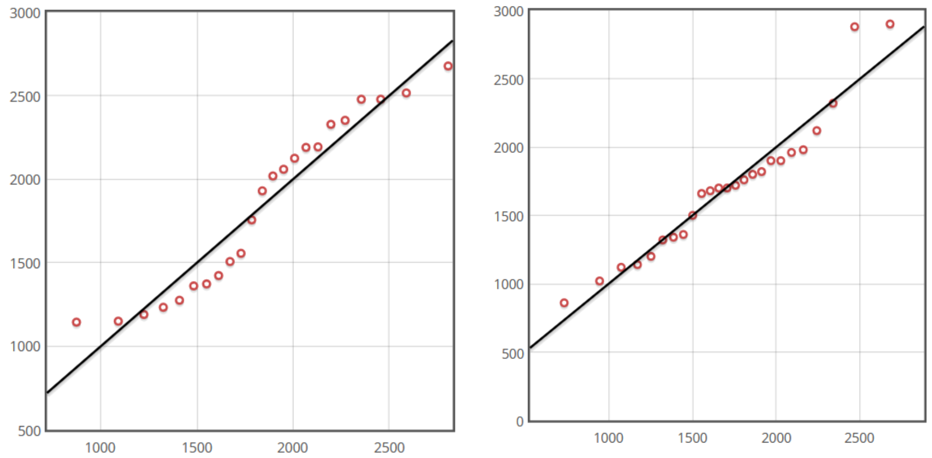

Figure 2: SPSS Analysis Data, left for the rear mound

To check if the data sets have homogenous variances the output of SPSS is used. It contains the variables of a Levene's test. If the significance (Variable 2 in table 2) is bigger than 0,05 there are homogeneous variances.

Since the assumptions are confirmed the result of the t-test can be interpreted without the need of any additional steps. Since the goal is to evaluate if there is a difference in the distances depending on the mount position, our Null-Hypothesis is that the dataset for the side LIDAR system would have a higher mean than that of the rear mounted system dataset and, therefore, there is no significant difference in the means of the two data sets. The variables t and df determine the level of significance which is represented by Sig (2-tailed). The level of significance is compared to a threshold of 0,05. Since 0,355 is bigger than 0,05 the Null-Hypothesis is rejected and there is a significant statistical difference between the means of the two data sets.

SPSS provides two variations of those variables for the instance that there is no equal variance. Since there is equal variance the difference in between those variants is almost none or none.

5. Conclusion

Looking into the paper by Ian Walker, “Drivers overtaking bicyclists” a few things to consider for a more in-dept study in this matter would be first to have a broader range of cities in which the experiment takes place. The size of the city as well as the amount of traffic could affect driver behavior and the way they overtake cyclists. For example, in a bigger city with more traffic, where drivers tend to be more stressed, they might have a more erratic behavior towards cyclists when compared to drivers from smaller villages, where they are likely calmer and more respectful. Second would be to have different cyclists and from different genders in the experiment, as the paper showed a certain bias in the behavior of the drivers regarding their preconceptions of the cyclist. The drivers might react different to a well-dressed person on a bike when compared to one that seems to be cheaply dressed, as well as factors like hairstyle and other physical characteristics. Those changes could provide a better overall view of how drivers analyze and behave while passing different cyclists, as it would explore the broader range of cyclists on the road.

When analyzing the different set-ups used for task 3, we noticed that when the LIDAR is side mounted, it extends outwards from the bicycle, making it easier to spot, as well as making the bicycle look unusual when comparing it to regular ones. As it is clear that the bicycle with this set-up is not an ordinary one, it might have affected the way in which the drivers were passing. On the other hand, the rear set-up is a bit more discrete, in the sense that drivers might just think it is a regular bicycle. As physical differences affect how drivers overtake bicycles, and there are differences to the way each LIDAR set-up looks, we believe that a possible improvement for this experiment would be to position the radar in a way that it is harder to spot and that both set ups look the same for a passing driver. This way, the possible overtaking differences only caused by physical aspects of the measuring elements would be eliminated.

Another factor to investigate would be to analyze the video recordings of the experiment along with the LIDAR data. With video, it would be possible to better identify the type of vehicle passing, and more importantly, the driver profile as well as its attitude during the overtake. This would enable an even more in-dept analysis to the issue, which would help finding co-relations between the type of driver, type of vehicle, behavior during the overtake, distance to the bicycle as well as the overall “mindfulness” towards the cyclist, e.g., how careful the drivers are while passing, does the physical characteristics of the drivers affect their attitude and respect towards the driver, how does the cars coming past from the other lane in the opposite direction affect driver behavior, between others. With the video files it would also be possible to evaluate other factors about the surrounding environment and observe if they can also affect the overtaking and therefore, a more holistic evaluation can be performed.

As an actual use for active safety systems on overtaking bicycles, we would suggest a system that would monitor the riding characteristics of the bicyclist to decide on how to make the overtake. As an example, if a cyclist rides steadily within lane, the system would take note of it and use a smaller margin of error to overtake, promoting the maneuver in a safe distance, but relatively close. If the rider is more unsteady, waiving around the lane, than the system would evaluate the situation even further for the overtake, leaving a wider gap so that the maneuver is done within a larger safety margin. Other factors would be to monitor vehicles in the incoming lane, as well as the vehicles in front of the bicycle to predict any possible hazards ahead.

Overall, the side mounted LIDAR provides more information for the entire overtaking maneuvers when comparing it to the rear mounted system, which is limited due to its angle of operation. Although the rear mounted LIDAR had a lower standard deviation for the overtaking distances when compared to the side mounted system, we cannot conclude which set-up is the most reliable, as the overtaking distances vary heavily depending on the driver, and the drivers were likely different for each of the experiment set-ups. Also, as the bicycle looked different for the different set-ups, and physical aspects since to play a role in the overtaking distances, it is hard to make a direct comparison between the set-ups, but in order to get a clear picture of bicycle overtaking maneuvers, we believe that the side mounted LIDAR is ideal.

6. Literature List

[1] Richard German, Road Traffic Estimates: Great Britain 2016.
UK: Department of Transportation, 2017.

[2] Ian Walker, “Drivers overtaking bicyclists: Objective data on the effects of riding position, helmet use, vehicle type and apparent gender,” Accident Analysis and Prevention, Vol. 39, pp. 417-425, 2007

[3] M. Ljung Aust, J. Engström, „A conceptual framework for requirement specification and evaluation of active safety functions,” Theoretical Issues in Ergonomics Science, Vol. 12, no. 1, pp. 44 – 64, 2011

[4] James J., Gibson, Laurence E. Crooks, “A Theoretical Field-Analysis of Automobile-Driving,” The American Journal of Psychology, Vol. 51, no. 3, pp. 453 – 471, 1938

Table 3: Contribution of the group members

Name	Introduction	Literature Review	Methodology	Results	Conclusions
Burak	x	2.2	x	x	x
Vicente	x	2.1	x	x	x
Sundar	x	-	x	-	x