Real-time prevention of accidents between cyclists and right-turning motor vehicles

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Abstract

Digital technologies can help to further improve the safety on our roads. As one of those technologies, surrogate safety measures can already greatly help to detect areas of conflict in the infrastructure. When computing the measures as part of real time systems, they can also be used to warn traffic participants of imminent danger. Our project aims to the implementation of such a system. In this abstract, the first results of the project are presented. The first driving simulator studies show great promise but still need for improvements. Same goes for the first prototype built, which soon will be deployed at an intersection in Germany.

Keywords

traffic safety, real time conflict detection, warning system, VRU

Introduction

The "Vision Zero" goal formulated by the EU aims to reduce the number of fatalities in road traffic to zero. Currently, the number of accidents in Germany is stagnating and even increasing for cyclists [Destatis, 2021]. Cyclists are some of the most vulnerable road users and the most frequently involved in accidents, the majority happening between cyclists riding straight and right-turning motor vehicles [Kircher and Ahlstrom, 2020]. Driver behaviour is still the highest source of these traffic conflicts due to a lack of attention and situational awareness.

After years of working on the challenge of detecting vehicle trajectories from camera footage in real time, the idea arose to use this technology to implement a warning system that can determine when a situation is going to be critical and warn one or both of the participants accordingly.

Collective measures, such as traffic signs, are not highly effective, often being subject to low acceptance rates and habituation effects. Therefore, it is necessary to develop a measure that can influence individual drivers. The effectiveness of similar measures has already been proven in another research project (www.mebesafe.eu), in which drivers were individually influenced to reduce their speed in a motorway exit. If speeding was detected, an animation pattern of LEDs was switched on, generating an optical flow against the speeding driver. This produced the effect of increased speed perception and caused the driver to slow down. With this measure the number of speeding drivers was reduced by up to 40%.

Methodology

In the project at hand we implemented and plan to further implement innovative visual measures as part of the road infrastructure of an intersection. These measures are based on situational control, and are activated only in the event of a potentially dangerous situation between cyclists and motorists. The vehicle drivers are informed and warned individually. The aim is to increase situational awareness so that the cyclists can be seen quickly enough to prevent an accident.

To implement such an innovative measure, several development steps are necessary. Firstly, a detection technology was developed that can detect cyclists and car drivers in critical situations. Secondly, a visual measure is being developed and analysed, taking into account the criteria of the psychology of perception.

The detection technology is based on thermal cameras and computer vision algorithms. An intelligent decision control logic activates the individual measure by detecting individual bicycles and cars and analysing their future interaction. This makes it possible to activate the measure only in the event of a potential conflict.

The infrastructure measure is based on remote-controllable LEDs, which can be embedded into the road or mounted at the roadside. From the perspective of perception psychology, the measure is being developed such that it prepares the driver for a potential critical situation and increases the situational awareness using a specific light sequence. In this regard, analyses of different animation patterns and flashing frequencies are currently being carried out using tests in the driving simulator.

Driving Simulator Implementation

In order to test the effectiveness and safety of the warning system, simulation studies are the safest method before entering a real traffic environment. This is done not only to have a first data base in order to convince traffic authorities that the system is not completely untested but also because the driving simulator allows for much more similar conditions for every driver. Here we can simultaneously record reaction times, give secondary tasks, and use an eye tracker to analyse the eye movements of the subjects.

The first exploratory simulation study is constructed as follows: The test subjects are put into the situation that they journey with a city chauffeur (level 3) in an urban environment. They don't have to steer the wheel, but are still responsible for braking in the case of an emergency. While they drive, they have a secondary acoustic task in the form of a podcast, about which they will have to answer questions. They drive through three different intersections, in each a cyclist appears to cross their way and they have to react. One intersection is used as a baseline, the other too have different warning systems installed.

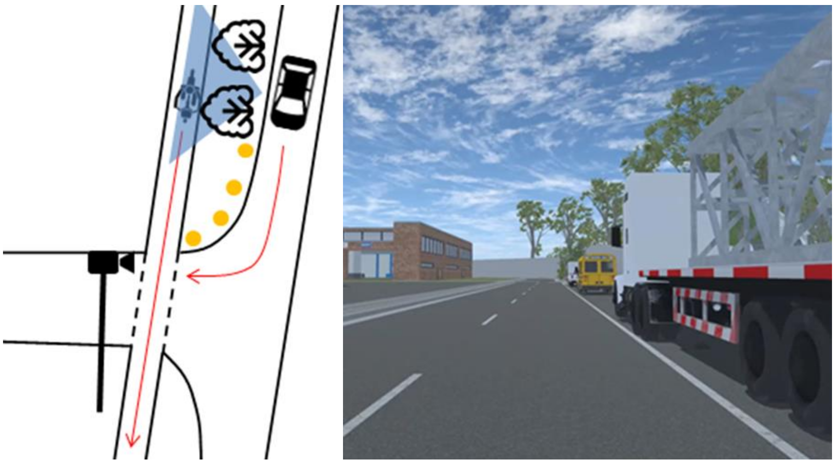

Figure 1: First driving simulator study, a cyclist driving not visibly next to the road and a right turing motorist who is being warned

The warning systems were parameterized with four different scenarios: A static flashing light with a) 1.5 Hz or b) 3.0 Hz or a dynamic flashing light with the lights being illuminated in a certain order, either c) coming towards the driver or d) going away from him. All scenarios as well as the baseline measurements are analysed towards the fixation probability and the gaze reaction time to the crossing cyclist.

The second simulator study concerns one of the possible issues that road authorities could present against the system, the potential to draw visual attention to critical areas of an intersection and to create a distraction effect. An automated driving scenario is again chosen, this time with a visual secondary task. Firstly, the driver has to drive through two intersections with a turning manoeuvre and cyclist, where again the detection probability of the cyclist and the gaze reaction are analysed. Secondly, there are two possible warning systems - a standardised single warning light and our newly designed system - installed next to the road which trigger at the same time as an emergency event where the lead vehicle does a hard braking. Here the reaction time between emergency braking with and without the warning system is analysed.

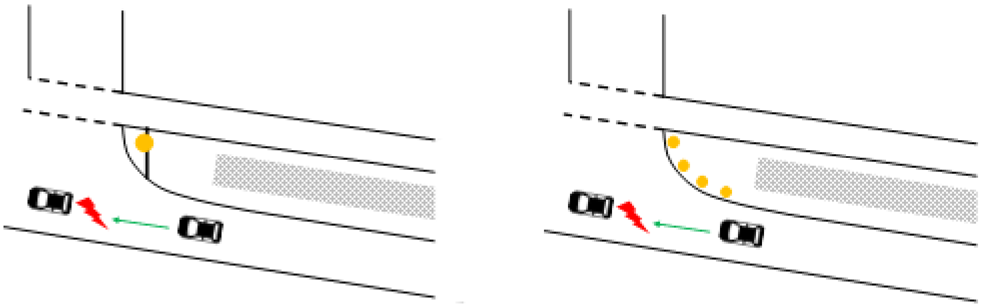

Figure 2: Seconds driving simulator study involving a braking next to a standart and the new warning system

Driving Simulator Results

The two studies which were done are to be seen as entry studies, in which we tested two study designs in order to find out how to best implement a realistic scenario. Therefore, the findings of the studies are certainly first results, but also provide insight into the complexity of the scenario construction as well as improvements to be implemented in the next study.

The first study shows that the pattern in which the LED lights are illuminated does not have a significant effect. The lights blinking at 1.5 Hz or 3 Hz and the two different patterns used all produced the same effect. An effect could be shown with regards to the drivers who were not aware of the crossing cyclist which decreased from 25% to 16% when comparing the baseline to the active warning system.

While the study did not show a decreased gaze reaction time for the usage of the system, we attribute this to the chosen scenario - while driving an automatic car with a secondary acoustic task, the subjects had a lot of freedom to check their surroundings. Additionally, the cyclist was already visible before arriving at the intersection and multiple drivers were therefore aware of him beforehand. The study also showed that most subjects did not remember the warning system, suggesting that it does not work on a higher cognitive level but simply deflects the attention to the right spot.

The results from the second study, while not complete at the creation date of this document, show that the new warning system produces almost exactly the same reaction times as a simple blinking warning light as it is defined in the German road traffic regulations, therefore not posing an issue in this regard.

Demonstrator Implementation

In the next months, a first prototype of the system will be installed at a critical intersection in Aachen, Germany. Since the system is to be minimally invasive, it is built up of self-righting posts made of extremely robust polyurethane. Since the posts are very elastic, they pose no safety hazard and can be installed and removed very easily.

The illumination is built up of led stripes attached to the poles with a very high density in order to produce enough light to be seen even in sunlight. The LEDs are activated over an Arduino board, which allows us to choose any pattern and to activate each pole separately. The poles run on small batteries and are remotely controllable over radio frequencies which enables a very individualistic and specific setting for every intersection.

The detection system is composed of a single thermographic camera attached to a small GPU-based edge device. Both are mounted on a lantern post and are remotely accessible. The system can either be connected to the main grid of the lantern or run on a battery pack when the safety measurement is only temporary.

The detection and classification uses specially trained detection networks which work on thermographic images and which therefore are able to detect in every weather condition and every light setting. Using a 3D model of the street, a mapping of image coordinates to world coordinates and therefore to real world velocities is realised.

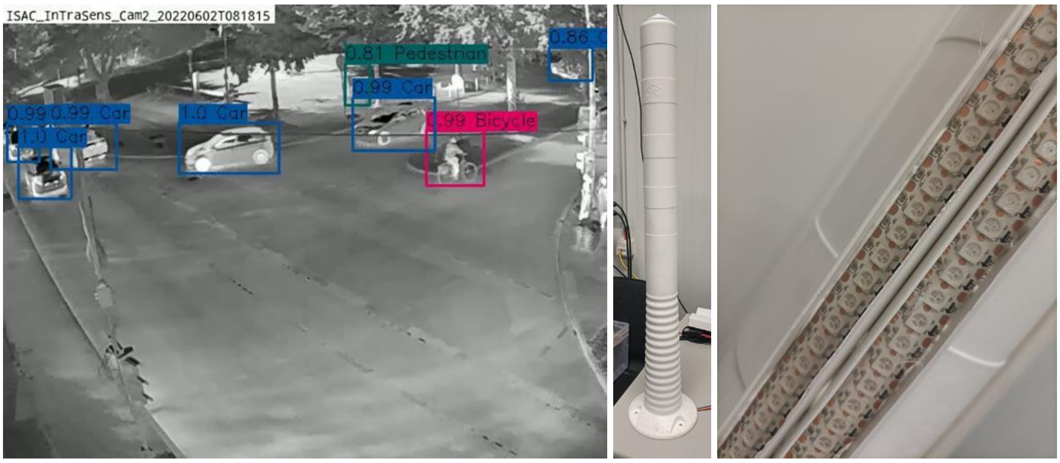

Figure 3: Example for the detection in thermal images and the prototypical LED-poles

In the first version of the system, the possibility for a critical interaction is simply defined by the presence of a cyclist and a motorist in close proximity and on a collision course. For this, two detection lines are defined and calibrated according to the infrastructure and the situation at hand. The next step in the implementation is the usage of the real velocity, acceleration and distances in order to compute a probability for a critical event and to activate the system accordingly.

The search for the best installation place is currently ongoing, although two promising sites are under consideration. In order to do a first screening for dangerous spots, data from a crowd sourcing portal quite popular in Aachen (gefahrenstellen.de) and crash data from the last 3 years is being used. To actually evaluate how many critical events happen at an intersection, the previously described system without the led poles can be temporarily installed. It is already apparent that due to the statistically varied number of critical situations depending on the intersection evaluated, a longer time of recorded traffic will be needed.

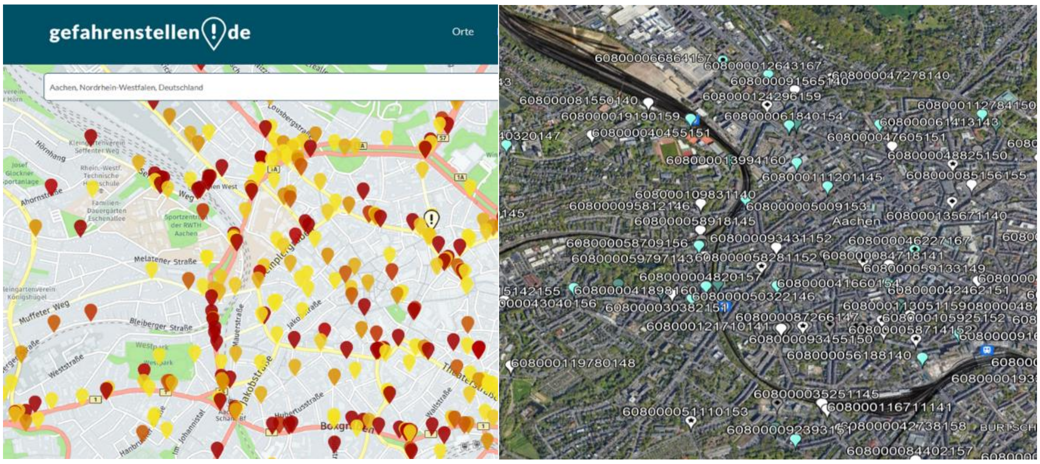

Figure 4: The two data sources for the initial search for critical intersections, left crowd sourced and right based on official crash reports

Future Works

The development of the system is still a work in progress. The detection system is still under improvement, as is the hardware of the led poles. New problems will certainly arise when initially installing the components at a real intersection. The psychological investigations are still at an early stage and there are many scenarios yet to be investigated. This also holds true for the evaluation of driver behaviour when the system is firstly in action - paired with interviews with cyclists and motorists.

With regards to the intelligence of the system, a real algorithm estimating the probability of a future interaction between the two participants is needed in order to increase the acceptance of the system

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