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Wireless Protection of Vulnerable Road Users

Seminar Thesis in Master's Computer Science

10. Januar 2018

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Wireless Protection of Vulnerable Road Users

Seminar Thesis in Master's Computer Science

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Submission date:	**10. Januar 2018**

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(Philip Frerk)
Paderborn, 10. Januar 2018

Abstract

Protecting Vulnerable Road Users (VRUs) is a very important task as in roughly 50 % of all traffic accidents VRUs are involved. VRUs are pedestrians or drivers of two-wheeled vehicles. A technology is needed that warns both the VRU and the car driver if an accident between them is likely to happen. This is a challenging task, because the warnings have to be sent in time and also it has to ensured that no people are warned who are not really affected by the approaching car. To achieve that goal, Wireless Networking, GPS and Sensor Perception will be used. Results show that the number of accidents with VRUs involved can be reduced dramatically. As the initial results are promising, research in this area is being expanded, especially as there are many further challenges, for example situations with many VRUs and so on.

Kurzfassung

Contents

Chapter 1

Introduction

umstrukturieren, vielleicht doch keine sektionen!

1.1 Motivation

Within the last century the usage of motorized vehicles has grown rapidly. While this fact brings the great benefit of full mobility, it does not come without its downsides. One of them is the high number of traffic accidents. According to [1] in roughly half of all traffic accidents, Vulnerable Road Users (VRUs) are involved. Hence, there is huge potential to prevent injuries or even deaths of many people. This thesis will give you an overview of the current state of research in this area. While there are many approaches beyond the discipline of Wireless Networking (e.g. Computer Vision for pedestrian recognition), this thesis will focus mainly on how to prevent traffic accidents by using Wireless Networking Technology. However, the other areas will also be explained briefly since they often work hand in hand with Wireless Networking.

1.2 Structure of the Thesis

The thesis is structured as follows. First, in chapter 2 we will look at so called Vehicle to Pedestrian Communication Systems (V2PCSs) which use wireless networks in order for pedestrian and vehicles to communicate so that accidents between them can be prevented.

Second, in chapter **??** we will look at detecting VRUs by using perception of cars. We will only shortly dive into this topic, because it is not directly connected to Wireless Networking. Nevertheless, it is necessary to know the basics in order to understand chapter 2.4.

There, a combination of V2PCSs and perception will be used to improve the protection of VRUs.

Finally, in chapter 3 all the approaches will be summarized and also we will see what future tasks are still left in this area to make it usable in the real world.

Chapter 2

Protecting Vulnerable Road Users

The basic idea behind V2PCSs is that a driving vehicle (most often a car) and a VRU (most often a pedestrian) exchange messages over a wireless network in order tell each other their positions. By doing that, accidents between them can be prevented because both the car driver and the pedestrian can react to the received messages.

There are several approaches to implements such a system and they will be discovered in this chapter.

2.1 With special Device

First, we will look at such communication systems which use a special device for the VRU in order to send his messages. In [2] and [3] such systems have been proposed.

The device from [2] can be seen in the bottom of figure 2.1. In the top of figure 2.1 you can see the warning unit that will be installed in the car.

Figure 2.1 – The Warning Unit for Cars and the Warning Device for Pedestrians from [2]

The task of the device for the pedestrian is to periodically send "Hello"-Messages including the pedestrian's position so that the warning unit in the car can receive those messages and detect a probably dangerous situation. Then the warning unit sets itself into a warning status (which can be seen in figure 2.1).

It is very important that the car driver does not get too many warning messages because otherwise he would loose sensibility for the warning. Therefore, a key issue is to ensure that only warning are created if the distance between car and pedestrian decreases gradually.

Figure 2.2 shows the ratio of meaningful warnings divided by the number of all warning which is roughly 50% because in this test scenario only one pedestrian is present. That ratio is not satisfying, but is only because of the low number of pedestrians.

In figure 2.3 you see the same statistics, but for a scenario with 10 pedestrians. Here the same ratio is almost 100%.

hier fehlt noch warum die ratios so sind

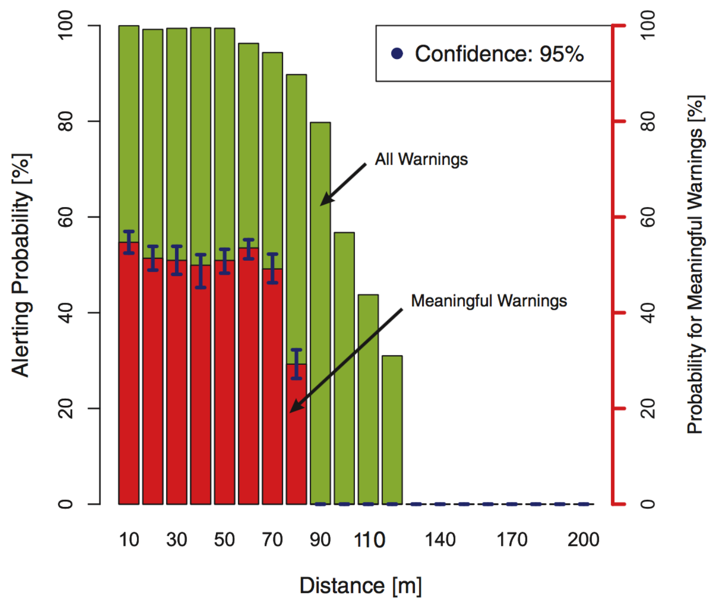


Figure 2.2 – Warning statistics in a test scenario with one pedestrian from [2]

grafiken noch genauer erklären, vor allem mit der distanz

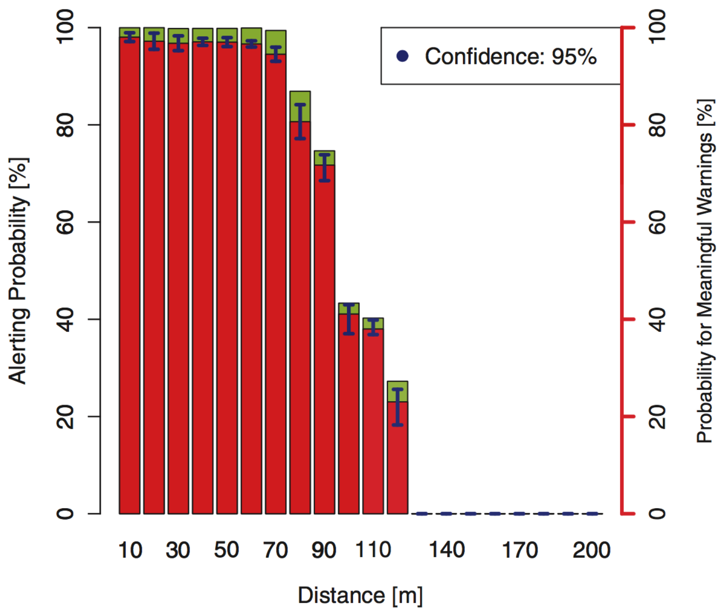


Figure 2.3 – Warning statistics in a test scenario with 10 pedestrians from [2]

2.2 Using Smart Phones

In [1], another approach has been developed which is based on the same idea as [2], but it is more detailed. Moreover, it has the great benefit that no additional device for the VRU is needed because in this system a smart phone or tablet will be used as the warning device for the pedestrians.

The approach is more detailed, because it formulates precise requirements that an implementation of a V2PCS should have in order to be able to work in reality. The requirements basically boil down to the following: One has to calculate the distance at which the warning messages are to be delivered. In section 2.1 we have already seen that this distance should not be too big, because otherwise too many meaningless warning would be received. But accordingly, the distance must not be too small, because the pedestrian and the car driver must have enough time to react to the messages.

To calculate this distance, the authors of [1] have taken into consideration many parameters, e.g. the velocity of the car, the reaction time of the pedestrian, the expected positioning error of GPS (which is approximately 10m), the expected packet transmission time of Wi-Fi and so on. As an example, we take a look at equation 2.1 where the lower bound d_{min} of the distance is written down.

$$d_{min} = v \times (t_p + t_r + t_{tx}) + gnss_{err_{car}} + gnss_{err_{ped}} \tag{2.1}$$

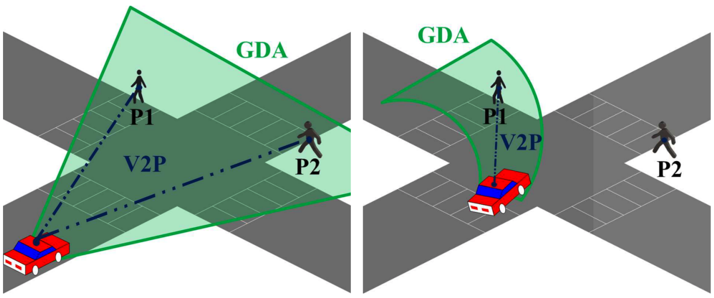
Here v is the car's velocity. Moreover, t_p is the time for perception of the pedestrian, t_r is the reaction time of the pedestrian, and t_{tx} is the packet transmission delay. $gnss_{err_{car}}$ and $gnss_{err_{ped}}$ are the positioning errors of the car and the pedestrian, respectively.

For simplification, we will not look in every detail of this calculation as it is very detailed. But in principle it is crucial to computer a lower and upper bound for the distance at which the warning messages should be sent. Because you can then check whether your system always fulfills these bounds which the system from [1] does.

Finally, the distance calculated is 39.5, 52.3, and 72.0 m, when the velocity of the car is 30, 50, 80 km/h, respectively. [1]

Another important concept in this context of when to send warning messages is the so called Geographical Destination Area (GDA). You can understand the concept by considering figure 2.4. In (a) a car is approaching to pedestrians, P1 and P2. As the car is yet far away from P1 and P2 it is possible that both P1 and P2 could be involved in an accidents with the car, therefore both of them are in the GDA.

In (b) the car has already come nearer to P1 and P2 and is currently turning left. Due to that fact, it is no longer possible for the car to approach the position of P2. So, P2 is no longer in the GDA of the car and P2 will not receive a warning message because of the car, only P2 will get one.



(a) Vehicle is moving straight. (b) Vehicle is turning.

Figure 2.4 – The Geographical Destination Area of a moving car at two different points in time, from [1]

The GDA of a car will be computed periodically and this makes sure that even less meaningless warning messages will be sent. The GDA can be computed by taking several parameters of the car (e.g. the yaw rate) into account.

jetzt erwähnen dass wlan auch lange dauert und so auf nächste sektion hinleiten

2.3 Faster WiFi Message Exchange by using Beacon Stuffing

The principle from chapter 2.2 has one disadvantage that has not yet been emphasized. Typically, when two devices want to communicate with each other over WiFi, they have to establish a WiFi connection first. This process takes time

WIE VIEL ZEIT??

. But there is an approach from the authors of [4] to avoid that connection establishing phase by using WiFi Beacon Stuffing. Beacons are usually used in order to propagate the existence of a WiFi network. They are broadcasted periodically by the WiFi access point and contain information about the network (e.g. the SSID).

In [4] the SSID field is replaced by a so called WiFi Honk Information Packet, which includes information about the moving car, namely the latitude, longitude, speed, and direction. VRUs or other cars then receive this information and compute the likelihood of an accident.

Figure 2.5 shows the results of [4] compared to WiFi without Beacon Stuffing. Sub figure (a) shows that pedestrians have a little more time to react, but obviously if the velocity of the car comes close to 100 mph there is almost no time to react. Sub figure (b) shows the probability of collision on which Beacon Stuffing has a decisive impact. Whereas the plot normal WiFi has an exponential growth, the growth of the plot for WiFi Honk (Beacon Stuffing) is only linear. Therefore, warning messages can be sent more aggressively.

WARUM???

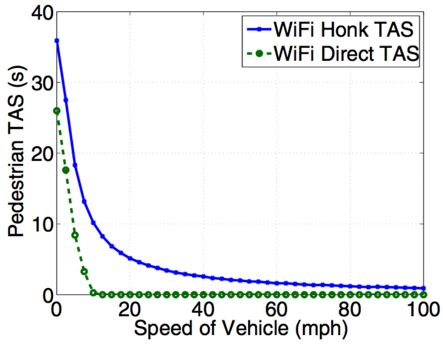
The Beacon Stuffing approach is a useful technique which can be added to V2PCSs to enhance the packet transmission time.

2.4 Fusion of Perception and V2P Communication

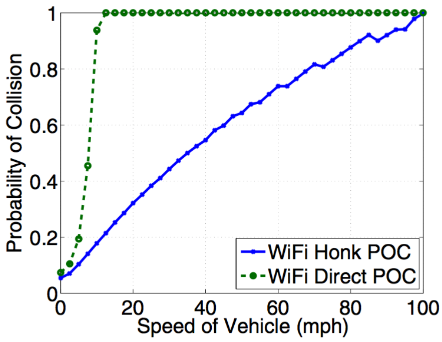
Apart from the discipline of Wireless Networking there is another approach for detecting VRUs. Nowadays, cars are equipped with laser sensors which are intended to detect VRUs. In [5] the authors explain how this method works.

pass nicht, unterscheiden zwischen sensoren und kameras!!!

You can think of the sensors as cameras which point to the area in front of the car. When the picture is taken, Machine Learning is used to detect pedestrians in it. This is not trivial, because pedestrians have significant differences regarding their appearance, because they have different height. Furthermore, they can carry several objects and the weather condition can also change the picture. But the biggest



(a) VRU time available to stop



(b) Probability of collision

Figure 2.5 – Evaluation of Beacon Stuffing, from [4].
POC stands for "Probability of Collision", TAS stands for "Time available to stop".

problem of sensors is that pedestrians are often occluded by obstacles. When they are partially hidden the Machine Learning Algorithms have problems to classify them as pedestrians and when they are hidden completely it is impossible for sensors to recognize them.

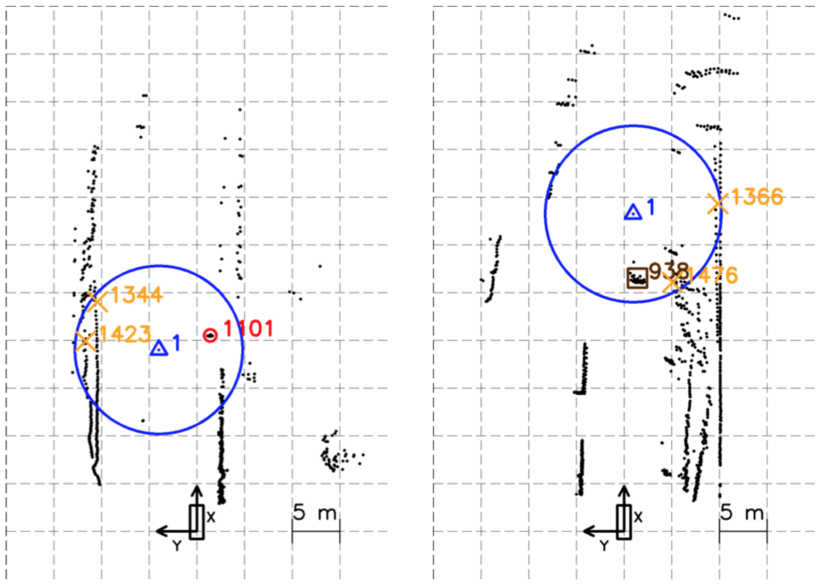
One can indicate that it is not satisfying to only use sensor perception for protecting VRUs. But sensor perception has also some advantages in comparison to V2PCSs. More precisely, the features of sensor perception and V2PCSs are complementary.

That is demonstrated by figure 2.6 where in sub figure 2.6 (a) the perception systems determines the position of the pedestrian more precisely. The blue triangle is the position transmitted by WiFi Communication (by using GPS), and the red circle is the position calculated by the Perception System. The Perception System works better here, because this is a Line-of-sight (LOS) situation which means that the pedestrian is not occluded by any obstacle. The Perception System is capable of determining positions very precisely whereas GPS can always have a small positioning error, as mentioned earlier.

In sub figure 2.6 (b) the condition is different, there we are confronted with a Non-line-of-sight (NLOS) situation. So, the pedestrian is not detected by the Perception System, because lasers or cameras obviously cannot look through obstacles. But the V2PCS still detects the pedestrian (blue triangle).

After seeing the advantages and disadvantages of both Perception Systems and V2PCSs the big task is now the fusion of data generated by the two systems. Since this process is quite complicated only the core idea will be explained here.

The objective of the fusion is to determine whether a communicating VRU is visible or hidden by some obstacle. In order to understand that, we take a look at sub figure 2.6 (a) again. The big blue cycle represents the area in which the pedestrian can be located, considering the GPS positioning error from the transmitted position



(a) LOS conditions. (b) NLOS conditions.

✚ Laser impact ○ Perception based VRU detection
□ Occluding obstacle × Other obstacle with perception
△ Communication based VRU detection

Figure 2.6 – Two different scenarios for VRU detection, from [6]
In (a) perception works better and in (b) WiFi communication works better.

of the pedestrian via the V2PCS. In (a) the pedestrian is visible, so the system could associate him with some of the objects in the blue area. But obviously, it should associate him with the correct object (the pedestrian himself). This can be done by receiving many tracks of the V2PCS, which will all be a little different due to the GPS positioning error. By looking at the set of those different locations, you can see that they will settle around a particular object detected by the Perception System and so the combined system can select the correct object and take the location computed by the Perception System as it is more precise.

In contrast, in sub figure 2.6 (b) the pedestrian is not visible. So, the Perception System will only detect other objects in the blue area. Again, by looking at the several tracks from the V2PCS, you realize that they will not settle around any of the objects detected by the Perception System. Therefore, you can conclude that the Perception System has not detected the pedestrian and rely solely on the data of the V2PCS (GPS position).

The results from [6] show that the combined system benefits from the advantages from both the V2PCS and the Perception System. In LOS conditions, the system can locate the pedestrian more precisely because of the very precise data from the Perception System. As the distance between the car and the pedestrian increases, the Perception becomes useless, and only the data from the V2PCS can be used. The same holds for NLOS conditions. Moreover, the combined has yet not been tested for situations with many communicating cars and pedestrians which will strain the system more. Nevertheless, the fusion approach is a very useful and promising technique for VRU protection.

2.5 Wireless Protection of Motorbikes

We will now look into a different topic, which is protecting drivers of motorbikes by using Wireless Networking. Yet we have focused mainly on pedestrians as VRUs, but motorbike drivers are VRUs as well, and due to the high popularity of motorbikes this area is also very important.

There are already approaches for a so called Intelligent Transportation System (ITS), which means that vehicles (in that case cars) communicate to each other over WiFi, to tell their position speed etc. in order to prevent accidents between them.

hier evtl referenz

But there are not many approaches for such systems considering motorbikes as special vehicles. In [7] such an idea is being developed.

One of the special requirements for motorbikes is that the communication system has to consume less energy than in cars. Therefore, the hardware from [7] is battery-powered. Also the human interface on a motorbike cannot be as rich as in car. Therefore, LEDs and a buzzer can be used.

The system works as follows. It receives the several messages from other vehicles including information like speed, direction etc. It then maintains a database of vehicles nearby and computes which other cars can possibly be involved in an accidents with the own motorbike by taking into account the own speed, direction etc. (analogously to a V2PCS as we have seen before). Of course the systems also broadcasts its data to other vehicles over WiFi in order to inform them.

Chapter 3

Conclusion

- summarize again what your paper did, but now emphasize more the results, and comparisons
- write conclusions that can be drawn from the results found and the discussion presented in the paper
- future work (be very brief, explain what, but not much how, do not speculate about results or impact)
- recommended length: one page.

List of Figures

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Todo list