Estimating Driver Unawareness of Pedestrian based on Visual Behaviors and Driving Behaviors

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1 STAGE OF THE RESEARCH

Every year, more than 1.24 million people die in traffic accidents around the world, half of which are among pedestrians and cyclists, and 22 percent of which are children (WHO, 2013). Thus, preventing pedestrians from motor accidents is an important problem in achieving a safe and secure society. A lot of research in the advanced driver assistance is able to detect the pedestrian with the in-vehicle sensors and inform the driver of their presence. However, most of these alert systems do not adapt to the driver, they become distracting, annoying the driver and will be often ignored or deactivated. Therefore, taking into account the driver's state and understanding fully the situation are the challenges for these systems.

This study is the first step of a project named MINARDA (Mobile and Interactive Augmented Reality for Driving Assistance). This system is strongly connected to the user. It aims to use a suitable visualization metaphor in augmented reality that allows the driver to avoid dangerous situations. Particularly, we focus on the situation in which the pedestrian is in danger.

This paper will be structured as follows. In sections 2 and 3, we underline our objectives of research and define the problem. In section 4, we review some related works. In Section 5, we describe the proposed methodology to treat this problem. Section 6 describes our expected outcome, conclusion and perspectives.

2 OUTLINE OF OBJECTIVES

As mentioned above, the MINARDA system needs to fully understand the situation to be able to provide the appropriate cues to the user. In the context of pedestrian safety, our first objective is to find out what the features that characterize the driver's awareness or unawareness of pedestrian are. Once we can identify these features, our second objective is to build a model of the awareness and unawareness a driver has of pedestrians appearing on the road ahead. At last, we will envisage estimating the different levels of danger to pedestrian. The more precisely the danger levels are classified, the more suitably the assistance cues can adapt to the driver.

3 RESEARCH PROBLEM

In a previous work, Engel and Curio (2011, 2012), Wakayama, (2012) proposed to estimate how easy it is for the driver to see and notice pedestrians. The studies included the estimate of driver's visual attention and pedestrian detectability in an image. In this study, we aim to provide a new and more direct approach. It can be assumed that the driver's awareness or unawareness of pedestrian could be estimated by observing his visual behaviors and driving behaviors. More precisely, our hypothesis is whenever the driver is aware of a pedestrian ahead, he has to direct his gaze to pedestrian and does some reactions on vehicle, (brake, deceleration, wheel angle change, etc.) what is not in the case of unawareness.

This preliminary suggestion leads to two related questions:

1. Is there any difference in visual behaviors and driving behaviors between two states driver's awareness of and unawareness of something on road (pedestrian in this case)?

2. Is it possible to extract and use those patterns to help identify or learn information about the danger to pedestrian?

In order to answer these questions, we have to envisage different experiments and consider different methods to measure visual behaviors and driving behaviors. Because of their reliability and flexibility, in this work, we use a vision-based method to observe the visual behaviors and various in-vehicle sensors to measure the driving behaviors.

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4 STATE OF THE ART

In the state of the art includes the related research that helps to understand the danger to pedestrian, particularly those are related to the driver. Thus, we talk about the problem of pedestrian detectability, we review in detail the studies of driver inattention detection, and the studies which are directly related to the driver's awareness of the pedestrian. We will then identify the strength and weakness of each method that should be considered in our works.

4.1 Pedestrian Detectability

The studies on the detectability of the pedestrian aim to estimate how easy it is for the driver to see and notice pedestrians. In the work of Engel and Curio (2011), the authors did the experiments to measure the time to recognizing the pedestrian on image. Then, they determined the features of pedestrians that correlated with this time. Thus, the detectability of pedestrian was modeled. The features of pedestrian on image could be for example, the position of pedestrian, size, color, light, etc. This study was also extended to the dynamic scene concept. Actually, instead of analyzing the pedestrian's detectability on images, it is possible to do the experiments on the sequence video (Engel and Curio, 2012). Another extension was proposed by Wakayama (2012) who considered the motion of pedestrian to be one of the features that characterize the pedestrian detectability. However, as before, because the fact that the pedestrians can be seen easily does not mean that the driver is cognitively aware of them (Fukagawa, Yamada, 2013).

4.2 Driver Inattention Detection

The lack of attention by drivers is the biggest single cause of serious road accidents. A great amount of work have been done on the inattention state of the driver. However, the inattention of the driver was defined in different ways. In this part (4.2), the inattention means the abnormal states of the driver such as fatigue, drowsiness or distraction, etc. Otherwise, in the rest of our research, driver's unawareness of pedestrian is considered to be a kind of inattention based on this definition: "Driver Inattention means insufficient or no attention to activities critical for safe driving" (Regan et al, 2011). According to this, unawareness of the pedestrian means insufficient or no attention to this pedestrian for safe driving.

The driver's behaviors and his inattention state are analyzed and detected under different techniques, the majority of which are as follows.

4.2.1 Physiological Measures Observation

The physiological signals such as heart rate, respiration or EEG and are considered to be the most reliable signals to analyze the driver behaviors and to detect inattentiveness.

Heart rate is easily determined through Electrocardiogram (ECG) signal. The mental stress while driving for example, increases blood pressure, heart rate and activate the sympathetic nervous system. (Moriguchi et al., 1992). There are significance impacts in the heart rate when a driver is in a state of cognitive inattention (thinking while driving for example) (Akin et al, 2008).

Moreover, the EEG (Electroencephalogram) signal has various frequency bands which can signify different states of the driver. For example, there is evidence that the increase of the alpha band (8-13Hz) corresponds to relaxation. Increase of the delta band (0.5-4Hz) and the theta band (4-8Hz) correspond to sleep activity and drowsiness which signify a potential failure of attention and behaviors. (Östlund, 2004), (Santana, 2002). In another experiment, twelve types of energy parameters computed from three bands alpha, beta, and delta were chosen as the evaluation index of driver fatigue (Li, 2012)

However, these techniques are obtrusive, since it is necessary to attach some electrodes on the drivers, causing annoyance to them. Consequently, it is difficult to be implemented in the real-life applications.

4.2.2 Visual Behaviors Observation

Driver behaviors could be somehow observed from the changes in their facial features like eyes, head and face. In this context, several methods have been proposed. This measurement has the advantage of being unobtrusive, since they could be collected with remote eye-head trackers. Moreover, they are quite reliable.

Measurements related to head movement such as nodding frequency and those related to the eye region such as eyelid distance changes, eye close duration, blinking frequency, and the recently developed parameter PERCLOS (percentage of time in a minute that the eye is 80% closed) (Lin,2012) were widely used in research. After extracting these features, Bergasa (2008) and Mohamad-Hoseyn Sigari (2013) built a fuzzy model or finite state machine to estimate the inattentive, distracted or fatigue state of driver.

Another cue is the size of the pupils. The pupils is the part of the iris that allows light to enter the retina. Besides light, the pupil dilates when mental or cognitive effort is given. It was observed that the pupil was dilated and the diameter of average pupil size increased by 15% when the driver was cognitively distracted (Akin et al, 2008), (Benedetto, 2011).

Gaze behaviors are another cues that can be used as a metric to find if the concentration of the driver was on driving or not. It was noticed that, when the driver was cognitively distracted, glancing at instruments and mirrors decreased significantly (Harbluk, 2007). A simple method to detect the driver's attention was proposed by Fletcher and Zelinsky (2009.). They used driver's gaze vector and road scene event correlation to estimate if the driver has seen the event or not. Due to the "looking but not seeing" problem, this work was not able to reliably determine if a certain road event (pedestrian for example) is perceived by the driver. However it could identify if the driver has not perceived a road event.

Deeper in this context, Doshi and Trivedi (2009) provided a result on the observation of the dynamic of overt visual attentions shifts. They found that there are various interactions between head and eye movements that are useful in detecting the driver distractions, as well as the driver intent. Indeed, their results validated the differences existing between goal-oriented and stimulus-oriented gaze shift. Moreover, this feature could be observed in dynamics of eye and head movements. They also investigated the problem of detecting the intent of the driver in changing lane which was considered to be a goal-oriented attention shift. (Doshi and Trivedi, 2012). This result showed that the driver attentiveness or awareness of something should be observed through the dynamic of many parameters.

4.2.3 Driving Behaviors Observation

Another method on the driver's inattention research is to detect it indirectly through driving behaviors such as vehicle speed, steering wheel movement, lateral position, and break or acceleration pedal states. (Imamura et al, 2008), (Ueno et al, 1994).

The projects conducted by HASTE (Human Machine and the Safety of Traffic in Europe) demonstrated that the steering measures were significantly affected by the visual task, when a subject had to perform the visual task, the steering effort was higher than in the baseline condition. (Östlund et al., 2004).

The IVDRs (In-vehicle Data Recorder) offer valuable information on a driver's behavior through the analysis of automobile-operating information. Jensen and Wagner (2011) also proposed a combination of three analysis methods to evaluate the driver performance: data threshold violations, phase plane analysis with limits and a recurrence plot with outlier limits. These methods were based on the measures of vehicle speed, engine speed, vehicle latitude and longitude coordinates, and lateral accelerations.

Although these techniques are not obtrusive, they are subject to several limitations such as vehicle type, driver experience, geometric characteristics, state of road, etc. (Bergasa, 2008).

4.3 Driver Unawareness of Pedestrian

To the best of our knowledge, there are no studies that are directly related to the estimation of the driver unawareness of pedestrian or other traffic events. The most closely related works are those of (Fukagawa, Yamada, 2013) who proposed a hypothesis that is likely linked to our work. Their study was based on the driver's operational data such as pressure on the accelerator pedal, pressure on the brake pedal (called acceleration reaction), steering angle and vehicle behavior data such as vehicle speed to estimate the driver's awareness of pedestrian.

Their hypothesis was that whenever a pedestrian appears on the road, if the driver noticed it, he had to do the acceleration reaction somehow. They used the driving behavior data collected by Research Institute of Human Engineering for Quality of Life (Akamatsu et al., 2003). From that, they proposed to calculate the probability of acceleration reaction being observed at a distance given that response to driver's aware of the pedestrian. This probability was assumed to be a log-normal distribution. They also proposed to calculate the probability of acceleration reaction being observed at a distance given that not in response to driver's aware of the pedestrian and this probability was considered to be a uniform distribution. Hence, using Bayes theorem, they calculated the probability that one acceleration reaction was caused in response to driver's awareness of pedestrian.

However, there is a couple of weaknesses in this study. Firstly, in the data collected in real and actual road condition, it was supposed that whenever a pedestrian appeared on road, the driver had to notice them, this is hard to verify. Secondly, the driver could totally accelerate if he had been aware of the pedestrians and identify that they were not in danger. On the other hand, this probability model is not reliable because of the use of a specific distribution law. Finally, this study can't determine if the driver has not noticed the pedestrian or has been unaware of them.

Figure 1: MINARDA system and CARMEN car- Ready for simulation driving as well as naturalistic driving data collection.

5 METHODOLOGY

In this work, we have defined the driver's unawareness and awareness of pedestrian. We use the camera-based system to observe his visual behavior and the in-vehicle sensors to measure the driving behaviors. Moreover, in the experiment, we have discussed two most important issues as follow. Hence, the methodology of research is determined

5.1 Driving Simulation Vs. Naturalistic Driving Data Collection

In our work, both driving simulations and real conditions driving are expected out. Firstly, a driving simulation is used to collect all information from different sensors. From that, the feature vectors representing the driver's awareness and unawareness of pedestrian will be extracted. The simulation environment is useful because we can control the situation and can propose different scenario that fit well to our research problem. For example, we can propose two scenarios. First, a scenario where the driver is asked to recognize the gender of a pedestrian while driving. On the other hand, a scenario of driver's unawareness in which the driver is demanded to do a second visual task while driving.

Naturalistic driving data help to verify the hypothesis in real conditions. Many experiments have been conducted in simulated environment and the results have been discussed. However, in real driving conditions the result might be drastically lower as a moving vehicle presents new challenges like variable lighting, changing background and vibration, etc. (Arun et al, 2012). The data collected in real conditions will be extracted and annotated whenever a pedestrian appears on road. Then, we will compare the driver visual reaction and acceleration reaction with the ones that have been extracted in simulation driving.

We use the help of MINARDA system embedded on CARMEN platform to collect the information.

5.2 Hybrid Measures

Each previously mentioned method get their own advantages and limitations. Nevertheless, in the advanced driving assistance systems, the environment, the vehicle and the driver have to be considered to be an overall driving system (Trivedi et al. 2007). Proposed study is to consolidate various measures which could lead to a good detection system. Indeed, beside the pedestrian detection system that provides all properties of pedestrian on road (position, distance, time to collision, etc.), we propose to use the visual behaviors, specially the looking vector which is provided by SMI Glass and head motion which is provided by the Facelab System. In the other hand, the driving behaviors such as the driver acceleration reaction are measured by the IVDR. These cues will be collected in high frequency to analyze the driver's awareness or unawareness of pedestrian.

Our hypothesis is that, this kind of driver inattention should be observed through the change of the looking reaction with respect to a pedestrian or the change in his driving acceleration. Or it may be characterized by the interaction of these both reactions, for example, by a reaction of looking first and followed by an acceleration reaction. This hypothesis may be complete the study of Yuuki Fukugawa (2013) since we are able to observe the case when the driver is aware of pedestrian and does no reaction acceleration and the case when the driver does the acceleration reaction but he is unawareness of a pedestrian.

6 EXPECTED OUTCOME

At the end of this study, the reliable patterns that characterize the driver's states of unawareness and awareness of pedestrian are expected to be extracted out. Then, we intend to develop a new learning algorithm based on these patterns in order to model this driver's behavior and the danger level to pedestrian. The whole algorithm will be implemented on the MINARDA system.

In this paper, we talked about the danger to pedestrian. We provided a review on the methods that help to analyze the driver behaviors and to detect his inattention state. We propose a novel approach directly related to pedestrian safety, the driver's awareness and unawareness of pedestrian. This study could be extended to other type of road events such as traffic light or other vehicles detection and help us to understand better the driving context.

REFERENCES

Akamatsu, M.; Sakaguchi, Y. and Okuwa, M. 2003. "Modeling of Driving Behavior When Approaching an Intersection Based on Measured Behavioral Data on An Actual Road". *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 47*, 1895-1899.

Akin, M.; Kurt, M.; Sezgin, N. and Bayram, M. 2008."Estimating vigilance level by using EEG and EMG signals". *Neural Computing and Applications, Springer-Verlag, 17*, 227-236.

Arun, S.; Sundaraj, K. & Murugappan, M.2012 "Driver inattention detection methods: A review" *Sustainable Utilization and Development in Engineering and Technology (STUDENT), 2012 IEEE Conference on*, 1-6

Benedetto, S.; Pedrotti, M.; Minin, L.; Baccino, T.; Re, A. and Montanari, R. 2011. "Driver workload and eye blink duration".*Transportation Research Part F: Traffic Psychology and Behaviour , 14*, 199 – 208.

Bergasa, L.; Nuevo, M.; Barea, R. and Lopez, E. Prokhorov, D. *(Ed.)*. 2008. "Visual Monitoring of Driver Inattention". *Computational Intelligence in Automotive Applications, Springer Berlin Heidelberg, 132*, 19-37.

Doshi, A. and Trivedi, M. 2009."Head and gaze dynamics in visual attention and context learning" *Computer Vision and Pattern Recognition Workshops, 2009. CVPR Workshops 2009. IEEE Computer Society Conference on,* 77-84.

Doshi, A. and Trivedi, M. 2012. "Head and eye gaze dynamics during visual attention shifts in complex environments" *Journal of Vision, 12*

Engel, D. and Curio, C. 2011. "Predicting human perception performance with machine vision". *Intelligent Vehicles Symposium (IV), 2011 IEEE,* 429-435.

Engel, D. and Curio, C. 2012. "Detectability prediction in dynamic scenes for enhanced environment perception" *Intelligent Vehicles Symposium (IV), 2012 IEEE,* 178-183.

Fletcher, L. and Zelinsky, A. 2009. "Driver Inattention Detection based on Eye Gaze-Road Event Correlation". *Int. J. Rob. Res., Sage Publications, Inc., 28*, 774-801.

Fukagawa, Y. and Yamada, K. 2013. "Estimating Driver Awareness of Pedestrians from Driving Behavior based on a Probabilistic Model". *Intelligent Vehicles Symposium (IV)*.

Harbluk, J. L.; Noy, Y. I.; Trbovich, P. L. and Eizenman, M. 2007. "An on-road assessment of cognitive distraction: Impacts on driver's visual behavior and braking performance". *Accident Analysis & Prevention, 39*, 372 – 379.

Imamura, T.; Yamashita, H.; bin Othman, R.; Zhang, Z. and Miyake, T. 2008. "Driving behavior classification river sensing based on vehicle steering wheel operations".
SICE Annual Conference, 2008, 2714-2718.

Jensen, M. and Wagner, J. 2011. "Analysis of In-Vehicle Driver Behaviour Data for Improved Safety". *International Journal of Vehicle Safety*. 197-212.

Li, W.; chang He, Q.; min Fan, X. and min Fei, Z.2012. "Evaluation of driver fatigue on two channels of EEG data". *Neuroscience Letters, 506*, 235 – 239.

Lin, S. T.; Tan, Y. Y.; Chua, P. Y.; Tey, L. K. & Ang, C. H. 2012 "PERCLOS Threshold for Drowsiness Detection during Real Driving" *Journal of Vision, 12*, 546.

Mohamad-Hoseyn Sigari, Mahmood Fathy and Soryani, M. 2013. **"**A Driver Face Monitoring System for Fatigue and Distraction Detection". *International Journal of Vehicular Technology,* 11.

Östlund, J; and al. 2004. "Delivrable 2- HMI and safety related driver performance". *Human Machine Interface and the Safety of Traffic in Europe (HASTE) project.*

Regan, M. A.; Hallett, C. and Gordon, C. P. 2011. "Driver distraction and driver inattention: Definition, relationship and taxonomy". *Accident Analysis & Prevention, 43*, 1771 -1781.

Santana Diaz, A.; Jammes, B.; Esteve, D. and Gonzalez Mendoza, M. 2002. "Driver hypovigilance diagnosis using wavelets and statistical analysis". 2002. *Intelligent Transportation Systems. Proceedings. The IEEE 5th International Conference on,* 162-167

Trivedi, M. M.; G, T. and Mccall, J. 2007. "Looking-in and looking-out of a vehicle: Computer-vision-based enhanced vehicle safety". *IEEE Trans. Intell. Transp. Syst, 8*, 108-120.

Ueno, H.; Kaneda, M. and Tsukino, M. 1994. "Development of drowsiness detection system". *Vehicle Navigation and Information Systems Conference, 1994. Proceedings. 1994*, 15-20.

Wakayama, M.; Deguchi, D.; Doman, K.; Ide, I.; Murase, H. and Tamatsu, Y.2012. "Estimation of the human performance for pedestrian detectability based on visual search and motion features".*Pattern Recognition (ICPR), 2012 21st International Conference on*, 1940-1943.

WHO, World Health Organization, 2013. "*Global Status Report on Road Safety Supporting a decade of action*".