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CORRELATING EYE GAZE DIRECTION, DEPTH AND VEHICLE INFORMATION ON AN INTERACTIVE MAP FOR DRIVER TRAINING

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ABSTRACT

The over represented number of novice drivers involved in crashes is alarming. Driver training is one of the interventions aimed at mitigating the number of crashes that involve young drivers. Experienced drivers have better hazard perception ability compared to inexperienced drivers. Eye gaze patterns have been found to be an indicator of the driver's competency level.

The aim of this paper is to develop an in-vehicle system which correlates information about the driver's gaze and vehicle dynamics, which is then used to assist driver trainers in assessing driving competency. This system allows visualization of the complete driving manoeuvre data on interactive maps. It uses an eye tracker and perspective projection algorithms to compute the depth of gaze and plots it on Google maps. This interactive map also features the trajectory of the vehicle and turn indicator usage.

This system allows efficient and user friendly analysis of the driving task. It can be used by driver trainers and trainees to understand objectively the risks encountered during driving manoeuvres. This paper presents a prototype that plots the driver's eye gaze depth and direction on an interactive map along with the vehicle dynamics information. This prototype will be used in future to study the difference in gaze patterns in novice and experienced drivers prior to a certain manoeuvre.

KEYWORDS: Gaze depth, Driver training, Intelligent Driver Training System and Interactive Maps.

INTRODUCTION

Even though automobiles have greatly improved the transportation of goods and people around the globe, crashes have been the most prominent danger associated with automobiles. Road traffic collisions cost an estimated US$518 billion globally in material, health and other expenditure [1]. Young drivers have been found to be over represented in crashes [2].

Driving is a complex task that requires navigating the vehicle safely on the road. In order to do this, drivers must be able to perceive information from the environment, process that information to create a mental map of the entire situation and then respond appropriately to that scenario. While experienced drivers are generally quite capable of performing multiple tasks (i.e. perceive hazards and control the vehicle), recently studies have been conducted to determine whether novice drivers can be trained to perceive hazards. Eye gaze pattern have been used with driving simulators to evaluate the effectiveness of hazard perception abilities [3, 4, 6 and 8]. And results have shown that driver training does improve the ability of novice drivers to anticipate hazardous situations [3, 4].

The rest of the paper is organized as follows: the next section will briefly review the related research in the field of driver gaze analysis and effectiveness of feedback during driver training. The following section will present the analysis on the driver’s gaze depth prototype that is one of the modules in the development of Intelligent Driver Training System (IDTS). This will be followed by the discussion on the effectiveness of prototype which combines the gaze depth and orientation on an interactive map. Conclusion will be presented in the final section.

RELATED RESEARCH

It is well known that drivers are at a greater risk during the early years of driving [2]. Researchers in [5] have defined the primary driving tasks as functions that are central to driving and without which moving a vehicle to a destination safely would not be possible. Research suggests that one of the reasons for this crash over-involvement on the part of novice drivers is their failure to scan areas of the road for information that are or might become hazardous. Eye behaviours have been used with driving simulators to evaluate the effectiveness of novice and older driver training programs for many years [3, 4, 6 and 8].

Training To Improve Driver's Gaze Pattern

One of the findings consistent in research is that novice drivers are looking less thoroughly for information than experienced drivers. Novice drivers tend to fixate longer and have a short horizontal spread of fixations [7]. This means that novice drivers are less likely to glance at a hazard in their periphery if they are already fixating on an object.

Pollatsek *et al.* [8] have shown that novice drivers can be trained to anticipate hazards better than untrained novice drivers and almost as well as experienced drivers. In Pradhan *et al.* [9], the aim of the study was to find whether the experienced drivers scanned a region containing the potential risk or they merely looked around more in general. They found out that experienced drivers looked more rightwards because most of the risky scenarios involved a rightward look for risk relevant information. Note that these researchers were working on left hand drive vehicle and roads. Therefore, we can assume that for right hand drive vehicles most of the risky scenarios should involve a leftward look for risk relevant information. After training, researchers [9] found that number of glances of trained novice drivers to the right (toward a potential threat when such existed) was much greater than the likelihood that they would glance to the right when no threat appeared. Thus making the trained novice drivers more aware of their surroundings and reducing unnecessary glances. The untrained drivers on the other hand glanced to the right when a potential threat was present more often. Furthermore, they glanced even when no threat was present. Hence training taught the drivers to look right when it is important rather than just looking right most of the time. In addition to this, training has been found to improve the driver's accuracy in estimating time to collision (i.e. following distance).

Along with these studies, other research [8] points out that by just training driver gaze pattern and hence enabling them to recognise risk would not reduce the willingness of young drivers to engage in unsafe driving. These researchers do concur that fixating appropriately during a scenario does not guarantee that the driver will take appropriate action if the risk in fact appears. However, not fixating appropriately during the scenario that requires urgent attention virtually guarantees that it would make things worse.

Feedback During Driver Training

It is well known that drivers, who are subjects to driver training, show an increase in behaviours that can enhance their situational awareness and also show increase in favourable driving behaviours [10].

One of the key aspects of driver training programs is assessment or feedback on the drive. This can be either self-assessment or assessment from another group or individual. Extensive research has revealed that it is not so much the lack of basic driving skills that caused the crash, but higher order skills. These higher order skills deal with risk perception, situational awareness, risk acceptance, self-assessment, and motivation to drive safely e.t.c [11]. Novice drivers misinterpret the situation (dismissing one of the crucial tasks in driving) and show inefficient visual search. Self assessment tools like questionnaires, scales and evaluations made by instructors or driver trainers help to address the gaps in novice drivers' driving abilities. By comparing the novice drivers' undertaking of a manoeuvre with that of experienced drivers', makes it easy to pinpoint the flaws (if present) in novice drivers' behaviour.

Efforts have been made in the past to measure aspects like driver distraction or risk perception. For example, researchers, Klauer *et al.* [12], studied driver distraction offline by manual analysis of video recordings. This was a cumbersome and time consuming process.

A system that can provide an integrated feedback on driver's proficiency is still lacking in current driver training and education. McKenna in [13] wrote "If it is considered that drivers would benefit from feedback and education on issues such as close following, general driving violations, fatigue and hazard perception, then mechanisms need to be put in place". Up till now a lot of driver feedback programs have been designed, each trying to cover as many aspects of driving as possible [6, 8 and 14]. Yet to our knowledge, there is no comprehensive automated feedback system that lets the driver and driver trainers to effectively and efficiently observe and measure all of the variables involved in driving (i.e. Driver , Vehicle and Environment also known as DVE).

As pointed out by Land and Horwood [15], some sections of the road ahead of the driver (i.e. Figure 1) provide more valuable information than the rest of the sections. This research [15] was conducted in a simulated environment where the road segments could be visible or hidden. A virtual scale was overlayed on the road in such a way that the scale had 10 segments from the horizon to the car (i.e. horizon being the first segment and the car being the 10th one), see Figure 1-a. It was observed that if the driver was only shown the middle segments (i.e. 4th -6th segment) the drivers manoeuvred the vehicle between the lanes very effectively. They matched the curvature of the road and the position in lane was smooth. If the driver just viewed the section that was low (i.e. 7th -10th segment), it resulted in difficult and jerky steering as the 'just near' available segment of the road forced the driver to drive with a 'bang bang' feedback strategy. Along with this, the lane positioning was not as good as compared to lane positioning when the driver viewed the middle segment of the road. This further emphasizes the belief that making the novice drivers look up and scan more might eventually improve their driving competency.

A successful feedback solution has to combine the benefits of multiple sensors such as GPS, accelerometers, cameras, vehicle information, driver's head/eye data and geographical data. In order to obtain a precise synchronization, a sufficiently accurate global time for all sensors and fusion system is necessary. This would then allow processing of drive related data using complex algorithms to retrieve information such as but not limited to; following distance during particular manoeuvres, indicator distance before manoeuvres, avg. speed during manoeuvres, excessive braking or accelerations, driver gaze depth and orientation e.t.c. All this information synchronously plotted on an interactive map would definitely complement the effectiveness of the feedback system.

PROTOTYPE

By adding the functionality to view the actual gaze depth (in meters) of the driver on an interactive map, it is possible to exploit the empirical data about the drive even more. This also enables the reporting and/or reviews of the drivers gaze pattern (for depth and direction) during driving manoeuvres such as turn, overtake, following vehicle e.t.c. This provides both drivers and their trainers with a tool to efficiently locate difference in gaze depth and orientation patterns for novice and experienced drivers during particular manoeuvres.

Apparatus

For designing the experiment for gaze depth calculation module, a few sensors (i.e. cameras) were used. These sensors were fitted in a test vehicle and the data from these sensors were time stamped and synchronized.

The test car used was a 2007 automatic Toyota 4WD. Two video cameras of FaceLab [16], which were facing the driver, recorded the head and eye movements. While another camera mounted with a fisheye lens recorded the scene ahead of the test vehicle.

Method

The basic idea behind the gaze depth calculation is to first create a real world environment model of the road ahead of the driver. Once this model is created, a link between the image of the environment (shown in Figure 1) and the real world is established. Hence it enables the system to calculate the real world approximate depth (in meters) and orientation (in degrees), for each coordinate in the image with respect to its location in the real world. After this, Facelab measures the eye and head movement and synchronizes the gaze data using timestamps. The gaze or fixation information from Facelab is then mapped on the image of the real world (as viewed by the driver). This is shown in Figure 1-b. This enables the gaze depth calculation module to calculate the real world approximate depth (in meters) for each of the gaze point, given its location on the image.

(a) **(b)**

Figure 1: (a) presents the road image overlaid by a virtual scale such that it has 10 segments from the horizon to the car. This image is also used in creating the world model just once, that would then be used to calculate the gaze depth and direction in future drives **(b)** demonstrates the mapping of driver's fixations (blue squares) on the road for a certain time on the road's image.

Since we already have the GPS points for the trajectory of the drive synchronized (i.e. timestamped using RTMaps [19]) with the FaceLab gaze/head orientation data, along with accelerometer and vehicle dynamics data logged during the drive, it is possible to calculate an approximate GPS location for each category of data (i.e. FaceLab data, accelerometer data e.t.c) collected. This logged data are then processed to create an interactive visualization of the drive, as shown in Figure 2. Using this synchronized data, we are able to calculate the GPS location for driver's fixation given the GPS location of the vehicle and the depth of his/her fixation.

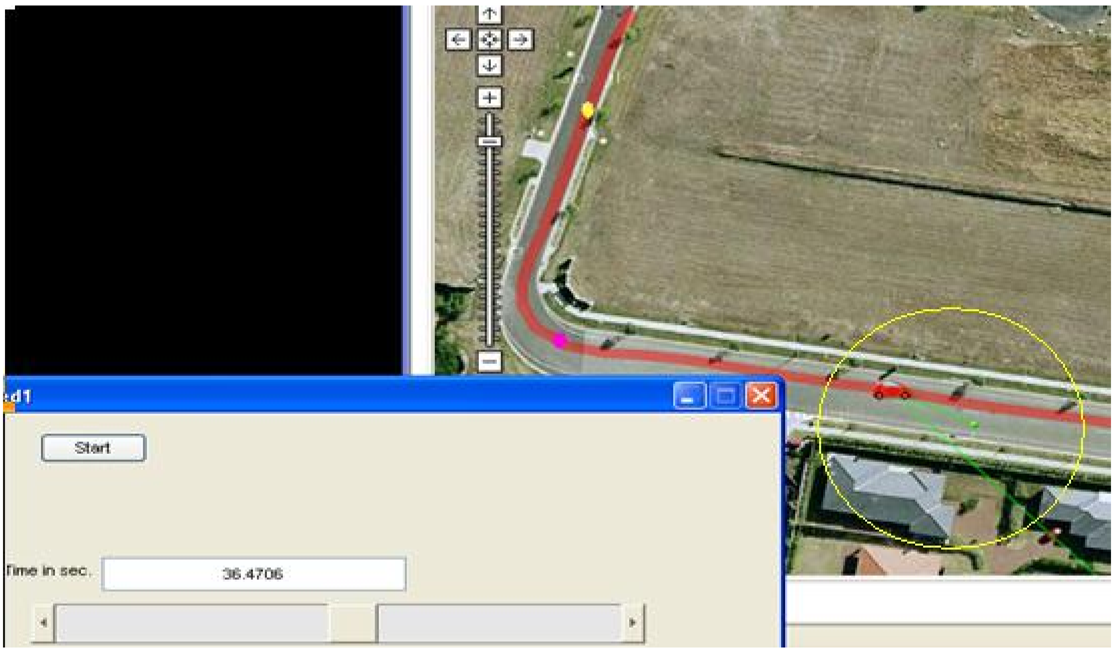

Figure 2: The viewing / reporting module for drivers' gaze depth for the drive.
At a specific time t=36.4 sec, Google Map presents the overlaid trajectory of the drive (the red line), the vehicle position, the fixations depth and orientation (the green line), the start of indicator (in yellow star) and indicator end (in pink star)

The second part of this module is to place these gazes/fixations along with the drive data on an interactive map for effective viewing by both drivers and their trainers. This enables its users to view the drive information at a specific time *t*. The fixation depth data retrieved above from FaceLab for a specific time *t* is then converted into GPS points using Haversine formula [17].

Once the fixation points are converted into GPS points, a user interface was developed using Google map. This map acts as a comprehensive computer based drive visualization system. It plots the vehicle trajectory and other driver's information related to competencies such as eye gaze depth and orientation, indicator status and points of excessive accelerations/decelerations on Google map. It also plots the projection of the driver's gaze on a 2D image acquired from the camera mounted on the windscreen.

POTENTIAL FOR GAZE DEPTH PROTOTYPE

As already mentioned, there is a need to identify the difference in gaze patterns between novice and experienced drivers in order to recognise any competency lack amongst novice drivers. Pollatsek *et al.* [8] found out, that novice drivers look less thoroughly for information than experienced drivers since novice drivers are less likely to glance to something new if they are already fixating upon some object. Training the novice drivers to gaze at the right place at the right time has proven beneficial in previous research [6, 8].

Ultimately, the driving training plan encourages drivers to plan ahead for what can be seen, what cannot be seen and what could reasonably be anticipated to happen [18]. The skills to achieve this are broadly to: observe by scanning the whole road scene effectively and using other abilities (situational awareness, vehicle handling e.t.c) to concentrate and maintain full awareness while driving.

Until now most of the information (related to driver gaze) that have been retrieved in previous experiments is related to the direction or the area in which the driver is gazing during certain manoeuvres. This system would bring forward new facets (i.e. depth and orientation of the gaze in a real world) to the field of driver's gaze behaviour understanding. The interactive user interface would complement this training system by enabling its users to observe at a specific time, the gaze depth patterns of different categories of driver (i.e. novice, experienced, old e.t.c.) during a particular drive manoeuvre.

CONCLUSION

Developing a model for driver gaze depth and pattern based on their competency level has clear practical applications both in testing and training of drivers. Such a model would allow driving attributes to be identified (in terms of gaze behaviour) that are required in particular manoeuvres. It would enable the linkage of key aspects of driver behaviour to specific situations. Feedback on the attempted driving manoeuvres, highlighting both the strengths and weaknesses of the driver has been found to be an effective measure to improve driving skills.

This paper introduces a system that would be able to measure the depth and direction of a driver's gaze in a real world situation. It also plots the depth of driver's gaze on an interactive map for effective viewing and feedback. By empirically observing and viewing the gaze depths and the road sections they intersect for certain manoeuvres, a scale can be devised which would allow both drivers and driver trainers to identify gaze depth patterns utilized for a smooth undertaking of a particular manoeuvre. Further research would enable the ability to empirically identify the depths of the roads that novice and experienced drivers' gaze follows, while attempting particular manoeuvres.

References

[1] World Health Organization (WHO). "Youth and Road Safety". Geneva: World Health Organization. 2007.

[2] Clarke, D., Foryst, R and Wright, R., "A statistical profile of road accidents during cross-flow turns.", Accident Analysis and Prevention, 37, 721-730.2005.

[3] M. Romoser and D. Fisher, “Effects of cognitive and physical decline on older drivers’ side-to-side scanning for hazards while executing turns”, Third international driving symposium on Human factors in driver assessment and vehicle design, June 2005.

[4] C. Ahlstrom, K. Kircher and A. Kircher, “Considerations when calculating percent road center from eye movement data in driver distraction monitoring”, Fifth international driving symposium on Human factors in driver assessment and vehicle design, June 2009,

[5] “Task analysis of ATIS/CVO Functions, Development of human factor guidelines for advanced traveler information system and commercial vehicle operations”, Publ. No. FHWA-RD-95-176.

[6] I. Hong, M. Iwasaki, T. Furuichi and T. Kadoma, “Eye movement and driving behaviour in curved section passages of an urban motorway”, Proceedings of the institution of Mechanical Engineers, Oct. 2006.

[7] A.K. Pradhan, A. Pollatsekb, M. Knodlerc and D.L. Fisher, “Can younger drivers be trained to scan for information that will reduce their risk in roadway traffic scenarios that are hard to identify as hazardous?” Ergonomics. 52: 6, 657 - 673, 2009.

[8] A. Pollatsek, V. Narayanaan, A. Pradhan and D. Fisher, “The use of eye movements to evaluate a PC-Based Risk Awareness and Perception Training (RAPT) on advanced driving simulator”, Human Factors. 2006.

[9] A.Pradhan, A. Pollatsek and D. Fisher. “Comparison of trained and untrained novice drivers’ gaze behaviour in risky and non-risky scenarios”. Fifth international driving symposium on Human factors in driver assessment and vehicle design, 2009.

[10] Guy Walker, N. Staton, T. Kazi, P. Salmon, D. Jenkins, “Does advanced driver training improve situational awareness”, Applied Ergonomics, 2008.

[11] Jose M, P. Mayora, “A human factor based approach for effective use of driving simulators and e-learning tools for driver training and education”, European conference on human centered design for intelligent transportation systems. Lyon, France, 2008.

[12] G. Klauer, A. Dingus, L. Neale, D. Sudweeks, J. Ramsey, “The impact of driver inattention on near-crash-crash risk: An analysis Using the 100-car naturalistic driving study data”, Virginia Tech Transportation Institute, 2006.

[13] McKenna, F. P, “Should speed awareness courses be only about speed?” Paper presented at the Behavioral Research in Road Safety 2006: Sixteenth Seminar, 2006.

[14] Vigil Systems, Vigil Vanguard Driver Training System, whitepaper on driving excellence, http://www.vigilsystems.com.au/uploads/media/VigilVanguard_Whitepaper.pdf

[15] M. Land , J. Horwood, “Which parts of road guide steering”, Letters to Nature, 377, 339 - 340 (28 September 1995); doi:10.1038/377339a0

[16] Facelab, “Complete face and eye tracking”. http://www.seeingmachines.com/product/facelab/

[17] Haversine formula, http://www.absoluteastronomy.com/topics/Haversine_formula

[18] Lisa Dorn, “Driver behaviour and training”, Cranfield University, 2003.

[19] RTMaps: A Software for new technologies, Real Time, Multisensor, and Advanced Prototyping Software: www.intempora.com/ENG/maps/index.php?nav1=maps&nav2concept