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The Need Of Intelligent Driver Training Systems For Road Safety

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Abstract

Automobiles have deeply impacted the way in which people travel but they have also caused a number of deaths and injury due to crashes. Driver inattention, inexperience, poor judgment and/or fatigue etc., are the major contributing factors in crashes. In order to address these complex issues, scientists have developed a number of technological systems ranging from Anti-lock Braking System (ABS), early warning systems to complete autonomous driving solutions. Driver's driving competencies also play a vital role in judging the road environment and reacting in-time to avoid any possible collision. Therefore driver's perceptual and motor skills remain a key factor impacting on-road safety. Currently, there is a need for researchers to develop and evaluate Intelligent Transport Systems (ITS) that assess driving competencies. These tools should be designed to help driver instructors and drivers to accurately evaluate the driving behaviour. This paper outlines a vision for future research in the area of intelligent driver training systems for enhancing road safety and also presents preliminary implementation.

1. Introduction

Automobiles have greatly improved human mobilitywhich has greatly impacted the way in which people and products move about and this factor in-return has enabled us to advance in many other areas. Crashes have been the most prominent danger associated with automobiles. These often result in serious injuries or tragic loss of human life. The financial aspects of these crashes are mind-boggling. Road crashes cost the Australian community forty million dollar every day or fifteen billion dollars each year. It represents three percent of the Australian Gross Domestic Product [25].

Road safety and Intelligent Transport Systems (ITS) are now at the core of academic and industrial research. Most of the developed countries are focusing their research and development to handle and reduce on-road crashes thus directly reducing the number of fatalities and serious injuries. Researchers have defined a term Intelligent Transport System (ITS), which uses technology to improve road safety [7].

Over the past years, a number of passive safety features have been introduced. These include air bags, crumple zones, seat belts and shatter-resistant windshields. These safety features have reduced the severity of injuries caused in crashes but they did not reduce the number of crashes. The safety features are being monitored to assess their safety. For example, it has been found that children should not be seated in the front seat because in case of a crash the airbags will probably harm instead of saving them [1].

One of the reasons for the increase in the number of crashes, even with added safety features is that competency of drivers has not necessarily improved. In the USA, investigation has determined that in 70% of all crashes the primary cause was the driver [2].

The above research implies that driver perception and learning of a particular driving hazard remains a key factor impacting road safety. For developing useful measures to tackle road safety issues, a complete and integrated framework needs to be developed that would include and examine all the parameters that influence driving (i.e. cues related to road, vehicle and driver). Therefore, for the reliable resolution of road safety issues, multidisciplinary research efforts are required.

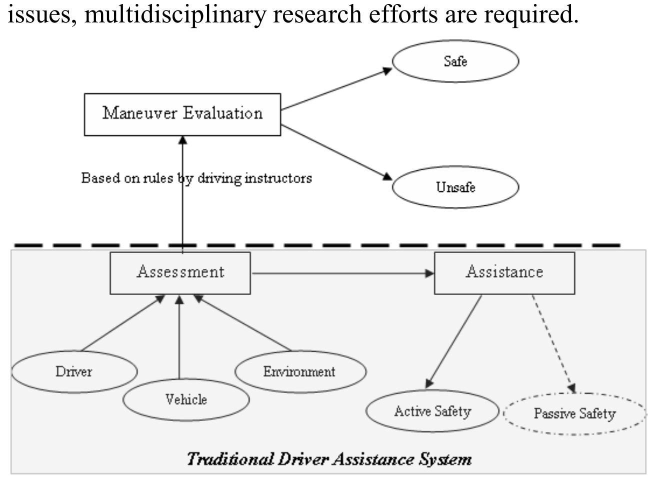

Figure 1: The intelligent driver training system

Figure 1 depicts how the traditional ADAS systems can be used to build an intelligent driver training

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system. The major addition is the evaluation criteria based on rules by driver trainers that determines if the manoeuvre performed is safe or unsafe. The top section (clear) in figure 1 describes the evaluation that the intelligent driver training would perform. This evaluation is done while taking into account the criteria used by driving instructors. This added module acts as an enhancement to the ADAS system (bottom section of Figure 1).

This paper will first describe the advances made in ITS and their impact on road safety. It is followed by an outline of future research in driver training systems. It also includes our proposed architecture for an intelligent driver training system. The architecture is followed by a description of our preliminary implementation and evaluation criteria used for this system.

2. Background & Related Research

2.1. Assessing Primary Driving Tasks

Researchers in [22] 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. The primary driving tasks are divided into three broad categories: navigation and routing, guidance and manoeuvres, and control [22]. A successful execution of all these tasks is necessary for the driver in order to drive effectively. Many intelligent systems up-till now have focused on warning the driver by predicting the trajectory of an oncoming obstacle [17], [7]. Only a few of these systems evaluate the overall driving situation and need to make the driver aware of relevant contextual knowledge extracted from sensors [10]. The driving situation or the contextual knowledge of driving could be conveyed to the driver via different type of Human Computer Interface (HCI). Visual and voice warning are the most commonly used HCI in cars. If the HCI designed to convey context awareness is not properly designed, it can be a distraction to the driver. Ignoring the context aware features of warnings might result in a cognitive overload. For example, in case of a sudden appearance of an obstacle (i.e. an animal or a pedestrian) on the road, the driver would have to brake hard. In a normal driving circumstance, braking hard would force the system to sound a warning for the driver. But in the above scenario, it was the only possible option and the context aware system should not sound an alarm. Also if the driver is making a lot of mistakes, it is possible that the repeated warnings might force a cognitive overload in the driver and that might lead to high frustration. Responding to critical events during driving requires timely response. A point reiterated in literature critical of driver training is that more in-depth analysis of the driving task and traffic situations taking into account the cognitive skill aspect such as hazard and risk perception, decision making, self-monitoring processes, learning styles, and risky attitudes may improve training [13, 17].

2.2. Monitoring Driving Events Using Sensor*s*

Since 1980, car manufacturers have been developing computer based in-vehicle devices [11]. Over the years, different type of sensors like radars, GPS, accelerometers, gyroscopic sensors and cameras have been used extensively in Advanced Driving Assistance Systems.

Computer vision has been used for the past couple of decades to provide solutions to the problems in the field of autonomous agents [3]. Researchers have been working on different algorithms for effective detection of road boundaries and obstacles [4], [5], [6]. A descriptive study has been undertaken in [7] regarding the use of computer vision in Intelligent Transportation Systems. A drawback of machine vision identified is that it does not extend sensing capabilities besides human possibilities (e.g., in foggy or rainy conditions), but can, however, assist the driver in case of a mistake, e.g., lack of concentration or drowsiness.

Machine vision has evolved over the past years to solve problems like pedestrian detection, obstacle and lane tracking for more robust and reliable autonomous vehicles. Different algorithms using single camera and stereo cameras have been used to reliably solve these problems. Computer vision has also been used to monitor drivers [8], [9].

Researchers are now using in vehicle mounted cameras to measure different aspects of driving experience i.e. fatigue, monotony, body movements etc. Many current intelligent vehicle solutions use radar and lidar technologies. Although these technologies are robust in varying weather condition, the sensor data acquired from these technologies is limited as compared to the information retrieved from a camera. A successful solution would be to combine the benefits of multiple sensors as GPS, radar, lidar and cameras.

2.3. Advanced Driver Training System (ADAS)

In the past, a number of prototypes of intelligent vehicles have been designed, implemented, and tested on the road. Many intelligent vehicles have used a number of techniques from the field of robotics. However, the difference between robots and vehicles is that vehicles are controlled by drivers. Therefore, when designing an intelligent vehicle, the human factors should be taken into account. It is important for intelligent vehicles to consider the psychomotor, perceptual and cognitive skills of the driver. This is a complex issue, because there are a lot of factors that influence human perception, interpretation and response.

Intelligent vehicles can be used for several different purposes. Firstly, they can inform/warn the driver in advance prior to possible risks (active safety). Secondly, they can reduce the severity of crashes (passive safety). Lastly, they can be used as a feedback mechanism or training by letting the driver know if an illegal or unsafe driving manoeuvre was performed. A little research has been done so far for this purpose. To date there have been a number of systems that focused individually on the three main aspects of intelligent vehicles, namely vehicle dynamics, driver and the environment. Some effort in fusing this information has been accomplished in [12] and [13], but there has not been any fusion of information for verifying if a certain driving manoeuvre was safe or unsafe.

1) Environment: In the past, many solutions for an advanced driving assistance system or an autonomous car started by acquiring information about the road (i.e. lanes) and obstacles (vehicles, pedestrians, animals etc.). It is a complex task and as with all other computer vision applications, robustness and accuracy is an issue that is difficult to solve.

Nevertheless, the systems have evolved from Generic Obstacle and Lane Detection (GOLD) [18] and RALPH [19], both of which were lane and obstacle detection systems to complete and complex autonomous driving systems [20] and context aware warning systems that also included driver assistance [10]. Along with lane and obstacle detection in the vehicle surroundings, there has been quite an effort in detecting and recognizing road signs as well [21]. PReVENT, a European project developed crash preventive safety applications and technologies [23]. PReVENT uses digital maps, sensors for collision mitigation, lane keeping, fusion of multi-sensory data, obstacle detection and classification and vehicle to vehicle communication.

2) Vehicle: Another important aspect in intelligent vehicles is that the system should monitor vehicle dynamics before activating any intervention such as a safety warning. It is also necessary to assess context sensitive information before declaring a situation as a possible collision course. Different telemetry devices, such as GPS and accelerometers, are now being used as tools to determine the vehicle position, motion and road quality. In addition, cameras and multiple types of sensors can be placed to determine the driver's feet, body movements and facial features. Mostly however, location, velocity and acceleration are all the information that is required for effectively judging the road scenario.

3) Driver: As already stated, that human factor is a major contributing factor in crashes. Therefore, an intelligent driving system should focus on the driver physical and psychomotor events during driving. Driver distraction has been studied in detail by researchers in ergonomics. Emphasis has been made by researchers on the fact that determining the driver mental workload when manoeuvring a driving scenario is necessary. Nowadays, in addition to performing the main driving tasks, drivers may use technologies such as: Entertainment, Telematic and/or Driver assistance systems. Although some of these technologies are intended to improve safety, sometimes during driving, the driver may divert their attention from the main driving task. In-order to avoid this situation, researchers identified the concept of selective attention as a key construct [26].

FaceLAB is a tool that focuses the driver's face and monitors the eye gaze, blink rates and eye closure. This can be further used to monitor driver attentiveness, gaze direction, fatigue e.t.c, [12], [13]. Along with this, Volpe center has developed a system named Safety Vehicle using adaptive Interface Technology (SAVE-IT). This system demonstrates a viable proof-of-concept vehicle capable of reducing distraction-related crashes and enhancing the effectiveness of collision-warning systems [24]. Researchers in [12], [13] and [24] have developed systems that take the human factor aspects into consideration. By using a Human Computer Interaction module that acts as a decision making module, [19 and 20] have tried to evaluate contextually if the warning should be given to the driver at a certain time. By evaluating the future situation and the intended driver action, their system acts as an advance warning system. However, none of [12] and [13] systems determine if the driver was driving in a safe or unsafe manner. Determining objectively a safe driving behaviour is difficult. However, driver instructors have a set of criteria to determine subjectively, safe driving manoeuvres. Such subjective knowledge can be combined and enhanced with objective measures gathered from ADAS. By enhancing the data acquisition tools and technologies that have been used in the past, we have designed an effective driver training system can be designed. This system would effectively fuse the data acquired from multiple cameras and sensors over time and evaluate the competency of the driver.

3. Driver Training System (DTS)

To our knowledge there is no ITS technology developed to improve the training and education of drivers. Even though there has been significant research focused on improving driver training practices, a comprehensive solution is yet to be discovered [27]. Our research monitors the entire driving scenario and offers feedback and education on issues such as close following, general driving violations, fatigue, and hazard perception. The resulting system complements the driving instructors by offering objective assessment. As previously discussed, a comprehensive driving training system would fuse data effectively from the following three fields: Driver, Vehicle and Environment (DVE).

3.1. Architecture of DTS

Figure 2 describes the variables which the driver training system would monitor and evaluate. This is quite similar to the condition that a driver has to face and judge during driving based on a number of variables (environment, current car dynamics). The driver training system would fuse the information acquired from the tripartite given above. The information would be fused and characterized into manoeuvres. The manoeuvres would than be recognized and analyzed using the rules set by driving instructor. Finally, the risk analysis of these manoeuvres would determine if the driving was safe or not.

Our system, called the Driver Training System (DTS) mainly consists of two main modules (i.e. Data Acquisition Module and Maneuver Identification Module). Details of these modules are given below in detail.

A sample assessment manoeuvre that a driver trainer uses is presented in Figure 4. For our proposed system, action 1 (referring to figure 4) can be detected by using computer vision algorithms and systems that have already been implemented i.e. FaceLAB. Action 2 can be detected by using lane change detection algorithms [10]. Action 3, 4 (referring to figure 4) can be monitored using accelerometers and gyroscopic sensors. Accurate GPS positioning will also enable the system to detect car positioning. Therefore, we can deduce that each task in a manoeuvre can be effectively captured using the technology at hand.

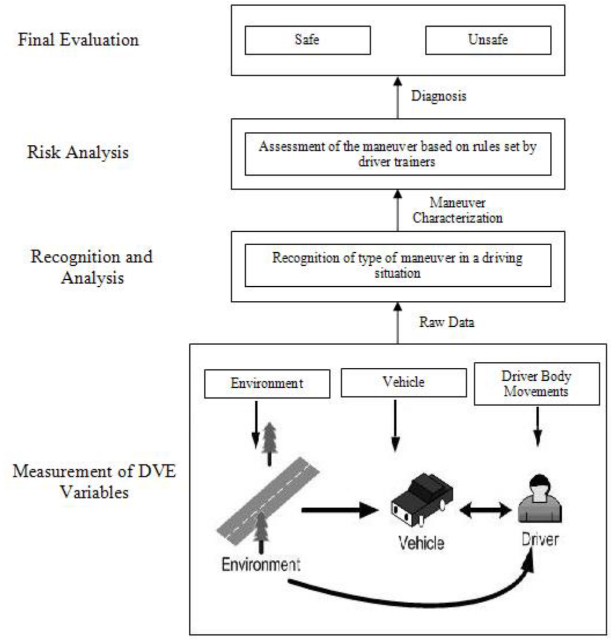

Figure 2: The block diagram of DTS

3.2. Implementation of DTS

As already stated that our system mainly consist of two main modules (i.e. Data Acquisition Module (DAM) and Manoeuvre Identification Module (MIM)). The DAM is responsible for handling all the data passed to it through sensors. And MIM manages the identification and characterization of manoeuvres. It also conducts the risk analysis of individual maneuvers. 1) Data Acquisition Module (DAM): Many sensors and machine vision algorithms have been developed for obtaining relevant data from the car and the road [6, 7, 8, 19, and 20]. But recently, there has been a growing interest in recognizing driver events and manoeuvres using Hidden Markov Models [8], [9].

ii) RTMaps: We are currently using RTMaps [28] as a tool to synchronize and record our multiple sensor inputs. RTMaps is the software that allows real time multiple data acquisition, data fusion and processing, at a high rate. The acquired data can also be stored for future replay. Heterogeneous data like the speed of the car, steering wheel angle, foot movement around the brake is recorded by RTMaps. The head and eye movement is also recorded in RTMaps using FACELab. Along with this the input from the road environment is recorded as well. At the moment, the prototype is being implemented on the SiVIC simulator [29]. Once all the required data has been acquired from the three mentioned variables (DVE), it is handed down to the Manoeuvre Identification Module (MIM).

2) Manoeuvre Identification Module (MIM): This module will synchronize the information over time and use extended automata for decision making. The statistical analysis of timed events will help to measure the performance of the driver. For example, a finite state machine for a proper “lane change” behaviour will change states with events like “mirror check”, “indicator on”, “head turn”, “wheel turn” and “road scanning” e.t.c. The most critical part of this module would be the time evaluation and synchronization. Reason being, all the mentioned events for a proper lane change like mirror, indicator on, head turn e.t.c. are only valid if they were made at the right time.

3) The Safe Performance Protocol: A typical driving scenario comprises of a certain set of driving events and patterns that are repeated over time. Driver instructors typically assess a certain set of skills to evaluate driver competency. They use various types of standard check lists to assess driving performance. For example, the analysis of a right-hand turn consists of observing a substantial number of subsets of behaviour. The breakdown of this particular behaviour as stated in a sample driver training manuals is shown in Figure 4. In the context of a driver training system, this list of driving behaviours will be assessed automatically through the combined information gathered from the in-vehicle recording devices featuring multiple sensors and algorithms used to analyse video data. An assessment such as the one described in Figure 2 can be used to develop a safe performance protocol model that will eventually automatically assess safe driving manoeuvres. The model will be used as a formal framework to evaluate the psychomotor, perceptual and cognitive skills of the driver.

(Example of) Driver Education Performance

Sample Right Turn Assessment

1. Checks mirrors
2. Positions car properly in lane
3. Signals right
4. Reduces speed and keeps wheels straight
5. Checks traffic thoroughly, yielding to pedestrians
6. Starts turn when front wheels are opposite ….

Source: Michigan Department of Education (1997, p35)

Figure 4: Driver Education Performance

Using such a system, an accurate measurement of the interaction between the driver, environment and the vehicle can be calculated. This will eventually help in evaluating the competency of the driver and act as an assisting tool for driver trainers. Similar to the driver assistance systems, this driver training system would be evaluated for user acceptability. Feedback from both the driver trainers and trainees would determine the user friendliness of such a system.

4. Conclusion

Driving is a complex task. It requires a great deal of skill in making a good decision by predicting and evaluating the road, environment and dynamics of the car. The need for research in driver trainer systems is significant because it extends the existing Advanced Driving Assistance Systems (ADAS) concepts to reduce post-licensing crash risks. This paper addresses the issues pointed out in [15], specifically that driver training needs to focus on the psychomotor, cognitive, and perceptual skill deficiencies that are associated with high collision rates among inexperienced drivers. Through this driver training system we will comprehensively integrate the vehicle dynamics, driver behaviour and road/traffic information. This information will help to contextualize, observe and better assess a range of driver behaviours. Along with this, the proposed driver training system can be further customized for assessing 4WD driver competencies. Future work also includes the evaluation of this system. Until now most driver assistance systems [16, 19] have not used qualitative assessment criteria for evaluating their systems to determine if the driver felt the system was user friendly and beneficial. Since all these systems are trying to focus on assisting the driver, it is therefore necessary to evaluate the system from the driver’s perspective.

5. Acknowledgement

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