MODELLING DRIVER BEHAVIOUR IN ORDER TO INFER THE INTENTION TO CHANGE LANES

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ABSTRACT: This study focuses on the examination and comparison of selected behavioural and environmental indicators that predict the intention to change lanes. These indicators were chosen from previous driving studies and driver models. The data were gathered in a field study with an instrumented car that can log data from the driver, the car, and the environment. The collected data were analysed and modelled with the help of a "knowledge discovery framework" (Georgeon, Mille, & Bellet, 2006). The first analysis of all lane changes caused by a slow leading vehicle focuses on the following indicators: glance to the left outside mirror, turn signal, and lane crossing. It is shown that the glance to the left outside mirror could serve as a predictor with a high potential to get information about the intention to change lanes in a very early stage. However, it is important to combine this predictor with additional information to avoid a high false alarm rate.

1 Introduction

The increase in the use of Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) in recent years has created the need for information about the driver and the traffic situation. To augment the benefit to road safety and the driver's acceptance of such systems, these ADAS and IVIS should react according to the traffic situation and according to the driver's intention. For example, a Lane Departure Warning System (LDW) warns the driver if he/she leaves the current lane. However, if the driver wants to execute a lane change the system should not warn the driver.

A lane change is a ubiquitous driving manoeuvre in common driving environments. It combines many critical features of driving such as low level control, monitoring, and decision making. Lane change is defined by a more or less stable sequence of actions which begins with a motivation to change lanes (for instance a slow leading vehicle), followed by a gathering of information about the surrounding traffic situation, and the decision whether to change lanes or not, e.g. [1].

Several sources of data could be used to infer a driver's intention to change lanes. First there are car data; for example, using the turn signal could be a valid predictor of the intention to change lanes. However, drivers do not use the turn signal in every lane change situation. In a field study, Olsen [2] reported that drivers tend to indicate a lane change in only 65% of all cases. Other predictors could be steering wheel angle or acceleration [3]. A second source of data is the car's external environment [4]. The surrounding traffic, the lane position, or geographical position can have some indicative power about the intention to change lanes. Third, the driver himself could serve as a source. In particular, eye movement behaviour could be a rich source of information about the current goals and motives of the driver [5].

There have been several attempts to build algorithms to predict a lane change manoeuvre. In a simulator study, Liu and Pentland [3] developed Hidden Markov Models (HMMs) to predict a lane change to the left out of several other driving manoeuvres. Prediction accuracy was 50 % 0.5 sec after the onset of the manoeuvre, but increased in accuracy over time. Liu and Pentland [3] only used information about the steering wheel for their models. Oliver and Pentland [6] also used HMMs to predict a lane change manoeuvre to the left among other manoeuvres in real traffic situations. Here, prediction accuracy was 23.5 % 0.1 sec before the manoeuvre took place. These authors used car data (speed, acceleration, brake, gear, and steering angle) and gaze information. McCall, Wipf, Trivedi, and Rao [7] used Sparse Bayesian Learning to develop an algorithm to detect the intention to change lanes to the left. Information used in this model was gas pedal position, brake pedal depression, longitudinal acceleration, vehicle speed, steering angle, yaw rate, lateral acceleration, road curvature metric, heading, lateral lane position up to 20 m ahead, and side-to-side and up-down head movement. Real traffic data of only three participants were used, and an accuracy of approximately 95 % was achieved, with 5 % false alarms. Salvucci [8] proposed a “mind-tracking architecture” based on a cognitive model of driver’s behaviour implemented in the ACT-R cognitive architecture [9]. He reported a hit rate of 85 % with 4 % false alarms by using information from the car, the environment, and the driver in a driving simulator.

All these attempts to build valid algorithms have some limitations. The studies suffer either from a very small sample size or they were conducted in driving simulators. Studies that were performed in real traffic environments with a sufficient number of participants had a low prediction accuracy.

The goal of the present study is to focus on the impact of specific indicators and their position in the lane change sequence. The present article describes in more detail the timeline of the following indicators: slow leading vehicle, glance to the left outside mirror, turn signal, and lane crossing. Those behavioural indicators were chosen according to the Intent Detection Framework proposed by Smith and Zhang [10].

2 Method

2.1 Participants

Data from 22 participants between the ages of 24 to 58 years were recorded (MEAN = 33.8 years, SD = 10.1 years). 10 of them were female, and 12 of them were male. Their driving experience in years ranged between 2 and 39 years (MEAN = 13.4 years, SD = 9.7 years), with an annual quantum of driving from 2,000 to 50,000 km (MEAN = 13,136 km, SD = 10,508 km).

2.2 Instrumented car

A Renault Scénic was equipped to record and synchronize sensor data and videos. The synchronization was done by using the time code from the video frame. The logged sensor data came from car dynamics (speed, acceleration, deceleration, yaw rate, and inclination), driver's behaviour (eye movement, steering wheel position, pedal use, and turn signal), and environmental data (distance to car ahead, GPS positioning). Video signals were recorded from five sources: stereo-vision camera with radar for distance estimation to obstacles (top left), the front view (top right), the rear view (down left – upper part), the view from the left outside mirror down to the surface of the road (down left – lower part), and the view to the participant's head with the indications of the eye-tracker (down right). Figure 1 shows the video logged during the experiment.

Fig.1. Video sources from: stereo-vision camera with radar for distance estimation to obstacles (top left), the front view (top right), the rear view (down left – upper part), the view from the left outside mirror down to the surface of the road (down left – lower part), and the view to the participants head with the glance direction of the eye (down right)

2.3 Test course

The field study was conducted in the area of central France around the city of Lyon. The subjects drove on a multi-lane motorway between Bron and the Lyon International Airport (Saint Exupéry) in both directions. The total length of this course was about 50 km. The speed limit varied between 90 km/h and 130 km/h.

2.4 Procedure

Participants were first informed about the goal of the study. They were told to drive like they normally do. There was no information about the issue "lane change manoeuvres" before and during the experiment. Then participants received information about the car. The experimenter calibrated the eye tracker and started the data logging. At least two experimenters were present during the test drive that could influence the driving behaviour. However studies indicate that the results are comparable to normal driving [11]. One of the experimenter sat on the passenger's seat and gave directions. The second one sat in the back of the car, watched the driving scene, and indicated silently a slow leading vehicle as a motive for a lane change by pressing a button, not noticeably for the driver. This signal was logged with a time stamp and was used for the post experiment interview. Participants were not urged to perform a lane change manoeuvre at all. They could initiate it when they wanted to. After the test driving, the data were immediately processed in order to find the sequences with a motive to change lanes in the video. With this information participants were questioned in two ways, depending on whether there was a lane change following or not. If there had been no lane change following, the participants were asked whether they had thought about executing a lane change or not. In the case of thinking about executing a lane change they were asked to show the starting point and the point where they had decided not to change lanes in the video. If there had been a lane change following, the participants were asked to show the point where they had started to think about a lane change and the point after the execution of a lane change where they had stopped thinking about the lane change. After the interview, participants filled out a questionnaire on demographic data. Finally they were debriefed and thanked.

2.5 Data Analysis

The following raw data was collected with the instrumented car: accelerator pedal position, brake pedal position, clutch pedal position, indicator lights, positions of gear stick, kilometric point, speed, steering wheel angle, distance to object ahead, time to collision, headway, GPS longitude and latitude, GPS indications about current road segment, and eye tracking data.

This raw data was analyzed through a step-by-step process of abstraction. This process of abstraction was made with a methodology and a software tool called ABSTRACT (**A**nalysis of **B**ehavior and **S**ituation for men**T**al **R**epresentation **A**ssessment and **C**ognitive ac**T**ivity modelling) [12]. The implementation of this tool took place in a collaboration between INRETS and the Chemnitz University of Technology.

With this method, the analyst is able to specify "patterns of interest", which are relevant to the analysis of lane changes. These patterns of interest are: acceleration, deceleration, stable speed, steering wheel angle threshold crossing, steering wheel angle maximum, eye glance to left mirror, eye glance to center mirror, eye glance to left side of the road, and obstacle detection.

Once specified by the analyst, these patterns are automatically computed. So the overwhelming raw data is filtered in such a way that only the data that we judge to be significant is finally displayed.

This computation produces a representation of the driving activity which is shown in figures 3 and 4. In these figures, the circles at the bottom are events on the basic level of abstraction (e.g. minima and maxima in the sensor data), whereas the triangles and squares above are the symbols of the higher level which are inferred from the basic level. Detailed descriptions of those symbols are shown in the qualitative description of a lane change manoeuvre.

In a post experimental process, a coding of valuable indicators from the video took place. The additional indicators were: distance to lane edge, distance to the following car in the destination lane, and the size of the gap in the destination lane. All these data were also incorporated into the ABSTRACT software tool.

3 Results

3.1 Quantitative description of a lane change manoeuvre

Altogether, 194 lane changes to the left were analyzed. The duration between the starting point of the lane change schema ('start thinking about a lane change') and the actual lane crossing for all lane changes are shown in Figure 2.

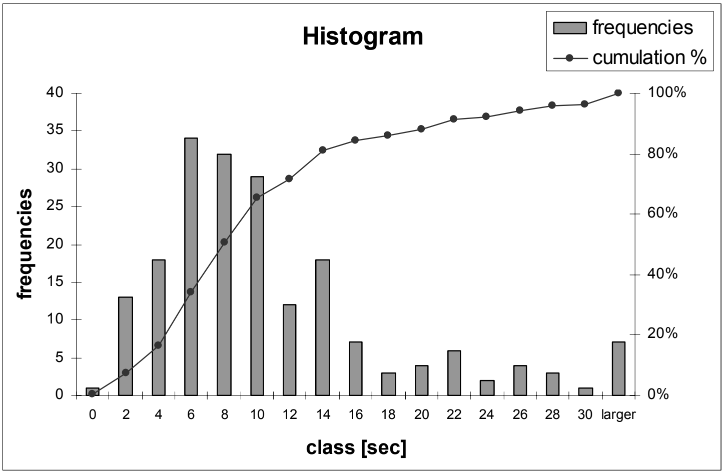

Fig.2. Histogram of the duration of all lane change schemas

The mean value is 10.53 sec (SD = 10.18 sec) with a median of 7.82 sec. The minimum was at 0 sec and the maximum at 88.64 sec.

All lane change manoeuvres were caused by a slow leading vehicle and were performed in order to pass this vehicle. This study focuses on the following indicators: a) first glance to the left outside mirror, b) turn signal, and c) the actual lane crossing. There was at least one glance to the left outside mirror in 99.0 % of all lane changes and the turn signal was used in 99.0 %. In 87.1 % of all lane changes the glance to the left outside mirror preceded the turn signal, in 11.3 % the order was preserved. Three lane changes were not preceded by a glance to the left outside mirror or a signal or both. The mean duration between the first glance to the left outside mirror and the lane crossing was 6.12 sec (MEDIAN = 4.00 sec, SD = 7.01 sec). The mean duration between the onset of the left turn signal and the lane crossing was 2.28 sec (MEDIAN = 2.00 sec, SD = 2.17 sec).

3.2 Qualitative description of a lane change manoeuvre

As an example, two lane change sequences were modelled with the help of ABSTRACT. The first schema (Figure 3) is characterized by the fact that it begins in a situation, where the driver had to drive below his preferred speed. In this schema, the acceleration associated glance into his left outside mirror appeared as a good predictor of the lane change. One second after this possible predictor the participant switched on the left turn-signal.

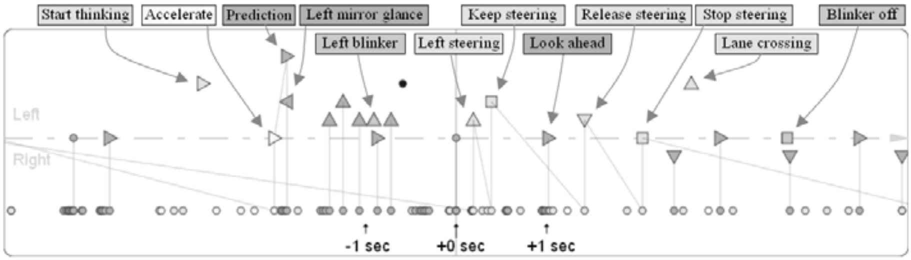

Fig.3. Lane change sequence with acceleration

In the second schema (Figure 4), the participant is not blocked by the obstacle and he performs the lane change "on the fly". In this case, there is no predictor before the turn signal itself. Nevertheless, the turn signal appears to be a sufficient predictor, since it is switched on by anticipation several seconds before the manoeuvre.

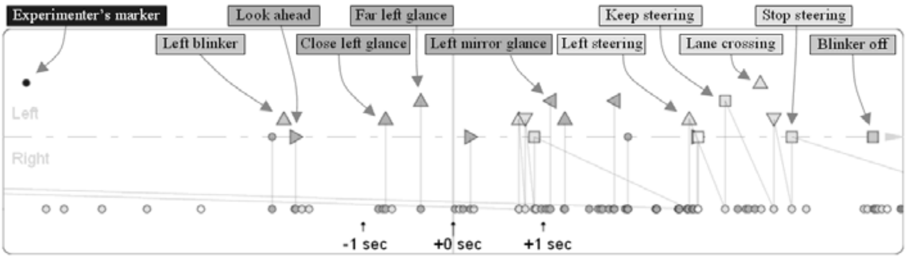

Fig.4. Lane change sequence without any acceleration

4 Conclusions

The preliminary results of the analysis suggest that there is a potential for several types of indicators and combinations of indicators to predict the intention to change lanes. It is shown that the left turn signal and the glance to the left outside mirror are two strong indicators. The high use of the turn signal in this study seems due to the presence of the experimenter. Olsen [2] reports a much lower frequency in using the turn signal in naturalistic driving conditions. In addition, it is shown that the glance to the left outside mirror is of high potential to increase the predictive power in two ways. On the one hand, the glance to the left outside mirror allows an earlier prediction than the left turn signal. On the other hand, the glance to the left outside mirror represents a chance to predict the intention to change lanes even if the driver does not use the turn signal. However, this glance to the left outside mirror is also present to a certain extent if there is no intention to change lanes. In two studies, Henning et al. [5] reported a probability for a lane change given a glance to the left outside mirror of p = 0.40 and p = 0.79, respectively. It shows that 60 % and 21 %, respectively, of all glances to the left outside mirror are within the baseline. The predictive power of the glance to the left outside mirror could be increased with the help of other predictors like the acceleration which is shown in figure 3. Another option could be the combination with the approaching of a slow leading vehicle or the specific patterns of a driver. A detailed analysis and discussion of this topic can be found in Henning and Krems [13].

This study has the chance to go beyond the previous work by a combination of four features: i) the use of field data, ii) a sufficient number of participants, iii) the chance to combine the indicators in a psychologically useful way, which incorporates the knowledge about human processes in the field of attention, memory, and decision making, and iv) the labelling of the lane change sequence by three sources (experimenter in the car, observation and labelling of the video after the driving by the participant, and a rating of three independent observers on the basis of the video). The practical implication of this study for the design of ADAS is that it shows that the use of eye glance data and the incorporation of several sources of data from the environment could not only increase the prediction accuracy, it also allows the assistant system to have information about the driver's intention earlier. One advantage and at the same time a limitation is the presence of experimenters while driving. This influences the driving behaviour to a certain degree [11] of the participants so that it is not "naturalistic" anymore. To get an idea about the differences between "naturalistic" and "observed" driving, it is planned to compare data from naturalistic driving studies with the data of this study.

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