Driver Activity Recognition from Sitting Postures

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Summary

Automatically adapting vehicle settings due to activities of the driver has crucial impact to safety in road traffic, intelligent driver assistance and vehicle control systems as well as driving comfort. Distraction continues to increase by reason of technology growth (classical office- and home electronics like entertainment and navigation systems, televisions, Email and internet-clients, multimedia player, on-board computers, multi-function dashboards, game consoles, etc. are now built-in in cars). We study the possibilities of identifying typical drivers activities inside the car by evaluating pressure patterns collected from force sensor arrays, invisibly and unobtrusively integrated into the fabric of the driver seat and backrest. Along this key task, algorithms are developed for sitting posture recognition and empirical studies are performed to assess the reliability of activity recognition from sitting postures.

1   Motivation

Driver safety and driving assistance systems are the catchwords in current automotive research and development. Numerous patents and proposals are presented all over the world. A novel technology, supporting this systems and complementing them, implicitly involves the driver by evaluating his/her sitting patterns with the goal of mapping them to in-car activities such as braking, controlling the navigation system or simple talking to the co-passenger. Interaction with persons or the driver inside the car requires identification of them. There exist several solutions for a passive/implicit mapping based on sitting postures, for example as described in (Zhu et. al. 2003; Overbeeke et. al. 2001; Picard et. al. 2001) and (Healey et. al. 2000). Thus, this subject area could be seen as covered and therefore could be checked off; nevertheless, we had done experiments to get better knowledge how to use sitting postures for person identification and how stable this mapping is (Riener et. al. 2007).

Driver distraction has increased significantly in the last years, caused by technology growth and popularity. The following list gives a few examples:

1. Cell-phone usage: According to a study from June 2007 there are more than 3 billion cell-phone users world-wide; most of them use their phones in the car; hands-free devices

maybe eliminate some issues regarding operating the car, studies have shown that cognitive demands of conversation are not eliminated and therefore distraction still appears.

2. In-car technology: Complexity inside the car is getting more and more since traditional office- or living room equipment is now built-in or is used in cars (multimedia video phones, entertainment systems, navigation systems, televisions, multimedia player, onboard computers, multi-functional dashboards, tablet computers, game consoles, e-mail and internet clients, etc.) – anything done at home or in the office can forthwith be done inside the car, with the drawback of generating additional distraction to occupants as well as the driver.

3. Traffic complexity: Traffic on the road itself steadily rises and the number of road signs and road works is constantly getting higher and increases driver's distraction.

Considering this, as well as latest studies regarding safety and distraction in traffic, presented in the EU and the US, support the demand of solutions for this problems:

1. US National Highway Traffic Safety Administration[1]: estimates 20-30% of crashes have driver distraction as contributing cause, in numbers: 8,400-12,600 fatalities, 600,000 - 900,000 injuries, 1.2-1.8 million crashes, as much as $ 40 billion in damage.

2. European Commission for Road Safety: Road safety directly affects all of the territory of the EU and all its inhabitants: 1.300,000 accidents a year cause 40,000 deaths and 1.700,000 injuries on the roads. The direct and indirect cost of this carnage has been estimated at € 160 billion, i.e. 2 % of EU GNP. The Commission proposed (and European Parliament and all Member States endorsed this) already in 2001 the goal to save yearly 25,000 lives on European roads by the target date of 2010[2].

Maybe this could be done implicitly by automatically endorse drivers activities.

1.1   Driver Activity Recognition

Drivers in a car are able to sit in different postures. These postures can be measured by force sensor arrays (FSA), shown in Figure 2. Special activities in a car (operating the navigation system, adjusting mirrors, talking to the co-driver or other passengers – a detailed list is given below in Section 2 – seems to correlate with specific sitting patterns – this leads to the question if sitting postures are qualified to be used as a method for driver activity recognition. For the examination we propose a „driver activity recognition system", implemented as a passive method that inspects the pressure patterns of FSAs on the driver's seat and backrest and performs corresponding reactions.

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[1] Research and Development of NHTSA, online accessible: `http://www-nrd.nhtsa.dot.gov`

[2] Saving 20.000 lives on our roads – a shared responsibility. European Road Safety Action Programme. Available online: `http://ec.europa.eu/transport/roadsafety_library/rsap/rsap_en.pdf`

1.2   Potentials

Increasing driver's comfort needs to distinguish between various „driving situations". In our considerations and experiments we want to talk about the following „activity-classes" and/or actions inside a car. Notice, that for some of them it is not necessary to know the actual driver – for that reason, this activities are driver independent.

1. Traditional driving: Considering activities like accelerating, braking, overtaking, etc.

2. Operational controls: This class covers handling of entertainment systems (such as car stereo, mp3-player, navigation system, etc.) but also „classical car activities" like adjusting the speed control, pushing the horn, turning the high beam on/off, etc.

3. Social activities: This are all activities that not directly belong to „car-driving", such as discussions with the co-passenger, twinkling because of dazzling sunlight, eating/smoking during driving, etc.

2   Related Work

(Fenety et. al. 2000) used a pressure mat for recording in-chair movements with the approach of interpreting sitting as a dynamic activity. Furthermore, they presented studies on how to measure sitting discomfort, use pressure mapping systems and analyzing dynamic patterns.

A proposal for a new human-computer interface based on a chair, recognizing static sitting postures, had been presented in (Slivosky et. al. 2000; Tan et. al. 2001). (Overbeeke et. al. 2001) introduced a concept study of an adoptable office chair that responds to the users emotions by sensing their macro-movements. In 2003 Mota and Picard did already studies about posture recognition in office chairs. They distinguished 9 types of postures, such as leaning forward left, sitting upright, leaning back, etc. with a detection performance of more than 80% for known subjects (Mota & Picard 2003).

Introduction of using Euclidean distance metrics for measurement and matching of sitting postures as well as experiments and comparison of different classification algorithms had been imagined in (Zhu et. al. 2003).

(Andreoni et. al. 2002) had already presented a system for analyzing postures of car drivers in 2002. They noticed, that „[…] it is evident that an integrated analysis of all the aspects involved in the car driver posture is very complex and practically impossible to propose […]". In (Ferguson 1992), an overview about pressure mapping systems and their usage is given. (Ishiyama et. al. 2006) introduces a model for extracting postures from humans in motion, (Miller 2002) discusses the usage of sitting postures and measurements with FSA-mats.

Several studies and results had been presented for distinguishing persons (drivers) from sitting postures, even in the car. A logical next step when knowing the driver of a car is to recognize his/her actual or upcoming activities with the aim of supporting the corresponding

person in routine jobs (denominated as „driver comfort"). Another possible field of application is driving safety, meaning that dangerous activities generates warnings for the driver or a monitoring system (before they actually take place).

Figure 1: Driver identification in utility car, sports car and comfort station wagon (from left to right)

As related work studies showed, only little research has been done in activity recognition of drivers until now, most of them used face tracking systems or body-sensors (marker). None of them utilized passive sensors for detecting driver activities.

Preliminary work in this research area has been done with experiments to identify drivers by means of sitting postures (Riener et. al. 2007). Already this prototype has been used in different types of cars (respectively on different types of seats), as showed in Figure 1, to get a generally applicable system and a meaningful interpretation of assumptions.

3   Research Hypothesis

We suppose that the driver's activity is extractable from his/her sitting posture on 2 FSA mats (placed on the seat and on the backrest). This hypothesis has to be proven by experiments on a limited number of activities (approximately 15 activities, see Table 1). It's all-purpose usability has to be shown by using them in different types of cars (see Figure 1).

4   Driver Activities

Table 1 gives an overview about identified activities and corresponding sitting postures in a car. The list tends not to be complete, but should cover 90% of common driving situations. For a higher qualitative mapping between postures and activities it is intended to use additional data from sensors which are also invisibly and unobtrusively embedded into the steer-

ing-wheel, gear-shift, etc. Similar postures should be differentiated by additional sensors to assign them correctly to the right activities. Figure 2 shows recorded sitting postures as results from previous experiments:
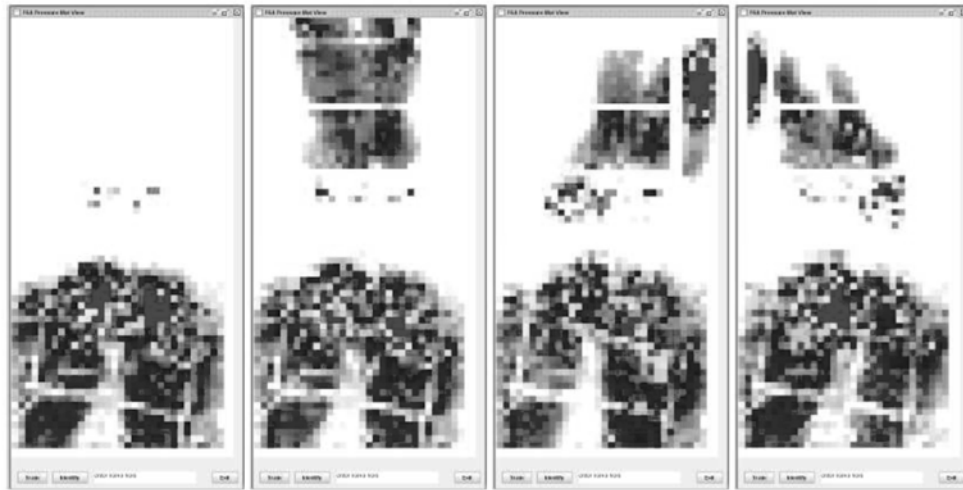

Figure 2: Sitting postures (leaning forward, backwards, left and right; from left to right)

1. Leaning Forward: Assigned activity is braking the car or cleaning the polluted front window. For a more exact discrimination this could be completed by measuring or monitoring the vehicle speed collected from car's OBD[3]-interface.

2. Leaning Backwards: Could be indicated by high pressure on the backrest mat and corresponds to the activity of accelerating the car.

3. Leaning Sidewards to the left: for adjusting the position and height of the seat by using the leverage left below the seat.

4. Leaning Sidewards to the right: Talking to the co-passenger with turning his/her body towards him.

4.1 The Prototype

As previous tests showed and due to the fact that drivers are able to sit on different positions (except in body-contoured seats), several enrolments for each activity are necessary; distinct features has to be extracted and stored, together with raw data, in the database.

1. Activity acquisition: Basis for the identification process is a database with a qualified data set for each activity (in case of being independent of the particulary driver, see Ta-

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[3] On board diagnostics (OBD) is an electronics self diagnostic system for the use in cars/vehicles

ble 1). The implemented enrolment process determines the features of one activity from different pressure mats, recorded from a number of drivers. Algorithms for calculating the features of one activity from the different activity pressure mats have still to be specified.

2. Identification: The identification process determines the features of a new pressure mat reading and tries to find the data set with the minimal distance to the actual reading. Pairwise distances between all feature elements are calculated, multiplied with a significance factor (weight) and accumulated to the final indicator. The weight factors should be obtained from experimental test series, with all features transformed in a „normalized space" to allow a meaningful comparison.

No.	Activity	Person Dependent	Seat posture	Backrest posture	Additional sensor	Capturing
				Driving Actions		
1.1	Common Driving	No	Normal	Normal	-	-
1.2	Accelerate	No	Normal	Increased pressure	OBD	Fuel consumption, Throttle valve position (angle)
1.3	Brake	No	Normal	Lower pressure	OBD	Braking pressure
1.4	Left/Right Turn (slow)	No	Increased pressure left/right	Increased pressure left/right	Car-Gateway	Position of steering wheel
1.5	Left/Right Turn (fast)	No	Increased pressure right/left	Increased pressure right/left	Car-Gateway	Position of steering wheel
1.6	Sliding/ABS/ESP	No	Turbulent	Turbulent	OBD	ABS/ESP warning
				Appliance Handling		
2.1	Operate the horn	No	Normal	Short-time increased pressure	ECG	Aggression detection
2.2	Turn high or low beam on or off	No	Normal	Pressure artefacts	Car-Gateway	-
2.3	Blink left/right	No	Normal	Pressure artefacts left/right	Car-Gateway	-
2.4	Entertainment system Stereo/CD/MP3/DVD, etc.	Yes	Pressure artefacts	Pressure artefacts	-	-
2.4						
2.5	Adjusting Speed Control	No	Pressure artefacts	Pressure artefacts	Car-Gateway	-
2.6	Nagivation system	No	Pressure artefacts	Pressure artefacts	-	-
				Other's (non car-specific)		
3.1	Discussion/Conversation	Yes	Dynamic change	Dynamic change	Camera	Face tracking
3.2	Cell phone call	Yes	Normal	Raised pressure in one shoulder	Camera	Arm tracking
3.3	Look into road map	Yes	Normal	Lower Pressure	Camera	Face tracking
3.4	Eating/Smoking	Yes	Normal	Normal	ECG, Smoke detector	Raised HF

Table 1: Activities and corresponding sitting postures inside a car, arranged in classes

5   Work Plan

To fulfil our considerations, following steps have to be accomplished:

1. Activity selection: First, the list of interesting and meaningful in-car activities, as shown in Table 1, have to be examined and completed.

2. Software: For previous experiments with the FSA mats we wrote a data collection and evaluation software (JAVA application with communication via OLE framework). This software for data collection and evaluation has to be adopted to match the newly identified requirements/issues, new algorithms for feature extraction and comparison have to be implemented.

3. In-car measurements: To avoid faulty measurements the two sensor mats should be stitched onto the car seat and backrest to prevent mat-shifting during test drives. This is, because in previous tests the mats were retained on the seat only with extra strong fabric tape with the consequence, that the position of the mats on the seats – and thus precondi-

tions for the following measurements – changed slightly.

4. Additional sensors: As described above, mapping of postures to corresponding activities could be significantly improved by using additional sensors (like ECG, skin conductance meter, OBD, eye tracker, etc.). They should be integrated unobtrusively and invisibly with no need of active driver participation. Appropriate sensors have to be selected and integrated into the car and the software package.

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