Detection of Driver Posture Change by Seat Pressure Measurement

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I. INTRODUCTION

Driver's movements, such as trunk rotation and feet operation, can provide pertinent information to aid understanding of the driver's physical state and intention [1-2]. More importantly, the detection of driver posture can also help to ensure a timely activation of intelligent driver-assistance systems. For this reason, many studies have been initiated to develop driver posture monitoring systems using various sensors [3]. The most prevalent systems are based on optical techniques, which exhibit critical limitations under different light levels. In addition, the recognition result will drop significantly when some body parts are occluded in the view of optical sensors. Furthermore, most of these vision-based monitoring systems are mainly focused on upper-body postures. In contrast, pressure sensors do not suffer from changing environment and can be easily embedded into the seat. Pressure mapping systems could offer a good alternative to provide additional information for monitoring lower limb movements. A few studies [4-5] used pressure measurement to identify driver static postures without considering temporal information. As postural change is of primary importance, this paper examines the robust parameters from pressure measurement to continuously detect driver posture and, more specifically, the movements of the driver's trunk and feet.

II. METHODS

Experiment

A total of 23 volunteers (12 males and 11 females from 22 to 65 years old) with driving experience were selected by stature and BMI. Prior to data acquisition, subjects were equipped with reflective markers whose positions were recorded by the optical motion capture system VICON. Two Xsensor pressure mats were used to record the pressure distribution on both seat pan and backrest. Synchronisation between the two systems was ensured by a trigger. Participants were instructed to perform seven types of motions, including trunk flexion (forward and backward), trunk rotation (to left and to right), body movements when depressing acceleration and brake pedals and when changing gear. For each movement, participants started from a standard driving posture (STP, with hands on the steering wheel, right foot on the acceleration pedal and left foot on the floor) and ended with the same posture. The IFSTTAR ethical committee approved the experimental protocol.

Parameters

To distinguish left, right, frontal and rear part of the seat pan, four regions of pressure mat were defined, as shown in Fig. 1. As a postural change modifies the pressure distribution, pressure ratios between different regions were calculated at every frame for each trial. Their variations along time were analysed to detect postural change. The same method was applied to extract features from the backrest pressure measurement.

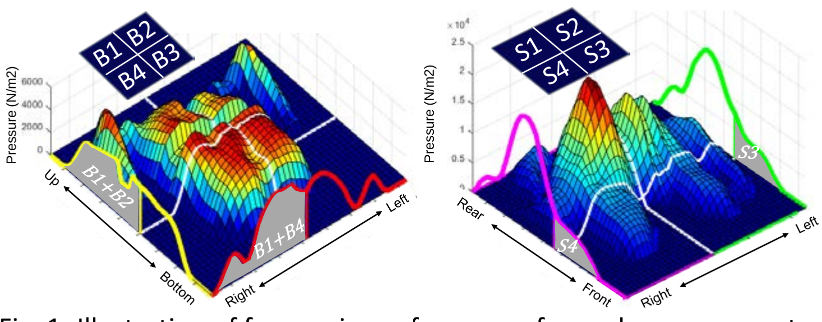

Fig. 1. Illustration of four regions of pressure for each pressure mat (*left*: backrest, *right*: seat pan) and profiles.

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III. INITIAL FINDINGS

Figure 2 gives an example of how to detect driver's right foot movement when braking. For this, the ratio $R\_S_{14}^{4}$ between the pressure applied at the frontal left (S4) and the pressure at the right side of seat pan (S1+S4) was used. By examining its variation along time, the right foot movement, characterised as a sequence of multiple motion clips, including keeping STP, lifting foot from acceleration pedal, depressing the brake pedal, etc., can be easily detected. Apart from the slight time delay for certain motion clips, the motion pattern was detected successfully when comparing to the reference one, which was defined by analysing the trajectories of the marker attached at the foot recorded by VICON system. The detection accuracy was estimated by calculating the mean true positive rates across all subjects for all frames in each motion. For braking, an accuracy of 84% was obtained.

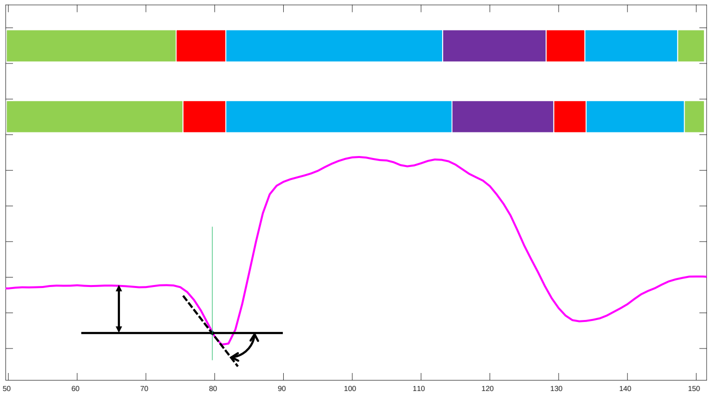

Fig. 2. Detection of right foot braking movement using $R\_S_{14}^{4}$.

Depending on motion type, different parameters were tested. Preliminary results are listed in Table I for the five motions investigated in the present study. The same parameter, $R\_S_{14}^{4}$, used for detecting right foot movement when braking was found suitable for detecting movement when depressing the acceleration pedal, with an accuracy of 83%. And 80% frames of left foot movement when changing gear could be correctly recognised by analysing $R\_S_{23}^{3}$, the pressure ratio between left frontal region and whole left part. For trunk movements, pressure ratios of the upper (B1 and B2, $R\_B_{1234}^{12}$) and the left side (B1+B4, $R\_B_{1234}^{14}$) relative to the whole seat back pressure were found relevant with an accuracy of 86% and 88%, respectively, for trunk flexion and rotation.

TABLE I
RELEVANT PARAMETERS AND DETECTION ACCURACY

Driver motion	Relevant parameters	Detection accuracy (N=17439 frames)
Accelerating	$R\_S_{14}^{4}$	83%
Braking	$R\_S_{14}^{4}$	84%
Changing gear	$R\_S_{23}^{3}$	80%
Trunk flexion	$R\_B_{1234}^{12}$	86%
Trunk rotation	$R\_B_{1234}^{14}$	88%

IV. DISCUSSION

In this study, we proposed a method to detect driver posture changes using pressure measurement. Preliminary results showed that relevant parameters could be extracted from pressure measurements for detecting the movement of a single body part. Note that multiple body parts may be involved in a driver posture change, which will inevitably result in ambiguity. More sophisticated algorithms, considering more than one parameter, should be explored to reduce these false detections. In addition, drivers' motion data were collected only for a limited number of movements in an isolated way. Future study will be expanded to a larger dataset of driver behaviours in longer driving journeys to test and optimise this method.

V. ACKNOLEDGEMENT

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VI. REFERENCES

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