Sensor Matrix Robustness for Monitoring the Interface Pressure Between Car Driver and Seat

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Abstract. An effective sensor system for monitoring the pressure distribution on a car seat would enable researches on Advanced Driver Assistance Systems (ADAS) and comfort of occupants. However, the irregularities of the seat shape or those of the occupant clothes challenge the robustness of such a sensor system. Moreover, the position identification of bodies of different percentiles by few pressure sensors is difficult. So, a higher resolution pressure pad has been developed. The number of sensors is significantly increased by means of a matrix scan strategy. Tests on the pressure pad with different occupants proves its robustness in scanning the contact area.

Keywords: Sensor matrix · Pressure · Driver monitoring · Car seat · Comfort · Advanced Driver Assistance Systems

1 Introduction

The body pressure distribution on the seat surface is a source of meaningful information in several lifecycle phases of a car. During design phases, experiments on seats for a prolonged time can evaluate the seat comfort [1, 2]. The relationship between pressure and temperature fields can also be investigated [3, 4]. The experimental equipment may also become an effective device to be embedded in the seats of production cars. In fact, the interface pressure monitoring may send information to safety systems committed to attention monitoring [5], up to adaptive systems for crash damage reduction [6]. Finally, the seat pressure can be processed by machine learning software for describing the driver patterns, in order to enhance the driving experience [7, 8].

Previous research proved the feasibility of this technology for driver monitoring [6]. A seat cover with pressure sensors is capable to monitor even the driver breathing when the car is stopped. When driving, a module for relative measurement monitors the driver, while an absolute one takes a reference on the car as a moving platform [9], whose accelerations significantly affect the pressure centre shift. Comparing the two

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modules, this system can detect the Out of Position conditions for the driver or other passengers, to be communicated to an adaptive Airbag Control Unit in order to reduce the damage in case of crash. Two shortcomings were detected. First, the body size percentile significantly affects the pressure distribution. Then, a system with a small sensors area is too prone to the irregularities of the matching between the seat shape and the clothing of the occupant. As a result, the relative module must be calibrated for each driver and for each driving session too.

A higher resolution of the sensor matrix may improve these shortcomings. It would have multiple applications, from the aforementioned verification tool for comfort purposes, up to the integration in an Advanced Driver Assistance System (ADAS). So, a pressure pad has been developed in the present research. It has been tested on different occupants, proving its greater robustness for driver monitoring.

The paper is organized as follows. Section 2 presents the experiment materials and methods. The pressure monitoring experiments are reported and discussed in Sect. 3, while Sect. 4 draws the concluding remarks.

2 Pressure Pad

The pressure pad consists of a sensor matrix with a dedicated control system capable of scanning the load over its cells. The pressure pad is conceived as a flexible layer to cover the interface surface to be monitored.

Three superposed layers form the pressure pad assembly. Each outer layer consists of a number of parallel copper strips, the lower in row while the upper in column directions respectively, as shown in Fig. 1a and b. The middle layer is a Velostat sheet (Adafruit®, New York, NY, USA). The Velostat is flexible, conductive and pressure sensitive so that its squeezing reduces its electric resistance. The 30 × 25 strips matrix have 600 mm × 500 mm overall dimensions, and it is covered with 750 sensorized cells of 20 mm × 20 mm size. Cells scan and data communication to a laptop through

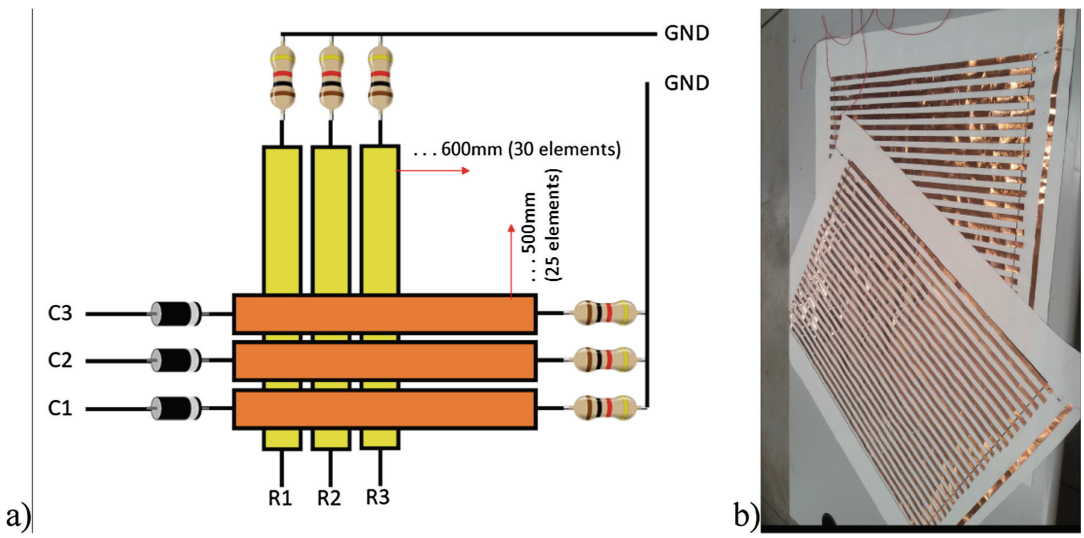

Fig. 1. Pressure pad: (a) sensor matrix concept and (b) copper strips on outer layers.

the serial port are controlled with an Arduino Mega 2560 controller (Arduino®, Turin, Italy). The matrix scan requires to power one by one the 25 Digital Outputs at 5 V and to read the 30 Analog Inputs at 0 ÷ 5 V for each powered DO. On the purpose, the DOs of the Arduino Mega 2560 are increased by a sequence of 4 74HC595 shift registers (Texas Instruments®, Dallas, TX, USA). The AIs are increased by 2 BOB-09056 multiplexers (SparkFun Electronics®, Niwot, CO, USA). In total, the cost for a pressure pad is comparable with that of the cover developed in [6]. For the experiments, two single pads are used for the seat bottom and the seat back, for a total of 1500 cells.

The controller powers one DO column at a time. The cells of each column are sampled by acquiring the voltage signal on all the AI rows. All the cell values are sent to a laptop through serial communication. The program structure is reported as follows:

```
libraries include();
variables declaration();
serial communication begin();
test loop() {
   ack();   //wait for the operator pushbutton to start
              the test
   for (int j = 0; j < 25; j++) {   //scan the 25 columns
      column[j]=HIGH;
      for (int i = 0; i < 30; i ++) {  //scan the 30 rows
         cell[i,j] = analogread(row[i]);
         print(cell[i,j]); //through serial communication
      }
      column[j]=LOW;
   }
}
```

At present, this software enables to scan the pressure field once after the operator commands that with a pushbutton. That is, it is conceived as a design verification tool. The average scan time is 2,39 s. However, the system can also works as a stand alone device, as if it were an ADAS equipment. In this configuration the average scan time is 0,19 s. Thus, the serial communication is the most time consuming function for this controller.

3 Experiments and Discussion

In the experiments, the pressure on the driver seat of a 308 SW Peugeot® (Paris, France) car is monitored. Both the sensorized seat cover from [6], shown in Fig. 2, and the pressure pad, shown in Fig. 3, are tested with three different male drivers. Table 1 lists their body sizes. The testers are asked to take a normal driving position with hands on wheel and feet on pedals. After one minute for self adjustment in a comfortable position the pressure field is scanned.

Figures 4, 5 and 6 report the experiment results for the three drivers. The colour scale ranges from 0 (green) to 500 (red), while each sensor full scale would be 1024. The results reveal the qualitative pressure distribution, while for having a pressure result the cells should be calibrated. It can be clearly noticed the greater continuity of the pressure field as measured with the pad. The total 1500 cells are a very fine subdivision of the surface that results in continuous transitions between different loaded areas. For example, let us consider the different height of drivers and the consequent pressure on the seatback. The first driver is taller by 5 cm than the second one and by 20 cm than the third one. The different pressure distribution can be clearly identified with the pad, as in Figs. 4a, 5a and 6a. This difference would be much more difficult to identify by scanning the surface with the cover, as in Figs. 4b, 5b and 6b. Also, the experiment of Fig. 5b identifies an asymmetric position for the second driver. Also the lateral support is better monitored by the pad. In the seat bottom area the leg pressure is clearly identified. In fact, in Figs. 4a and 5a for the first and second driver with larger bodies, there are two lateral loaded bands, corresponding to the contact between the legs and the lateral supports. The pressure pad of (a) experiments accurately monitors the pressure field and the contact configuration with the seat. The sensorized seat cover of (b) experiments is not able to appreciate this contact area. On the other hand, the seat cover better identifies the different weight of drivers.

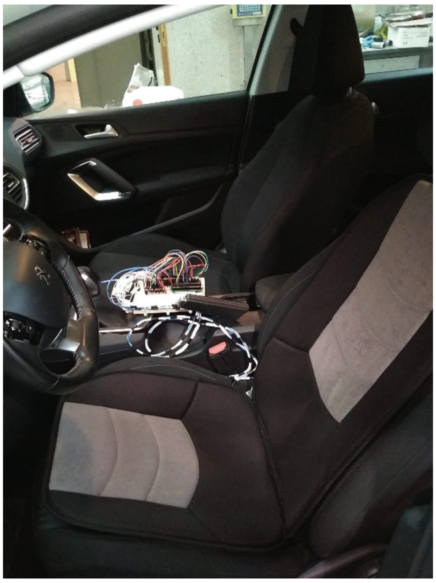

Fig. 2. Installed sensorized seat cover.

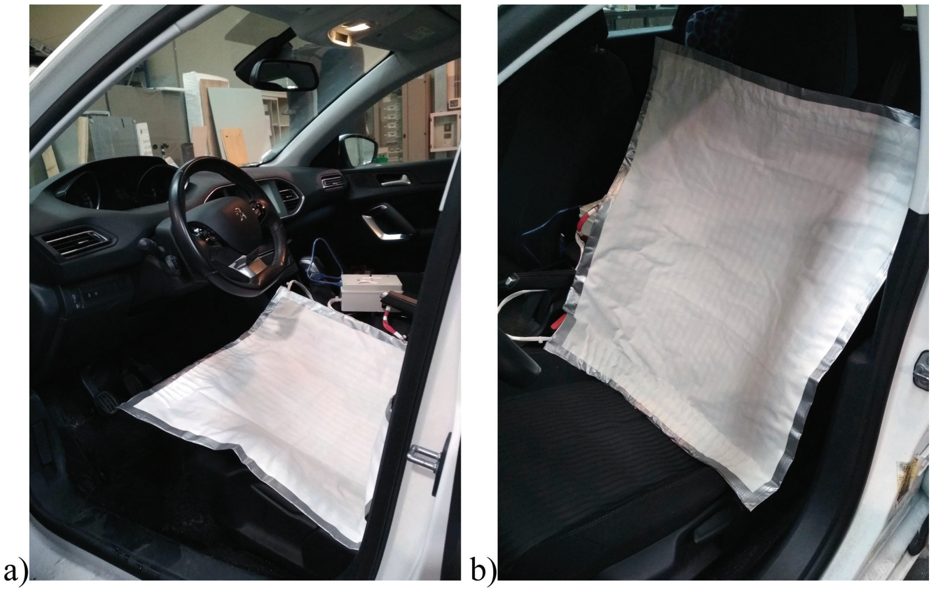

Fig. 3. Installed pressure pad on (a) the seat and (b) seatback.

Table 1. Body sizes of the test drivers.

Driver	Weight [kg]	Height [cm]	Age [y]
1	90	185	36
2	80	180	26
3	60	165	24

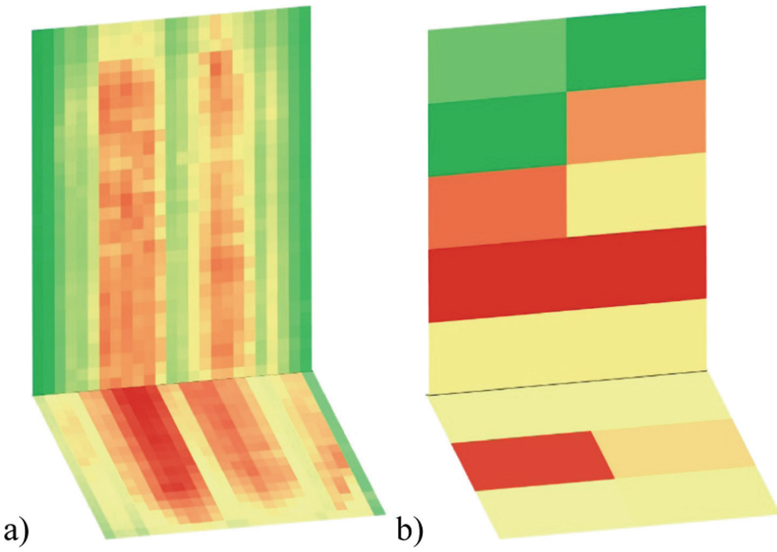

Fig. 4. Pressure fields for the first driver on (a) the pad and (b) the seat cover.

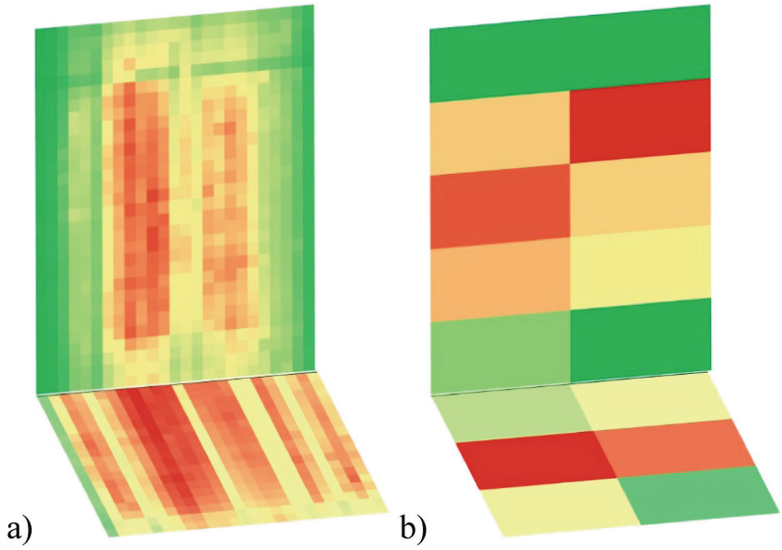

Fig. 5. Pressure fields for the second driver on (a) the pad and (b) the seat cover.

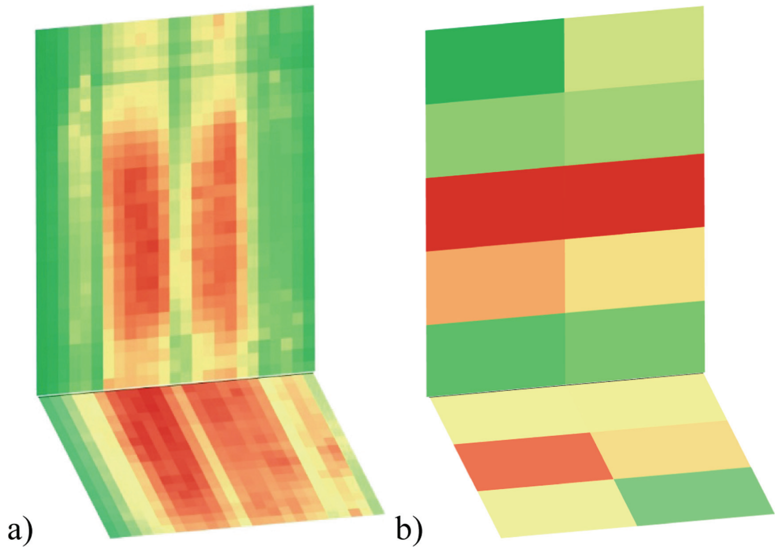

Fig. 6. Pressure fields for the third driver on (a) the pad and (b) the seat cover.

4 Conclusions

In the present research, a pressure pad has been developed and tested in order to provide a robust design equipment for comfort testing in car seats and a sensor system for car occupants monitoring. The pressure pad is capable to monitor the pressure of an occupant on his seat with a fine resolution. So, the pad is less prone to the irregularities of the seat shapes, clothes folds and accessories of the occupant. The present research proved the feasibility of a pad with a sensor matrix as a design verification tool and robust sensor tool to be integrated in an ADAS. On the other hand, the sensor robustness and calibration have to be improved. Moreover, a careful material selection would enable the pad permeability to the air.

Future work will merge the features of the pressure pad and the seat cover in order to synthetize both the advantages in an ADAS solution.

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