Feasibility study to distinguish movements automatically by analysing the pressure distribution on a seat

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Abstract:

Fatigue is an important factor in the occurrence of car accidents. In Germany, there are an average of almost 2000 car accidents with personal injuries due to tiredness of the driver per year [1]. Automatic detection of fatigue by constantly monitoring a person's condition allows the initiation of emergency braking and therefore reduces the number of car accidents. In this work, a pressure mat was used to record the movements of a driver, simulated by a male healthy volunteer. 18 sitting positions were defined and performed by the volunteer. In total, 103 measurements were evaluated. The results show, that it is feasible to detect movements, when the torso is moving. Movements of the arms without moving the torso were not clearly detectable. However, small differences in the quantitative measurements were detected. Using innovative artificial intelligence algorithms might enable the classification even if there is no torso movement included.

Keywords: pressure mat, position recognition, movement detection

1. Introduction

Sitting is quite a common action in our daily life. Especially lorry and train drivers are sitting almost their entire working time on the driver's seat. According to the German Federal Statistical Office, the number of car accidents in Germany went up by more than 11 % during the years from 2010 to 2019. Tiredness of the driver causes almost 2000 car accidents with personal injuries per year. This results in costs of more than 80 million € [1]. Studies show, that accidents can be prevented by constantly monitoring the driver's health condition [2,3]. Generally, there are 3 classes of parameters that can generate risks: the state of the vehicle, the environment (traffic, weather, etc.) and the physiological state of the driver. Conventional methods of monitoring the driver's activity and movements usually require the installation of a camera into the driver's cab. This might lead to a situation of discomfort by the driver. Analysing the movements using a pressure mat to record the pressure distribution overcomes that problem. In this study, we focus on the evaluation and monitoring of the driver's physiological state. For that, we tried to recognize mundane movements automatically by analysing pressure changes on a pressure mat, without limiting the user's movements or field of vision. The objective was to find out how a person's inclination, posture and additional weight affected pressure distribution on the pressure mat.

1.1 Related Works

With recent technical advancements, pressure sensors are increasingly used in various devices. Pressure mats can measure the interface pressure applied to the subject continuously. The approach to distinguish movements is based on continuous pressure measurements at the hips and thighs of a person.

In our research, we could not find any studies, which dealt with distinguishing movements on a pressure mat for drivers in a seated position. That's why we looked for similar research areas. Elsharif et al. proposed in 2021 a monitoring system that provides a comprehensive system to avoid pressure ulcers and provide proper care. The authors obtained promising results, where sleep posture classification achieved 99.6 % overall accuracy using feed-forward artificial neural networks [4]. Authors in [5] achieved 97.9% accuracy for three posture classifications using artificial neural network. Diao et al. proposed a smart mat system that recognizes sleep posture using deep residual networks. They reached an accuracy up to 95.08 % for the short-term test and up to 86.35 % for posture classification [6]. Channa et al. monitored sleeping postures of sleep apnea patients using pressure mats. They used supervised machine learning algorithms for the collected data and used it for posture identification [7]. Lima et al.

used unsupervised machine learning algorithms for vital sign monitoring. This type of setup has the advantage of reacting only to movement changes, and no offset signal due the person's weight is measured [8].

All the works described above focused on the classification of sleeping postures, which is not applicable to our system that focusses on seated postures.

1.2 Paper Organization

The remaining of this paper is as follows: Section 2 describes the system design and the test scenarios. Section 3 presents the obtained results. Finally, the discussion and conclusion are given in Section 4 and Section 5.

2. Method

This work evaluates the feasibility to detect small body movements on seat on a pressure mat. In this first exploratory work, data was collected on one adult male volunteer. He was 26 years old and weight 90 kg. During the tests, he was asked to take different seating positions on the pressure mat with various additional weights. In addition, the volunteer was asked to maintain normal breathing during measurements.

The measurements were obtained using the TexiMat system (TexiSense, Rue Evariste Galois, 71210 Torcy, France) which is a bi-dimensional pressure mapping sensor, that was placed under the upper torso. The two outer layers are composed of artificial silk (row or column) of conductive fiber while the intermediate has piezoresistive properties. A voltage is applied to one of the outer layers and a voltage reading is applied to the other. The voltage deviation at each zone gives the resistivity of the intermediate layer which is an image of the pressure. TexiMat is composed of three layers (see Fig. 1) and consists of 32 x 32 pressure sensors given a total of 1024 measuring points obtaining a measurement up to a frequency of 10 Hz. The maximum pressure allowed is 34.4 kPa while the resolution is 1/11 Pa. Each measuring point is written into a 32 x 32 Matrix and then applied to a colour scale (see Fig. 1). The resulting image is the pressure distribution [9].

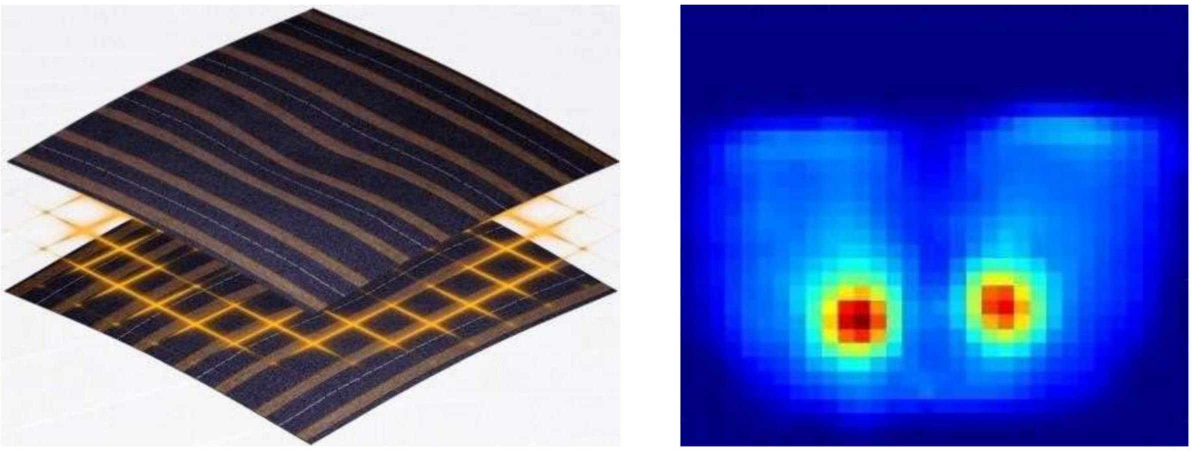

Figure 1. Structure of TexiMat [10] (left) and an example of a pressure distribution (right)

2.1 Influence of inclination

The first examined parameter was the influence of the inclination of a person on the pressure mat measurements. For this, seven positions were tested: no inclination, 3 levels of inclination to the side (slight, strong and very strong inclination), 2 levels of forward inclination (slight and strong) and slight inclination backwards. The scale of the different imprints is not the same, because it is normalized. The normalization ensures, that the maximum pressure is always the greatest value on the scale. This way pressure differences can be evaluated better.

2.2 Influence of additional weight

The weight of a person varies over time. There are differences between morning and evening and the impact of clothes. Thus, in the next test series additional weight was added to the volunteer and the pressure distribution was observed again. The additional weight was increased from 0 kg to 0.5 kg, 1.0 kg, 1.5 kg, 2.0 kg, 3.0 kg, 5.0 kg and finally 10.0 kg by a weighted vest worn by the volunteer.

2.3 Influence of specific postures without the movement of the torso

Last but not least different postures solely by the arms without a clear movement of the torso were examined. These are right arm stretched out, left arm stretched out, both arms stretched forward and both arms stretched upwards.

3. Results

Measurements were taken in real time. In total, 103 measurements were evaluated on the subject and compared with another. It is clear, that movements of the entire upper part of the body are clearly visible by the change of the pressure distribution.

3.1 Influence of inclination

The pressure distributions of the various test scenarios are shown in Fig. 2. In Fig. 2a the volunteer has no inclination. He sits upright and his hands are on his lap. The maximum pressure is in the area of the hips with two centre points coloured in red. The pressure distribution is symmetrical to the vertical axis. The maximum pressure is 49 kPa. Fig. 2b shows a slight inclination to the right side. The pressure on the right side increases and at the same time it decreases on the left side. The pressure is distributed over the surface of the right leg. The maximum pressure is 47 kPa. Stronger inclinations ensure that the pressure distribution shifts even further to the right (Fig. 2c & 2d). The maximum pressure is 46 kPa (Fig. 2c) and 44 kPa (Fig. 2d). A very strong inclination ensures that nearly the total weight is on the right side. A forward inclination ensures, that the pressure distribution is less punctual, but more homogenous. The persons weight is distributed more on the thighs then on the hips. This phenomenon can be clearly seen in Fig. 2f, where the maximum pressure is 19 kPa and occurs on the thighs. Even with a slight inclination the maximum pressure reduces to 22 kPa. A backward inclination behaves similar like a forward inclination. The pressure distribution is less punctual, but more homogenous. The maximum pressure reduces to 22 kPa.

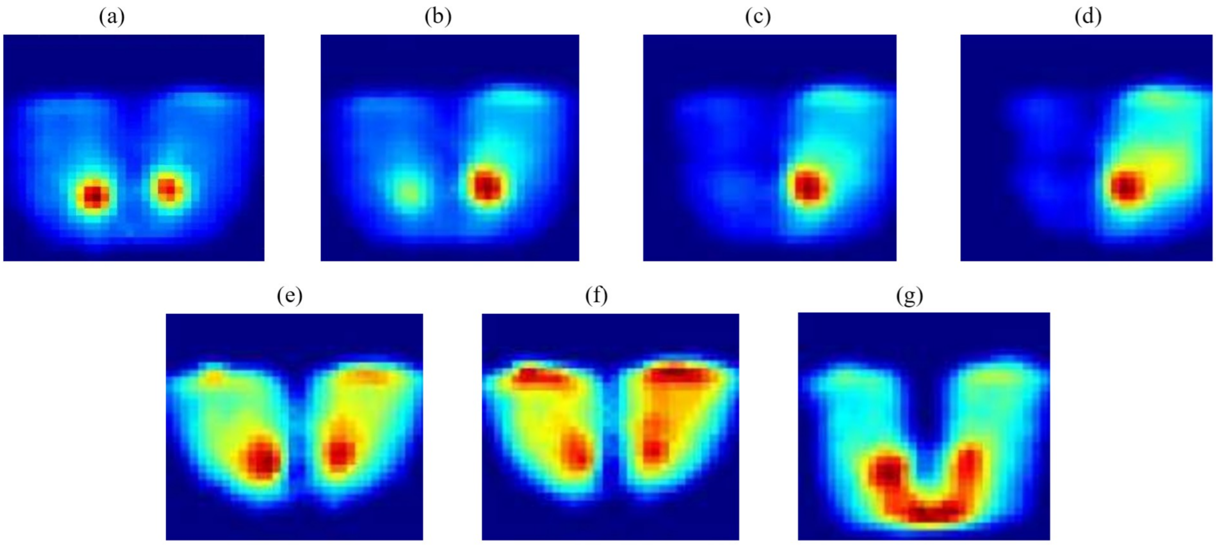

Figure 2. impression of pressure distributions at different inclinations: (a) no inclination, (b) slight inclination to the side, (c) strong inclination to the side, (d) very strong inclination to the side, (e) slight inclination forward, (f) strong inclination forward, (g) slight inclination backwards

3.2 Influence of additional weight

By adding additional weights, the pressures on the entire pressure mat are increased. The pressure distribution on the entire mat becomes more homogeneous and the pressure is again divided over the entire surface (Fig. 3). The red areas, i.e. the maxima, do not change their positions like they did before. It is interesting to see, that the maximum pressure is decreasing, when additional weight is added from 0 kg to 10.0 kg. That could be caused by the more homogenous pressure distribution. The maximum pressure reduces from 49 kPa with 0 kg additional weight to 37 kPa with 10.0 kg additional weight. An addition of 10 kg, could be interpreted as a slight forward inclination, since both scenarios reduce the maximum pressure and shift the pressure distribution more to the thighs.

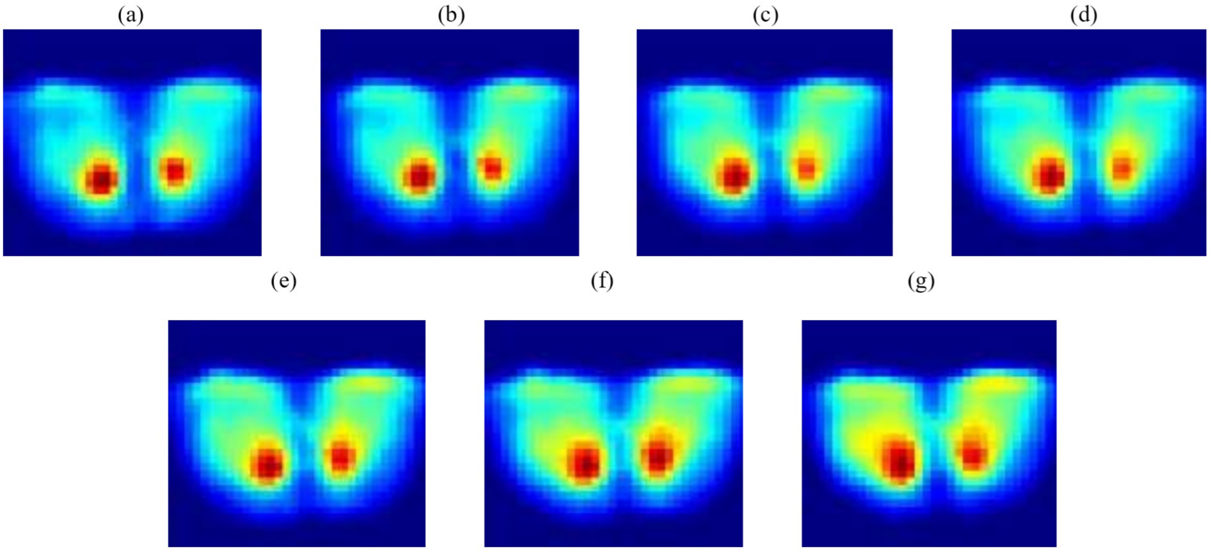

Figure 3. impression of pressure distributions at different additional weights: (a) 0.5 kg, (b) 1.0 kg, (c) 1.5 kg, (d) 2.0 kg, (e) 3.0 kg, (f) 5.0 kg, (g) 10.0 kg

3.3 Influence of specific postures

A movement of the arms without movement of the torso does not lead to an obvious change in the pressure distribution on the mat. Figures 4a, 4b and 4d are nearly identical. However, a difference can be observed by looking at the measured values. When both arms are stretched upwards, the pressure forward (thighs) gets reduced (16 kPa), but the pressure in the centre of the mat (hips) increases (47 kPa). The extension of the arms forward causes the pressure to be shifted forward, like when leaning slightly forward (compare Fig. 4c and Fig. 2e).

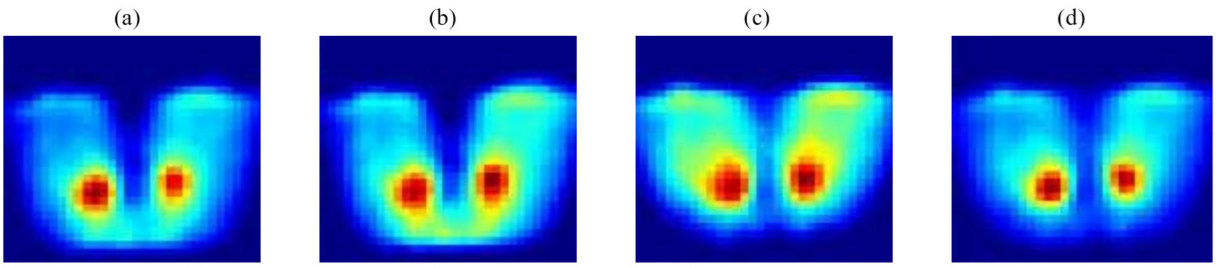

Figure 4. impression of pressure distributions while doing specific postures: (a) right arm stretched right, (b) left arm stretched left, (c) both arms stretched forward, (d) both arms stretched upward

4. Discussion

In this paper we have shown that it is feasible to distinguish movements automatically by analysing the pressure distribution on a pressure mat. We collected data on one adult male volunteer, who was asked to take different seating positions on the pressure mat with various additional weights. For the measurements we used the TexiMat system [10]. During the measurements, the volunteer was asked to take following positions: no inclination, 3 levels of inclination to the side (slight, strong and very strong inclination), 2 levels of forward inclination (slight and strong) and slight inclination backwards. Furthermore, additional weight was added to the volunteer, which was increased from 0 kg to 10.0 kg. Finally, different postures solely by the arms without a clear movement of the torso were examined. The results show, that an inclination to the side ensures a shift in the pressure distribution to the same side. The pressure is distributed over the surface and therefore the maximum pressure decreases. A forward inclination ensures, that the pressure distribution is less punctual, but more homogenous. The persons weight is distributed more on the thighs then on the hips. A backward inclination does the same like a forward inclination, only that the weight shifts to the back instead of the thighs. Adding additional weight increases the pressure on the entire pressure mat. The pressure distribution on the entire mat becomes more homogeneous and the pressure is again divided over the entire surface. A movement of the arms without movement of the torso does not change the pressure distribution significantly. In our research, we could not find many studies, which dealt with distinguishing movements on a pressure mat for drivers in a seated position. That's why we looked for more similar research areas. Several studies focus on classification of sleeping postures on a pressure mat using machine learning algorithms [4-7]. In this first exploratory work, our goal was to find out, if it is possible to find out the seating position with a pressure mat. So, we didn't include any machine learning algorithms yet but aim to include this analysis in the future. In addition, there are other difficulties that may bias the measurements. One of them are the volunteer's feet. By pressing or removing his feet to/from the ground the volunteer can change the pressure distribution on the mat. If the driver presses the gas pedal, the pressure on the right side of the pressure mat increases. As a result, the system detects an inclination to the right. Especially for the evaluation of the driver's health condition who presses the gas and braking pedal regularly, the influence of the foot position needs to be investigated further. The second difficulty is the angle of the spine during an inclination. For every inclination an angle has to be defined as a fix value. At the same angle of inclination, the absolute position of two people of diverse sizes is different. In the case of a tall person, the pressure distribution shift more to the side, than it shifts in the case of a small person. As a result, an inclination to the side can be evaluated incorrectly. This aspect must be considered for future work

5. Conclusion

The results of this study are very promising to automatically classify mundane movements. Although movements of the arms without moving the torso were not clearly detectable in this qualitative evaluation, quantitative differences in the measurements were recorded. The pressure distribution on the mat has symmetries that can be described and define descriptors for further quantitative analyses. Furthermore, using machine learning methodology might overcome this issue and enable the classification of defined movements. Improvements need to be made for future measurements like more data needs to be collected with a larger study group. In addition, more postures need to be included. In the future it would be of interest to record measurements of an entire day period to classify 'normal' situations.

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