# A Comparison Result Between Garment-Type and Bed-Sheet-Type Pressure Sensor for Pressure Ulcer Prevention

Ryosuke Onose[1(✉)], Yu Enokibori[2], and Kenji Mase[2]

[1] Graduate School of Information Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi, Japan
onose@cmc.ss.is.nagoya-u.ac.jp
[2] Graduate School of Informatics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi, Japan
enokibori@i.nagoya-u.ac.jp, mase@nagoya-u.jp

**Abstract.** Preventing pressure ulcer is one of important aims in nursing. Our project has tried to estimate and reduce the risk of pressure ulcer using the sheet-type pressure sensor. However, we found a problem that body-pressure dispersion cushions interfere with accurate sensing when the previous experiment in nursing institute. A garment-type pressure sensor proposed in this paper successfully detected body-pressure changes regardless cushion replacement as the sensor could classify more accurate score in the classification task of postures using both of sensors.

**Keywords:** e-garment · e-textile pressure sensor · Sleeping posture
Pressure ulcer prevention

## 1 Introduction

Pressure ulcer prevention is one of important achievements in the field of elderly care. One cause of pressure ulcer is high continuous pressure that is put on the same skin position. Some seniors and patients, e.g. bed-ridden seniors and spinal cord patients, cannot sufficiently move their bodies to prevent such cause. Therefore, care givers make sleeping-posture of patients change every 2 h to avoid pressure ulcer developing, even at midnight. It causes heavy workload of care givers. On the other hand, actual pressure ulcer developing threshold is depending on individuals' characteristics, such as micro existence of slight movement. Thus, there is a possibility of workload reducing by interval optimization of the care depending on the actual risk level changes estimated by sensors.

In order to establish that workload reducing, our project has been implementing a bed-sheet-type pressure sensor [3]. However, such bed-sheet-type sensor sometime cannot measure suitable values to estimate pressure ulcer development risks in unusual contact situations, such as body-pressure-dispersion cushion use


K. Murao et al. (Eds.): MobiCASE 2018, LNICST 240, pp. 233–238, 2018.
https://doi.org/10.1007/978-3-319-90740-6_16

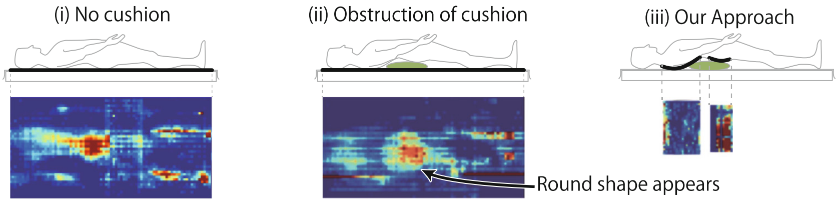


**Fig. 1.** Overview of approach difference and cushion's obstruction

and severe joint structure developing. An example is shown as Fig. 1(ii). Therefore, now we have been trying to implement a garment-type pressure sensor that can measure pressures put on patients' skin directory in most of situations [2]. An overview of our approach is shown as Fig. 1(iii).

In this paper, we introduce a result of comparison between the bed-sheet-type and garment-type pressure sensors. We collected the pressure-distribution data using bed-sheet-type and garment-type sensors and evaluated their performance to detect pressures on human body surfaces. Such evaluation was discussed through sleeping posture classification as described in Sect. 6. As the result, we found that the proposed garment-type pressure sensor could detect the pressure changes on the skin rather than a bed-sheet-type since the proposed garment-type sensor could classify postures more accurately.

## 2 Related Work

Sleeping-posture detection studies are used for pressure ulcer prevention because they can identify how long patients have remained in the same posture. Weimin et al. classified sleeping posture by a multi-modal approach using video and a 60-points pressure sensor [4]. However, use of video introduces privacy and refusal issues. Mineharu et al. [6] estimated sleeping postures only using the pressure distribution that is exerted on the bed. However, this study suffers from the same issues causes by body-pressure dispersion cushions described in Introduction.

The following are typical studies related to garment-type sensors. Paradiso et al. proposed a knit-type garment sensor that measures heart-rate, respiratory functions, and monitors body temperature [7]. Leong et al. implemented a sock-type pressure sensor to estimate the fitting of artificial legs [5]. However, no current device can measure the whole body-pressure, and no study uses such a device for pressure ulcer prevention.

## 3 Overview of Compared Sensors

In this section, we introduce an overview of our e-textile sensor and the compared two types of sensors.

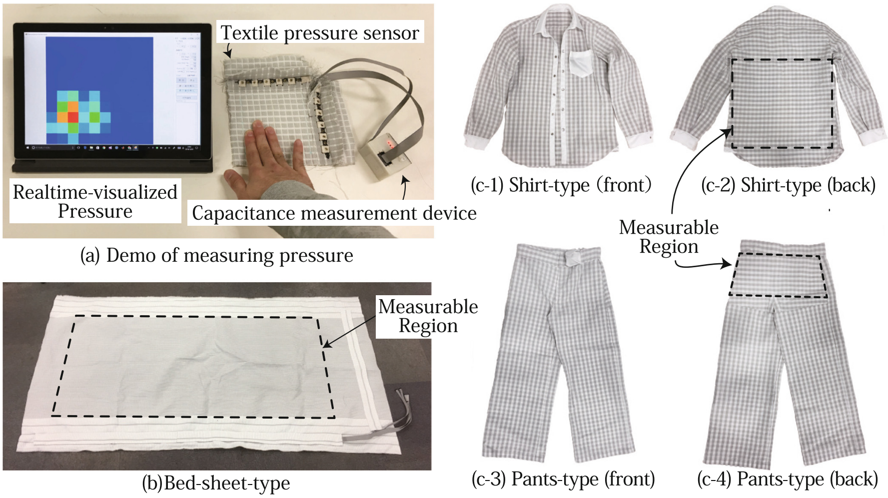


**Fig. 2.** Pressure sensor devices

### 3.1 Pressure Sensor Textile

An example of our textile pressure sensor is shown in (a) of Fig. 2. Our textile sensor has multiple capacitance sensors between the weft and the warp in the cross points of the gray conductive yarn lines. The capacitance value changes depending on the distance between the weft and the warp that is altered if additional load is added to the textile surface. Thus, we can measure the size of the load that is placed on the textile through capacitance value change measurements using a capacitance measuring device. The sensing point is 7.5 mm by 7.5 mm square, and the distance between neighboring sensing points is 10.0 mm.

### 3.2 Bed-Sheet-Type Pressure Sensor

An overview of our bed-sheet-type pressure sensor is shown in (b) of Fig. 2. The dashed region is the measurable area. Although the e-textile has $158 \times 78$ sensor points in the area of 158 by 78 cm, we combined four adjacent sensor points, $2 \times 2$, as one sensor point. Thus, there are $79 \times 39$ sensor points in the area. It is depending on a limitation of the capacitance measurement device.

### 3.3 Garment-Type Pressure Sensor

An overview of our garment-type sensors are shown in Fig. 2 (c-1)–(c-4). They are composed of the pressure sensor textile, except for the collar, sleeves, pockets, and front placket. They can measure the pressure wherever we set up electrodes and wires. Figure 2 shows the measurable region as a dashed region that covers the areas at risk for pressure ulcers. The shirt-type sensor has $18 \times 31$ sensor points. The pants-type sensor has $12 \times 23$ sensor points.

# 4 Dataset

We acquired matrix data using bed-sheet-type and garment-type sensors from 20 subjects (4 males and 16 females, height: $162.95 \pm 6.57$ cm, age: $34.65 \pm 7.18$, BMI: $20.06 \pm 1.90$). They alternated between supine and lateral positions five times each in 2 situations: with or without cushion.

# 5 Feature and Test Method Selection for Evaluation

Since pressure-distribution data can be considered as image, features that are suitable for image processing, such as HOG and SIFT, were expected to be suitable for in-bed posture classification. On the other hand, our data set seemed too small to applied such image processing features because the bed-sheet-type sensor has only $79 \times 39$ pixels. Therefore, we investigated which feature works well before the evaluation. The details are described in Sect. 5.1.

In addition, the most of classification accuracies obtained through the evaluation were higher than 0.9. It means that those distribution did not have normality and homoscedasticity. Therefore, we considered the use of a test method that do not require normality and homoscedasticity. The details are described in Sect. 5.2.

## 5.1 Selection of Features

Before the sensor comparison, we investigated the best feature vector from basic method in image classification. Candidate feature vectors are (1) $F_a$ for measured value as they are, (2) $F_b$ for HOG mainly used for human body detection, (3) $F_c$ for SIFT used for key point detection in images. SVM with RBF kernel was used for classification. Parameters are set as: gamma-value is set from $1 \times 10^{-3}, 1 \times 10^{-4}$, automatic (reciprocal number of dimensions' amount), and C-value is set from 1, 10, 100, 1000. These were optimized with Grid Search. In addition, the accuracies were derived by leave-one-subject-out cross validation.

The results of taking the average values of accuracies were $\bar{F_a} = 0.93$, $\bar{F_b} = 0.73$, $\bar{F_c} = 0.72$. Therefore, we used measured value as they are in consequent experiments.

## 5.2 Selection of Test Method

The distribution of accuracies when the pressure-distributions were classified lateral and supine postures is tend to come one side. In addition, homoscedasticity cannot be expected because there is no value of 1.0 or more and the mode value is close to 1.0. Therefore, we used Brunner-Munzel's test that does not assume normality and homoscedasticity [1]. Brunner-Munzel's test shows the almost same performance as Welch's test even in the case that samples have normality or homoscedasticity.

# 6 Comparison of Detecting Performance of Two Types

We investigated the detecting performance with both of bed-sheet-type and garment-type sensors. We used the data acquired by both of sensors.

## 6.1 Investigation

We assumed that classifier can provide the almost same performance for cushion use situation if sensors can detect correct pressure-value. Therefore, we evaluated accuracies for classification with cushion placement using the classification-model that is learnt from pressure-distribution without cushions. SVM with RBF kernel was used for the identification. The parameters were optimized by Grid Search for every trial. As the result in Sect. 5.1, we used one-dimensional vector reshaped from raw pressure-value matrix as the feature vector. In addition, the accuracy were derived by leave one subject out cross validation.

## 6.2 Result

Figure 3 shows the box-plotted accuracy derived from posture classification using the data acquired with bed-sheet-type and garment-type sensors. The garment-type pressure sensor showed higher intermediate value then the bed-sheet-type pressure sensor, with 15% type I error according to the Brunner-Munzel's test. It means that there would be a tendency that the garment-type pressure sensor can classify at more accurate than bed-sheet-type. From this result, garment-type pressure sensor caught the pressure-value change more sensitively regardless cushion replacement.

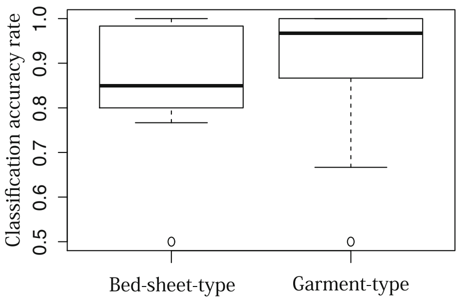


**Fig. 3.** Box-plotted accuracies of binary classification (supine and lateral postures)

# 7 Conclusion

We investigated the performance of detecting pressure-value changes with garment-type and bed-sheet-type pressure sensors aiming to detect the risk of pressure ulcer. We acquired the pressure-distribution data using both of sensors with 20 users and evaluated with posture classification with cushion placement. As the result, although type I error will occur at 15% according to Brunner-Munzel's test, there was tendency that the garment-type pressure sensor could classify more accurately. It leads the conclusion that is the garment-type pressure sensor has higher performance to detect high pressure than bed-sheet-type pressure sensor.

**Acknowledgements.** This work was supported by JSPS KAKENHI Grant Number 15H02736.

## References

1. Brunner, E., Munzel, U.: The nonparametric Behrens-Fisher problem: asymptotic theory and a small-sample approximation. Biom. J. **42**(1), 17–25 (2000)
2. Enokibori, Y., Mase, K.: Are they effective in actual workspace? - case of pressure ulcer prevention features. In: Internal Workshop on Informatics 2016 (IWIN 2016), Riga, Latvia, pp. 13–18 (2016)
3. Enokibori, Y., Suzuki, A., Mizuno, H., Shimakami, Y., Mase, K.: E-textile pressure sensor based on conductive fiber and its structure. In: Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication, UbiComp 2013 Adjunct, pp. 207–210. ACM, New York (2013). https://doi.org/10.1145/2494091.2494158
4. Huang, W., Wai, A.A.P., Foo, S.F., Biswas, J., Hsia, C.C., Liou, K.: Multimodal sleeping posture classification. In: 2010 20th International Conference on Pattern Recognition (ICPR), pp. 4336–4339. IEEE (2010)
5. Leong, J., Parzer, P., Perteneder, F., Babic, T., Rendl, C., Vogl, A., Egger, H., Olwal, A., Haller, M.: proCover: sensory augmentation of prosthetic limbs using smart textile covers. In: Proceedings of the 29th Annual Symposium on User Interface Software and Technology, pp. 335–346. ACM (2016)
6. Mineharu, A., Kuwahara, N., Morimoto, K.: A study of automatic classification of sleeping position by a pressure-sensitive sensor. In: 2015 International Conference on Informatics, Electronics & Vision (ICIEV), pp. 1–5. IEEE (2015)
7. Paradiso, R., Loriga, G., Taccini, N.: A wearable health care system based on knitted integrated sensors. IEEE Trans. Inf. Technol. Biomed. **9**(3), 337–344 (2005). http://dblp.uni-trier.de/db/journals/titb/titb9.html#ParadisoLT05