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A Study on Heat Strain Estimation Based on Unsupervised Learning Using Wearable Sensors

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Heat strain and heat stroke in hot and humid environments have been becoming more serious. Since it is difficult to recognize the progress by oneself, appropriate heat stroke prevention is important. This study focuses on a prediction technique for heat strain based on wearable sensors. As a prediction method, a supervised learning method by integrating multiple vital data has been studied [1]. On the other hand, since it is necessary to manually input the degree of heat strain for acquiring supervised data, this study introduced unsupervised learning to enable clustering without supervised data, and investigated the feasibility of heat strain estimation based on the unsupervised learning through experimental evaluations.

As an unsupervised learning method, we employed one-class support vector machine (SVM), which is one of outlier detection algorithms. Normal (non-heat strain) data were used as training data, and test data (unknown data) were clustered into either normal (predicted negative) or outlier data (predicted positive) according to the threshold values. In general, the true negative rate (TNR), false positive rate (FPR), true positive rate (TPR), and false negative rate (FNR) are used as criteria for the detection accuracy of classifiers.

In order to evaluate the accuracy of the heat strain estimation method by the unsupervised learning, vital data were measured from wearable devices on the an upper arm of 20 adult males working in a train maintenance factory. In the measurement environment, the average outside temperature was about 28 °C and the average relative humidity was about 72% (please see [1] for details). As the vital data, we used the data of personalized heat strain temperature (pHST, proposed in [1]), heart rate, and the amount of activity. Figure 1 shows the estimation accuracy against the threshold value under k-fold cross validation. The results show that there is an threshold that simultaneously optimizes both TPR and TNR. We can also see from Figure 2 that the proposed unsupervised system achieved more than 90% in the TNR and TPR.

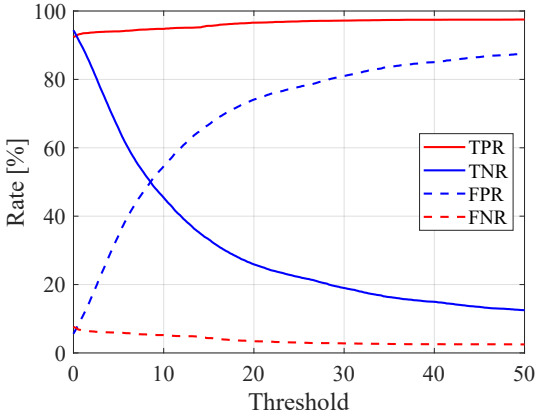

Figure 1. Estimation evaluation results

Actual \ Predicted	Negative	Positive
Negative	TNR 92.62 %	FPR 7.38 %
Positive	FNR 7.32 %	TPR 92.66 %

Figure 2. Confusion matrix

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References

[1] T. Shimazaki, et. al., "Heat stroke prevention in hot specific occupational environment enhanced by supervised machine learning with personalized vital signs," Sensors, vol. 22, no. 1: 395, Jan. 2022.