Intelligent reactions between human body and the environment: Design of smart clothing

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Abstract: The aim in smart clothing design is to embed sensors and other electronic devices into clothing to collect signals from the human body and the environment in order to make intelligent reactions accordingly. One of the biggest design challenges is the difficulty of addressing both comfort and sensor accuracy in actual real-world application. Usually skin-tight sensors yield good signal accuracy but an uncomfortable feeling for the wearer whereas comfortable sensors loosely in contact with the skin lead to poor accuracy. In this work, we propose a concept that employs a statistical machine learning approach to enhance the sensor performance by integrating the information from inaccurate non-contact sensors thereby allowing for greater accuracy without making people uncomfortable. We determine the feasibility of the concept by having sensors that are not in direct contact with the skin detect body temperature and then analyzing the results. We develop several types of features for the temperature sensors and integrate them into a non-linear regression model.

Keywords: Human Centric Design; Creative Design; Sensor; Machine Learning; Design and Technology; Smart Closing

1. Research Question

For this study, we focus our experiments on the task of predicting body temperature by integrating various sensors that are attached to the inner surface of a shirt but are not directly in contact with the skin. The goal is to maintain the accuracy at an acceptable level without making people feel uncomfortable.

2. Research Methods

2.1 Measuring Body Temperature

The major shortcoming for each of the measurement methods is low wearer comfort when embedded in clothing. We use electronic temperature sensors that are not in contact with the skin of the human body, where the sensors are located either in the space between the skin and clothing or between two layers of cloth (Figure 1and Figure 2, respectively). combining different types of signals from different sensors.

2.2Machine Learning Framework

The central problem of this task is to determine how to get an accurate approximation of body temperature using the signal from inaccurate sensors that function with noise.

2.3 Learning Algorithm

The regression algorithm we used in this work is support vector machine (SVM), a prevailing machine learning algorithm for classification and regression.

2.4 Experiments Results

A critical challenge in smart clothing design is the need to balance the tradeoff between the accuracy of sensors embedded in the clothing and the resulting comfort of the clothing. This study addresses this challenge by applying a machine learning approach to identify the best combination of sensor locations and measurement parameters that optimizes the sensor accuracy while keeping the comfort level constant.

3.Diagrams and Charts

Table1: Performance of sensors from different body parts

ID	Sensor-chest	Sensor-waist	Sensor-back	R^2
1	No	No	No	0% *
2	Yes	No	No	34.93%
3	No	Yes	No	5.99%
4	No	No	Yes	14.49%
5	Yes	Yes	No	33.52%
6	No	Yes	Yes	12.34%
7	Yes	No	Yes	26.49%
8	Yes	Yes	Yes	29.8%

Table2:Impact of features from different tome intervals

Features	R^2
Average temperature	13.5%
Average temperature + Variance	20.57%
Average temperature + Environment Temperature	27.93%
Average temperature + Variance + Environment Temperature	**34.93%**

Table3: Performance of different types of features

Time Interval (min)	R^2
1	30.86%
2	32.66%
3	20.80%
1+2	**34.93%**
1+2+3	33.23%

Table4: Performance of various kernels

Kernel	R^2
Linear (c = 0.01)	4.22%
Polynomials (d = 3, c = 0.1)	29.85%
RBF (g = 0.1, c = 0.5)	**34.93%**
Sigmoid (c = 0.5)	31.72%

Fig. 1 Garment with non-contact temperature sensors.

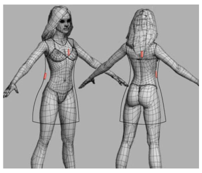


Fig. 2 The positions of sensors in garment pattern

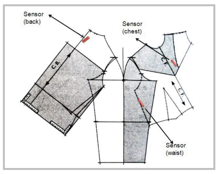
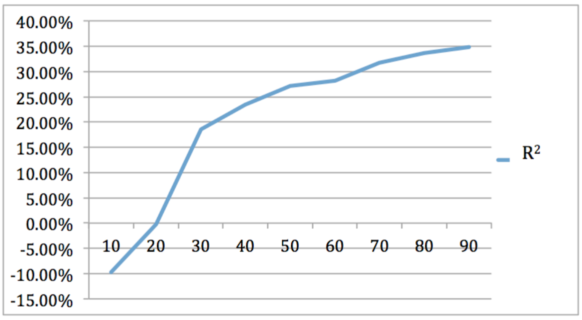


Figure 3: Learning curve with different amounts of training data



5. Conclusion

tradeoff of accuracy and comfort in smart clothing design, we used a non-linear regression method to find a better predictor of body temperature based on non-contact sensors attached to the clothes, so that an acceptable accuracy could be achieved without making people uncomfortable. The results were very promising. An over-30% performance improvement was achieved using only simple methods and a small amount of training data. This reveals great potential for further development of this method. Our contributions can be summarized as follows:

(1) We are the first to use machine-learning methods to optimize the tradeoff between comfort and accuracy in smart clothing design, which is one of the biggest challenges in this area.

(2) This study will contribute to both clothing design and artificial intelligence (making clothes smarter).

(3) Improving the accuracy using existing hardware can reduce the cost of developing new hardware.

In future work, we may try more features, learning algorithms, and training data to improve the performance of the current system. We may also apply machine learning to different types of sensors to measure other body indicators in healthcare monitoring. In addition, it would be interesting to combine textile-based sensors and machine-learning methods to achieve a better tradeoff between comfort and sensor accuracy in smart clothing design.

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