SELF-AWARENESS IN REMOTE HEALTH MONITORING SYSTEMS USING WEARABLE ELECTRONICS

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INTRODUCTION

Predicting patient's health deterioration is nowadays done by healthcare professionals with the help of Early Warning Score (EWS) systems. Vital signs such as heart rate, blood pressure, oxygen saturation, and body temperature are monitored and abstracted to an EWS. To help people who are currently not in the hospital, portable devices that monitor the patient's vital signs, calculating the EWS, and alarm (if a health deterioration is predicted) are needed [1]. However, such an automated device needs to monitor vital signs and calculate the EWS accurately. Noisy or faulty data can lead to a wrong calculation of the EWS, which can result in false, or - even worse - in missing alarms. Therefore, we propose a modified EWS (MEWS) system that is inspired by the concept of self-awareness. It provides a data reliability validation to correct the sensory data in case of faulty readings.

EXPERIMENTS/FUNDAMENTAL OF THE PROBLEM/EXAMINATIONS

Data Reliability is a meta-data which consists of accuracy and precision of sensory data [2]. It provides additional knowledge and perspective to the data. For example, a body temperature sensor that is detached from the patient's body provides accurate and precise data, but it is not valid in the context of the EWS system. Therefore, a reliable system must not consider such invalid values. For examining the reliability of the input data, our system uses consistency, plausibility, and cross-validation.

Consistency: Are the changes in the value consistent? For example, in our study, changes in the body temperature are not very fast; a change of several degrees per minute is impossible [3]. Whereas, a sensor failure or its detachment of the patient's body can lead to these fast signal changes that are not valid and, therefore, they should not affect the EWS.

Plausibility: Is the absolute value itself plausible? For example, an oxygen saturation outside 0 to 100 is not plausible, and regardless of the cause, it should not be considered for score evaluation of the EWS. The same goes for extremely high or low temperature. For instance, a sensory value of 60 or 70°C is highly unlikely anywhere in Europe.(if not impossible)

Cross-validity: Could data be plausibly valid or not, given some other (complementary) data and given certain conditions? For example, a body temperature of few degrees is valid only if the subject does not have any other vital signs (and is practically deceased). Otherwise, it shows a discrepancy and the data cannot be trusted.

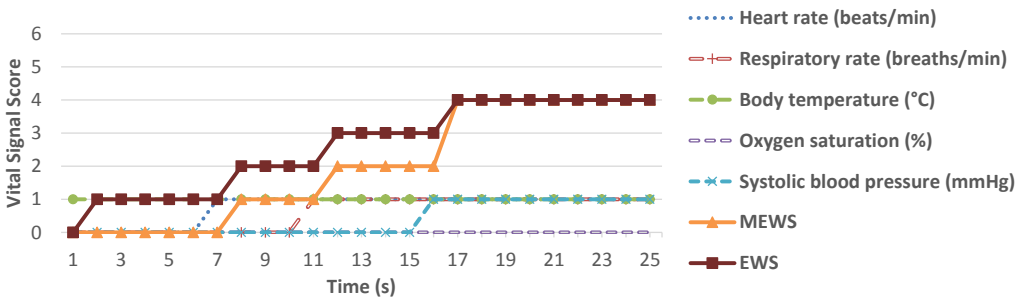

Figure 1: Calculation of the MEWS and EWS with the same data set. Body temperature is manually set to $32°C$ (score 1) and the other input signals are time-displaced (one after the other) to non-zero score values.

RESULTS

The data set that we applied is from experiments carried out by Azimi et al. [1], and contains records of heart rate, systolic blood pressure, respiratory rate, and oxygen saturation of a 35 years old healthy male subject. The measured temperature was replaced by a faulty temperature data to assess the system's behavior during a malfunction. Three different scenarios were simulated. For the evaluation of the first two validation steps, temperature data was introduced such that, firstly, was out of plausible range and, secondly, had an impossible slope (in the context of the body temperature). For the evaluation of the cross-validity, the body temperature was set to a non-perfect score but in a valid range without changes that are implausible. For the sake of brevity, only the cross-validation experiment is explained here in details. While the body temperature was set to $32°C$, which implies a non-zero score, the rest of the vital signs were score 0. Time-displaced, these input signals also changed to non-zero score, one input after the other. As shown in Figure 1, the conventionally calculated EWS (without cross-validity check) is higher because of the invalid body temperature. Such a case, nonetheless, is physiologically not possible and hence, the EWS should not be considered. On the other hand, MEWS is changing only when more than 50% (3 out of 4) of the input variables reach a non-zero score (that is, at 17s).

CONCLUSION

We show that it is possible to check the reliability of the input data with our modular solution based on self-awareness. The proposed system allows processing both the data and their meta-data, such as the reliability assessment. The modularity of our system and its good match of the data processing flow from lower to higher abstraction levels showed to be a promising architecture for EWS or similar systems. In future, we want to expand the system by a fuzzy logic reliability classification that is not just binary anymore. Instead of the input data is just reliable or not, it will have a grade of reliability.

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