Self-Aware Internet-of-Things Based Medical Early Warning Score System

Arman Anzanpour[1], Iman Azimi[1], Amir M. Rahmani[1], Pasi Liljeberg[1], and Hannu Tenhunen[1,2]
[1]Department of Information Technology, University of Turku, Finland
[2]Department of Industrial and Medical Electronics, KTH Royal Institute of Technology, Sweden
{armanz, imaazi, amirah, pakrli}@utu.fi, hannu@kth.se

I. Introduction

With the advent of IoT in healthcare, not only the traditional standalone equipment used in hospitals for monitoring, diagnosis and treatment will be replaced or reinforced with more intelligent and automated systems, but also in-home monitoring can be implemented in a more comprehensive way [1]. Early warning score (EWS) [2] introduced in 1997 is among the most critical applications which can be enhanced by IoT technologies. EWS is a standard procedure of predicting acute health deterioration for patients at risky situations or suffering from threatening sicknesses. EWS monitoring has been traditionally performed using paper-based methods for periodical checkups where, at each iteration, a score is calculated based on patients vital signs. The summation of all scores at every iteration then reflects the patients risk level [2].

In hospital, a patient often has a stationary position and predictable daily activities (e.g., resting) in a standard environment. Conversely, such a reliability cannot be easily achieved in non-clinical situations (e.g., home or nursing home) due to the susceptibility of vital signs to situation variations (i.e., patient's condition and the surrounding environment). Therefore, an adaptive system is required to behave autonomously with respect to the changes in patient's activities and the situations. In this work, we introduce a self-aware EWS system to provide patients with a personalized remote monitoring system. We also propose an adaptive solution inspired by [3] where we also consider "Attention" as a beneficial feature to improve the energy efficiency, sensitivity, and specificity of our approach by adjusting the priorities of sensory data.

II. The Proposed Self-aware EWS system

The proposed EWS system, which is based on our IoT-based EWS platform presented in [4], has been reinforced by using the concept of self-awareness in the architecture as well as in the analysis layer to enable the system to be personalized for remote patient monitoring. It implements two main functionalities, situation awareness and attention.

Situation awareness: A patient under monitoring may have several activities (sleeping, walking, etc.) in different situations, where the system collect data from multiple sensors to consider (cancel or adapt) the impact of situation variations in vital signs and to obtain a correct score. With this intention, we consider such impacts from two different viewpoints: patient state and environmental state. Patient state includes constant parameters (e.g., age, body mass index, gender) and variable parameters (e.g., physical condition and activity). Using customized machine learning and pattern recognition algorithms, the type and influence of the patient state on the final score are determined. For instance, a sharp increase on the scores, while a patient is travelling, is more seriously considered due to the lack of medical back-ups in close proximity.

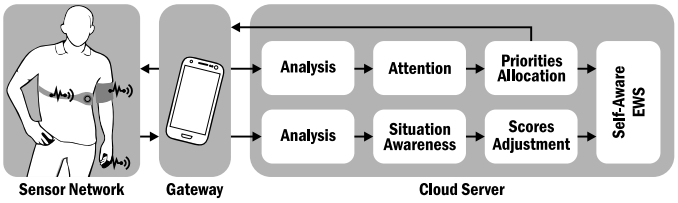

Fig. 1. Architecture of the proposed self-aware IoT based EWS system.

Attention: Paying "Attention" to critical parameters from data acquisition (e.g., data collection rate) to analysis phase can improve different system characteristics such as the sensitivity and specificity of the results as well as the energy efficiency of the system, leading to prompt decisions and system responsiveness in case of emergency. In this regard, our self-aware EWS system allocates different priorities to parameters during the monitoring and adaptively adjusts them. For instance, for a patient with cardiovascular disease, the system assigns a higher data collection rate and faster processing intervals to heart-related parameters. In addition, the system offers further personalization by considering patient requirements, and removing redundant data and parameters which have insignificant influence on the final results.

III. Demonstration

In our IoT-based self-aware EWS system, sensor network layer collects data via wearable devices to obtain different health data such as heart rate, respiration rate, physical activity, posture, temperature and SpO_2. In the gateway layer, we use a smartphone that receives data from sensors via Bluetooth. It manages data sampling rate and network connectivity. Moreover, it sends data to the cloud server while Internet is available and records it when the network is not accessible. The cloud server layer has been developed for all the calculations (i.e., EWS, situation awareness, and attention). As a case study, the system recorded a set of data from a 35 years old male subject for 24 hours and continuously calculated the early warning score considering the situations (e.g., ignoring high scores related to heart rate while subject was climbing stairs) and attention (e.g., adjusting the frequency of data collection). The proposed proof-of-concept system demonstrates that self-aware implementation of an early warning score system considering environmental and activity parameters can offer promising features and enhancements.

References

[1] A. Zarabzadeh et al. Features of electronic early warning systems which impact clinical decision making. In *CBMS Intl. Sym.*, pages 1–4, 2012.

[2] Morgan et al. An early warning scoring system for detecting developing critical illness. *Clin Intensive Care*, 8(2):100, 1997.

[3] J. S. Preden et al. The benefits of self-awareness and attention in fog and mist computing. *Computer*, 48(7):37–45, 2015.

[4] A. Anzanpour et al. Internet of Things Enabled In-Home Health Monitoring System Using Early Warning Score. In *MobiHealth*, 2015.