uHealth: Smart Clothing Enabled Intelligent Ubiquitous Health Monitoring System

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***Abstract*—The development of Internet of Things and artificial intelligence has greatly advanced the design and implementation of remote monitoring systems for intelligent healthcare services, of which the sensing and data analysis components play central roles. To this end, we propose a smart clothing-based ubiquitous health monitoring system, called uHealth, to collect physiological signals and behavioral data of the users and to support high-level applications. Specifically, we here introduce the design of smart clothing and illustrate the architecture of uHealth and its key components.**

I. Introduction

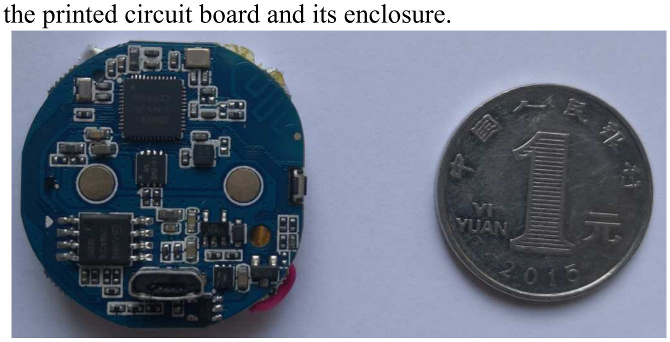
Our world is facing serious economic and social issues that are partially accompanied with the population aging, such as ever-increasing healthcare demands and imbalanced nursing resource distributions, which poses a grand challenge to the quality of life of older individuals, especially empty nesters. On the other hand, recent years have also witnessed the rapid development and integration of new technologies (e.g., sensor, Internet of Things (IoT) and artificial intelligence). They have been widely used in different fields and enabled researchers to develop smart solutions for a better problem-solving process. Accordingly, researchers have designed and developed a large number of algorithms, tools, systems, and platforms with an aim to provide pervasive and context-aware services such as fall detection, wellness evaluation, medication reminder, and rehabilitation instruction [1, 2]. For example, Haque et al. evaluated and discussed ambient intelligence for healthcare in the hospital and daily living spaces [3].

From the view of information flow, how to automatically and accurately obtain the physiological signs and behavior of an individual and perform meaningful data analysis remains critical for IoT enabled health monitoring applications. There are generally three types of methods accordingly to the used sensors: vision-, environment sensor-, and wearable-based methods [2, 4]. Compared with vision-based and environment sensor-based methods, wearable-based methods are suitable for both the indoor and outdoor scenarios and can measure the physiological signs and physical activity data accurately. Due to the fact that one is required to wear devices, however, it is important to ensure user comfort and less-intrusiveness to better support long-term use. Considering the properties (e.g., less intrusive, and direct contact with the skin surface) of clothes, they are much more suitable for sustainable heath monitoring than smart watch, ring, belt, and even smart phone. To this end, we propose a ubiquitous health monitoring system (uHealth) based on smart clothing for healthcare. The system can pervasively collect both physiological and behavioral data of an individual and further support high-level applications with the intelligent data analysis engine. Accordingly, we here present the smart clothing enabled system and briefly discuss its applications for elderly healthcare.

II. Smart Clothing

With an aim to develop product-level smart clothing rather than a prototype, we choose the electrocardiograph (ECG) chip and G-sensor towards a tradeoff between user demands (e.g., practicability and functionality) and resource limitations (e.g., device sizes and energy consumption). Such a choice, even though simple, can measure physiological and behavioral indicators and potentially support high-level applications. Specifically, we can infer the heart rate, stress, and mood from ECG data, and recognize human activities with G-sensor. The Bluetooth protocol is used to transmit the sensor data of smart clothing to a smartphone or server.

As for the hardware, we design a circuit board to assemble the sensing units, Bluetooth, Microcontroller unit, and lithium battery in a sealed enclosure. The wearable device has the shape of a circle with 3.8 cm in diameter and can be easily attached to clothes with the customized button. Fig. 1 shows the printed circuit board and its enclosure.



(a) The printed circuit board and a RMB 1-Yuan coin.

(b) The front and reverse sides of the device.

Fig. 1. The printed circuit board and its enclosure.

The two bright circles in Fig. 1(a) correspond to the points that are connected with the ECG input. Flexible conductive fabric is used and contact points are placed on the two sides of the clothes in order to collect ECG data. This makes the smart clothing less-instructive and comfortable as much as possible. It is washable if we remove the device from the clothing. Also, the device has the waterproof level of IPX4 that is resistant to water splashes from any direction. Besides, we use the component-based development, where we take as independent components the ECG chip and G-sensor and use them jointly or separately according to the specific application scenarios such as only using the ECG chip to monitor heart rate.

III. Health Monitoring System

In this section, we introduce the proposed smart clothing enabled health monitoring system. Fig. 2 gives the architecture that has four layers of a typical IoT application: *sensing layer*, *network layer*, *middleware layer*, and *application layer*.

1) Sensing Layer

The function of this layer is to use various sensors to sense, collect, record, and store information about the environment and users. In our system, the used sensors include ECG chips, G-sensor, and Bluetooth. They are integrated in the device and can collect the physiological signals and physical activity data of the user.

2) Network Layer

It receives data from the sensing layer and is responsible for data transmission with mobile network, Internet, and wireless sensor network. It enables the connections of objects, devices, and servers. We here use the wireless Bluetooth protocol to send data to a smartphone for storage and further analysis.

3) Middleware Layer

This layer lies between the network layer and application layer. It aims to process the sensor data collected by the smart clothing. In this layer, we can use cloud computing resources and data mining algorithms to analyze the data. For example, we provide feature extraction and feature selection methods to extract discriminant features from the raw sensor data, analyze the ECG data to obtain heart-related parameters, and train an activity recognition model by fusing the ECG and G-sensor data.

4) Application Layer

The application layer delivers the end-users services such as emotion management and behavior analysis [5, 6]. In our work, we provide fall detection, wellness evaluation, and heart rate monitoring. For example, we collect behavior data of an older individual over long periods of time and use the temporal similarity to detect behavior changes. We also design a fall alert using the G-sensor data for timely response.

Besides, there are techniques that are shared across the four layers. For example, security is involved in the aspects of link, network, data, and system, and it concerns privacy protection, identity authentication, encryption, key management, and communication security. Quality of service (QoS) and trust assessment are also a requirement in the network environment.

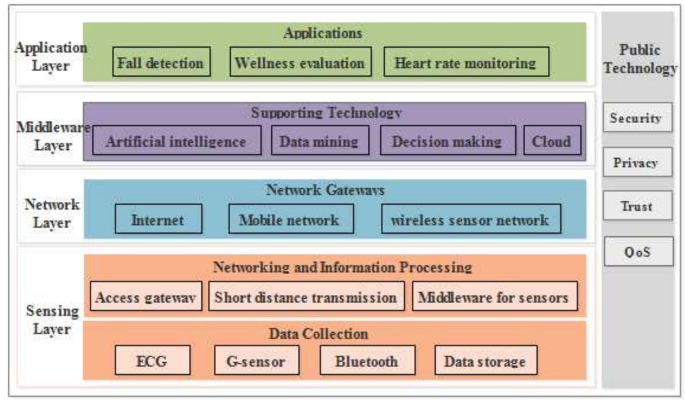


Fig. 2. The proposed four-layer architecture: sensing layer, network layer, middleware layer, and application layer.

IV. Conclusion

With an aim to advance elderly healthcare, we propose a smart clothing enabled health monitoring system with the IoT and artificial intelligence techniques in this study. We first detail the designed smart clothing and illustrate its features. We then introduce the system architecture by illustrating each of the four layers. For the future work, we plan to integrate other sensing units (e.g., gyroscope, audio, temperature, light sensors) into smart clothing under the constraints of resources such as the device sizes and energy consumption.

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Reference

[1] P. Rashidi and A. Mihailidis, "A survey on ambient-assisted living tools for older adults," *IEEE J. Biomed. Health Informat.,* vol. 17, pp. 579-90, December 2012.

[2] A. Wang, S. Zhao, C. Zheng, J. Yang, G. Chen, and C.-Y. Chang, "Activities of daily living recognition with binary environment sensors using deep learning: A comparative study," *IEEE Sensors J.*, vol. 21, pp. 5423-5433, February 2021.

[3] A. Haque, A. Milstein, and F.-F. Li, "Illuminating the dark spaces of healthcare with ambient intelligence," *Nature*, vol. 585, pp. 193-20, September 2020.

[4] M. Haghi, K. Thurow, and R. Stoll, "Wearable devices in medical internet of things: Scientific research and commercially available devices," *Healthc. Inform. Res.,* vol. 23, p. 4, January 2017.

[5] J. Zhang, Z. Yin, P. Chen, and S. Nichele, "Emotion recognition using multi-modal data and machine learning techniques: A tutorial and review," *Inform. Fusion*, vol. 59, pp. 103-126, July 2020.

[6] A. Wang, G. Chen, J. Yang, S. Zhao, and C.-Y. Chang, "A comparative study on human activity recognition using inertial sensors in a smartphone," *IEEE Sensors J.*, vol. 16, pp. 4566-4578, June 2016.