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Development of a low-cost wearable device for Covid-19 self-quarantine monitoring system

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A R T I C L E I N F O

Keywords:
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BLE

A B S T R A C T

Objectives: The objective of this study is to develop a Bluetooth-based low-cost wearable device for a self-quarantine monitoring system.
Study design: The designed wearable device focuses on data transmission via Bluetooth, integration of tracking, tracing, and fencing into a single system, and low energy usage from its battery.
Methods: We design a wearable device using smartphone equipped with GPS, a communication module, Bluetooth low energy (BLE) and a high-capacity battery as a solution for low-cost device with excellent efficiency. We divide the designed system into two parts, the client and the server parts. The client parts are wearable device attached to the individual being monitored and the mobile phone as GPS and telecommunications module. Whereas the server parts are user interface, digital map, notification system, and backend database. Then, the whole system was tested in laboratory and field scale.
Results: We tested functions of integrated device such as wearable device, mobile applications, and server for laboratory scale test. Then, performing field test with geofencing, communication module, battery, web interface, and resource computing usage. The field test was conducted on a small scale with a limited number of trial patients. We found that the designed wearable device was successfully implemented for both self-quarantine and centralized quarantine requirements. The majority of the components used met the specifications and functioned properly as well.
Conclusions: A BLE-enabled wearable device can be used for tracking self-quarantine patients. The laboratory and field scale tests demonstrate that the designed wearable device functions properly and meets the requirements. We anticipate that this low-cost wearable device is effective in limiting Covid-19 virus spread and preventing the formation of a new Covid-19 virus-infected cluster.

1. Introduction

An outbreak of a pandemic disease known as Coronavirus disease-2019 was discovered at the end of 2019. This disease is highly contagious, deadly, and may be even more dangerous in people who have comorbid conditions such as hypertension, diabetes, or ischemic heart disease [1]. The primary mode of transmission is through respiratory droplets, which justifies the recommendation to wear masks when leaving the house and meeting new people [2]. The residents who are suspected of being exposed to Covid-19 or potentially transmitting Covid-19 after traveling from the red zone are usually required to undergo 14 days of self-quarantine [3].

Typically, self-quarantine is carried out under the supervision of local authorities at the neighborhood association or sub-district level, based on the principle of trust. However, self-quarantine does not work properly since many people violate quarantine rules by traveling and interacting with others.

Various technologies were developed for individual monitoring to provide contact tracing during the Covid-19 pandemic. In general, these technologies can be classified as a smartphone application for movement monitoring, a smartphone application for interaction tracing, a QR code identity bracelet, or a GPS bracelet [4–10]. However, those technologies have disadvantageous, like vulnerable to be damaged by its users, large size and high-power consumption due to its numerous embedded electronic components, needs an extra cost, easy to conceal and remove due to its simplicity, privacy and security issues, high cost and a complex

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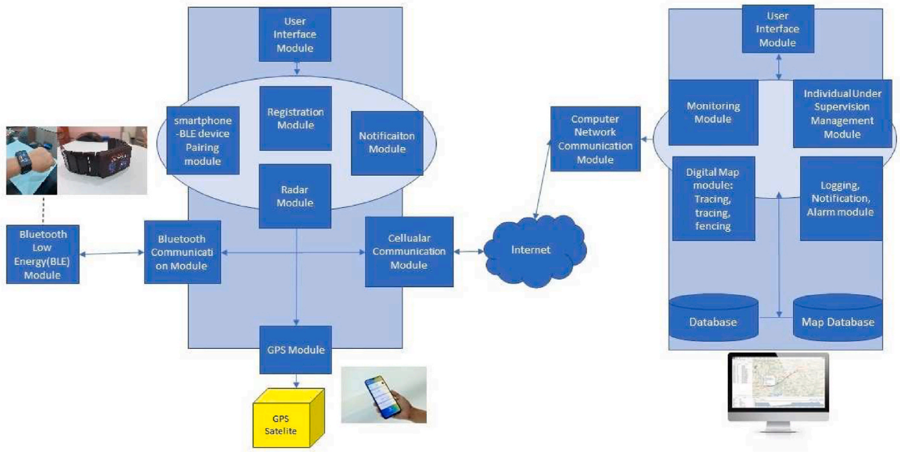

Fig. 1. An overview of wearable device design system.

system.

For these reasons, we designed a wearable device in the form of wristband based on BLE to track and monitor self-quarantine patients that is quite reliable, difficult to damage or remove by its users, easy to operate, low cost, simple, secure for privacy, and high efficiency. It is also supported with rechargeable battery and waterproof magnetic mesh which acts as protector and fastener.

2. Methods

The proposed system design is divided into two parts, the client and the server parts. The client parts are wearable device attached to the individual being monitored and the mobile phone as GPS and telecommunications module. Whereas the server parts are user interface, digital map, notification system, and backend database. The wearable device equipped with BLE chip with a unique ID for identification. The wearable device sends a beacon to the smartphone which serves as a GPS component provider, providing location information from individuals under supervision, as well as a communication component, delivering information from the wearable device to the server.

There are three distinct users of mobile application, which are individuals under supervision, supervisors or authorities, and public. Individuals under supervision are given registration features, information about their self-quarantine status, and a reporting function to their supervisor if there is any change related to a health condition or a problem with the wearable device equipment. The supervisor is given access to know the status of self-quarantine performed by individuals under supervision, such as violation status of self-quarantine, which is informed by notification or alarm. The public uses this mobile application to avoid infected patient under quarantine. Fig. 1 shows an overview of wearable device design system.

3. Results

Each part of wearable device is tested on a laboratory and field scale. Lab-scale testing is performed to determine the compatibility of each module functions. Meanwhile, limited field-scale testing is performed to test various use-cases involving various system modules. Field testing reveals potential issues that may arise if each module is integrated into a single system to form a more significant function. Such as, due to poor signal quality, GPS is not precise when defining position. In this condition, the monitored individuals appear to be moving. False movement occurs when the GPS position lock is unstable, making it difficult to decide on a geofencing zone setup. The solution is to set a threshold that prevents the system from alarming when there is a sudden change in position in a short period of time. It can be labeled as a fake movement. Furthermore, if an individual is in an area with poor signal and mobile apps cannot connect to the server, this is detected by the server as a violation of quarantine rules. The solution to this problem is to add a module to the mobile apps that detects the historical condition of the poor signal, so that when a poor signal is detected, there is no alarm trigger for violating quarantine rules.

4. Discussion

According to laboratory results (wearable device, mobile apps, and server), each component functions properly as a pre-designed system. The battery can live for more than two weeks. Meanwhile, the field test scale reveals that the mobile apps component is a critical issue in terms of resource computing usage. When used for continuous tracking, it uses more computing resources and energy. However, this issue is solved by enabling only the processes that are required, resulting in a lighter computing process. Furthermore, a strong signal level for GPS and mobile smartphone is required to accurately control quarantine patients.

When compared to similar available technologies [11–15], the proposed system outperforms the other wearable devices in terms of cost and reliability. Although the wearable device developed in Ref. [14] is also Bluetooth-based, the device type, i.e., token, limits its reliability. Meanwhile, in this proposed system, the wearable device takes the form of a wristband that is resistant to force removal by users, ensuring that all users are constantly monitored. Based on the test, we select a specific sampling time and power for more efficient battery usage. The battery in our design lasts 30 days and is rechargeable, making this wearable device low cost and reliable. Users can use the wearable device for the entire 14-day quarantine period without having to charge it in the middle.

5. Conclusions

The designed wearable device was successfully developed for both self-quarantine and centralized quarantine requirements. Most of the components used met the specifications and functioned properly. From the interface to the backend module, mobile apps are being improved to make them more stable, comfortable to use, and energy efficient. To ensure data privacy on the server, additional apps was installed. This wearable device is deserving of use in the control of a small number of quarantine patients. Following the implementation of system components and server configuration to support the system's capacity and scalability, a larger scale of testing is required to obtain more feedback on system implementation from users.

Author statements

This study does not require ethical approval because it does not employ humans as research subjects. A number of participants actively test the designed wearable device to ensure that it works properly to control quarantine individuals. The designed wearable devices track participants' movements during self-quarantine and send an alarm signal if they violate quarantine rules. Furthermore, this research is supported by Indonesia Ministry of Research and Technology and funded by Indonesia Ministry of Finance. We do not have any competing interests with other employers or companies.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhip.2022.100299.

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