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Healthcare and Emergency Response Service Platform Based on Android Smartphone

Hoan-Suk Choi [1] and Woo-Seop Rhee [2,*]

[1] Hanbat National University; Post-doctor, hkrock7904@gmail.com
[2] Hanbat National University; Professor; wsrhee@hanbat.ac.kr
* Correspondence

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Abstract: *As the elderly population is becoming an aging society, the elderly are experiencing many problems. Social security costs for the elderly are increasing and the un-linked social phenomenon is emerging. Thus, the social infrastructure and welfare system established in the past economic growth period are in danger of not functioning properly. People socially isolated or with chronic diseases among the elderly are exposed to various accidents. Thus, an active healthcare management service is imperative. Additionally, in the event of a dangerous situation, the system must have ways to notify guardians (family or medical personnel) regarding appropriate action. Thus, in this paper, we propose the smartphone-based healthcare and emergency response service platform. The proposed service platform aggregates movement of relevant data in real-time using a smartphone. Based on aggregated data, it will always recognize the user's movements and current state using the human motion recognition mechanism. Thus, the proposed service platform provides real-time status monitoring, activity reports, a health calendar, location-based hospital information, emergency situation detection, and cloud messaging server-based efficient notification to several subscribers such as family, guardians, and medical personnel. Through this service, users or guardians can augment the level of care for the elderly through the reports. Also, if an emergency situation is detected, the system immediately informs guardians so as to minimize the risk through immediate response.*

Keywords: e-health; Healthcare Service; Emergency Situation; Cordova; Ward Monitoring

1. Introduction

Among the total population, more than 14 percent of people aged 65 or older are defined an aged society, and 20 percent are defined a post-aged society. Japan already entered an aging society ahead of Korea. At the end of 2015, 33.92 million people in Japan (26.7% of total population 127.11 million) were aged 65 or older. The number of people aged 75 or older amounts to 16.41 million that is 12.9% of the total population. Japan's population, which first declined in 2005, has continued to decline for 10 years. Thus, the social infrastructure and welfare system built in the past economic growth period are in danger of not working properly. Also, a problem about aged society has arisen such as public pension and social security-related funding, unlinked social phenomenon [1]. In addition, physical abilities of older people such as vision, reflexes, and muscle strength are increasingly impaired. There is a higher probability of suffering from diseases than younger people such as high and low blood pressure, osteoporosis, glaucoma and cataracts [2, 3]. Also, the strength of muscles or bones are weak, which can cause serious damage in the accidental event of daily life such as a fall. For example, falls can easily occur on slippery surfaces, such as bathrooms and wet floors. When fallen has occurred, the patient with osteoporosis has a higher probability of bone fracture than a healthy person [4]. Older people tend to have slow natural recovery when bone fractures occur, and often require surgery. In this case, advanced surgery can be required by additional conditions, such as vascular or heart disease, and significantly increases the physical burden of the patient [5, 6]. In the worst-case scenario, the patient may not be able to act alone or his life may be in danger. For example, heat exhaustion and heatstroke are caused by prolonged exposure to hot conditions, especially during the summer in hot, humid environments. It also happens when you work a lot or exercise a lot in a hot environment. Especially, when working in the countryside on a summer day with exposed to heat for a long time, there is a high probability of heat exhaustion and heatstroke. Specially, heatstroke is a very dangerous disease that can lead to death in severe cases. In this case, the patient's temperature should be lowered as soon as possible [7].

Therefore, it is very urgent for single household members or older people to manage user activities and health conditions based on continuous monitoring. Also, detecting emergency and taking immediate response in the emergency situation are extremely significant. According to [8], the mortality rate is very high if proper treatment is not provided within the Golden Time according to injury in the accidental event. Therefore, in this paper, we proposed the smartphone-based healthcare and emergency response service platform. The proposed service platform aggregates movement relevant data in the real-time using a smartphone that users always carry with them. Based on aggregated data, it always recognizes the user's movements and current state using the human motion recognition mechanism. Therefore, the proposed service platform provides real-time status monitoring, activity report, health calendar, location-based hospital information, emergency situation detection and cloud messaging server based efficient notification to several subscribers such as family, guardian and medical personnel.

In the ordinary situation, the user or guardian takes care of their health condition through the exercise reports which is generated based on the real-time status analysis results. In addition, in the event of an emergency, such as a fall, the system immediately informs guardian and medical personnel of the emergency situation. And then, guardian and medical personnel can minimize the risk through immediate response.

The rest of paper is organized as follows. In Section 2, we survey some related work on existing healthcare service. In Section 3, we propose the smartphone based healthcare and emergency response service platform. This section describes the proposed service environment, platform architecture, database structure and information delivery procedure to notify emergency. Section 4 provides implementation results about the proposed service and application. Finally, we conclude with remarks on future work in Section 5.

2. Related Works

The goal of healthcare service is to provide valuable information and efficient healthcare for patients. Recently, it is going to use variety of Internet of Things (IoT) including wearable devices to measure and diagnose health condition for patient [9].

[10] analyzed the changes in healthcare paradigm due to convergence of Information & Communication Technology (ICT) technologies and components of smart healthcare services. It is changing from a traditional diagnostic-treatment-oriented paradigm to a preventive-care oriented paradigm, and the personalized healthcare is emerging. They divided the healthcare sector into three categories: Telehealth care provides telemedicine; Mobile healthcare built on personalized smart devices; Health analysis based on machine learning and deep learning technology to predict and prevent diseases. Also, they defined steps of a smart healthcare system as follows:

1. Digitize: Step to digitalize health status by collecting bio data and life logs using IoT and various sensors.
2. Analysis: Step to analyze and produce results of collected data through ICT technology.
3. Service: Step to continuously manage health by providing the right service to the target user.

The platform proposed in this paper is also designed and implemented based on these three steps. [11] provided healthcare service analysis to improve usability, focusing on the most actively used for hospital and pharmacy search applications. The top three applications were analyzed (i.e., Gooddoc, Ddocdoc and Pocket Doctor). Hospital/ pharmacy search services are basically provided based on location. Also, it has expanded to provide a variety of search methods and health information contents. In common, all services provide current location-based and around subway stations search modes, and support detailed medical subjects and specialties. Recently, hospital reservation and comments functions were added. Therefore, these services allow users to access health information and medical institutions in an easier way.

[12] proposed a structure for service composition to realize interoperability between medical services or between service functions. It consists of a Healthcare Service Element (HSE) and a Healthcare Service Agent (HAS). HSE is all individual services associated with healthcare. It exchanges information based on a defined interface. HAS actively selects the desired service element and provides the appropriate service configuration and delivery through the service composition when required by the user. Based on these technologies, personalized and context-aware medical services can be provided.

[13] studied the Android based healthcare service component for customized healthcare services. The proposed service handled user personal data and food information to provide available calorie for a day and recommended exercise. To do this, they are defining data formations, studying reasoning methods, and providing an augmented reality technology for food information based on marker recognition. The defined data format was implemented by ontology to provide inferred information such as insufficient amount of exercise. In addition, they registered food photos in the Vuforia Developer Portal and established a marker recognition system using Unity. As a result, personalized health information is provided through inference based on ontology.

[14] has developed a smartphone-based postnatal care service that can help pregnant women. Pregnant women use their smartphones to collect and monitor vital signs from four types of personal health devices (i.e., pressure system, weight system, blood glucose meter and oxygen saturation meter) and send them to pregnant women caregiver. The caregiver constantly monitors and helps pregnant women's conditions through the mobile Web.

According to preventive-care oriented paradigm [10], the [11, 13] and [14] provided healthcare related service based on smartphone. The [11] and [13] provided useful information for health management such as, hospital information and recommended amount of food or exercise. The [12] and [13] provided personalized service. And the [14] described importance about patient condition monitoring to caregiver. Therefore, we propose the healthcare and emergency response service platform. This platform provides smartphone based real-time activity monitoring and health calendar for daily healthcare and management. Also, it provides user location based hospital information. For healthcare and emergency response service about target user (e.g., patient, older people, child and a person living alone), the proposed platform detects dangerous situation and notifies immediately to protectors.

3. Health-care and Emergency Response Service Platform

Figure 1 is an overview of the proposed smartphone-based healthcare and emergency response service platform (HEALTICE). The proposed service is provided as an Android App based on Cordova [15]. It collects movement (acceleration data), location, temperature, and weather information of target user and environment in real time. In order to recognize the user's status, the service platform analyses the collected information of user and environment. The target recognition movement status are defined as sitting, squatting, slow walking, normal walking, fast walking, and driving.

The status recognition mechanism was implemented based on our previous research work [16], to recognize a consecutive motion including transitions among various motions. The previous research work describes the adaptive movement data weighting method and state transition model for detecting a vulnerable condition. The state information which recognized smartphone based on the status recognition mechanism, is uploaded to the HEALTICE server in real time.

The HEALTICE server manages information such as user profile, health data, guardian profile to provide emergency warning, user status monitoring, and user activity report functions to pre-authorized guardian and medical personnel based on the service App.

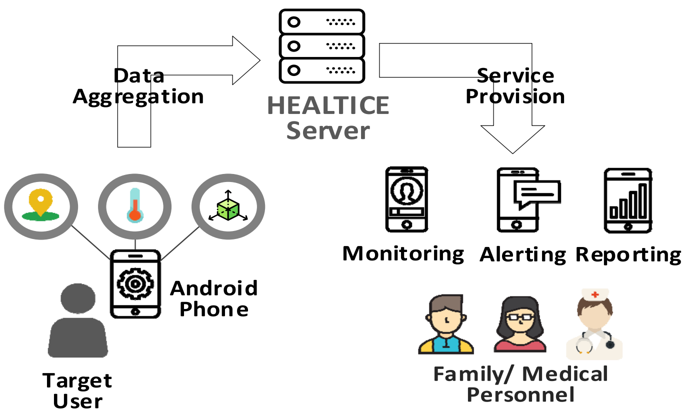

Figure 1. Smartphone-based healthcare and emergency response service platform overview

3.1 Healthcare and emergency response service platform functional architecture

To provide healthcare and emergency response service, the functional architecture of the proposed service platform is shown in Figure 2. The platform consists smartphone App, HEATICE server and Firebase Cloud Messaging (FCM) server.

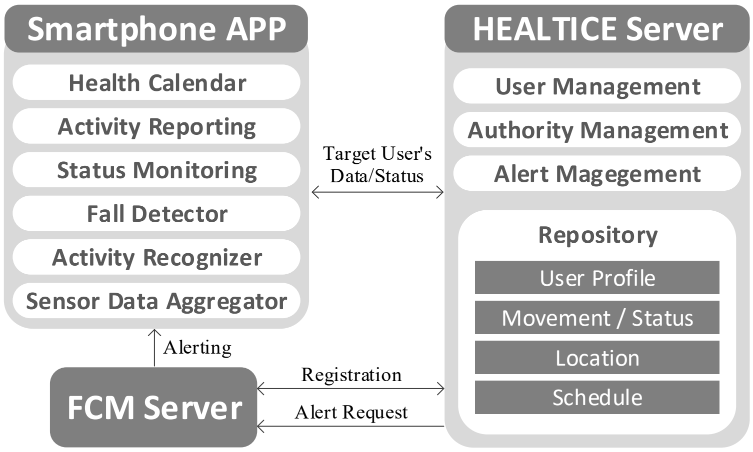

Figure 2. Proposed platform functional architecture

The smartphone App includes six sub-functions, sensor data aggregator, activity recognizer, fall detector, status monitoring, activity reporting and health calendar. The sensor data aggregator uses the Android Application Programming Interface (API) to collect movement sensor data from acceleration, Global Positioning System (GPS), and step sensor. The activity recognizer recognizes the user's activity types based on collected data periodically. The fall detector continuously detects whether a fall occurs and an analyzed result (i.e., movement and fall state) is stored at the App internal Database (DB) and is sent to the server. The status monitoring provides a function to monitor the user status based on continuously aggregated data and analyzed results. The activity reporting analyzes the user's motion data and generates an activity report. This report provides ratio information for each motion in a specific period of time. Based on this, a user can make exercise plans and identify the overall activity level. In addition, the health calendar provides calendars to store and notify health information such as medication administration and exercising schedule to help health management. All information collected and generated by the App is stored on the HEALTICE server to be provided to the ward and guardian. It also enables to maintain data and settings based on user account when reinstalling the App.

The HEALTICE server includes three sub-functions and repository, user management function, authority management function and alert management function. It stores and manages the information collected from App based on Hypertext Preprocessor (PHP) and provides subscription information and authority management of service users who are ward (e.g., children, patient) and guardians (e.g., family, medical personnel). The repository stores user profile, movement and status data, location data, healthcare schedule data. It also stores profile and authority information of guardians who authorized to access. The user management function provides user subscription and profile information management. The authority management function provides guardian registration and authentication to allow appropriate access. The alert management function notifies dangerous situation to guardians (family and medical personnel) who are authorized to acquire that information in accordance with predefined authentication. The alert is sent by FCM server as a push message.

FCM is a cross-platform messaging solution that lets user reliably deliver messages [17]. It was developed and serviced by Google. Using FCM, user can notify a client App that has new email or other data to synchronize. For use cases such as instant messaging, a message can transfer a data of up to 4KB to a client App. It provides three main capabilities, send notification messages or data messages, versatile message targeting and send messages from client Apps. FCM sends notification messages to display for user. It also can send data message. FCM supports three ways of message distribution to client App which are to single device, to groups of devices, or to devices subscribed to topics. For reliability, FCM sends acknowledgments, chats, and other messages from devices back to your server through the FCM's reliable and battery-efficient connection channel [17]. As a result, we can deliver messages (user status or dangerous alert) efficiently to smartphones which are authorized.

The proposed platform manages the server to allow the transfer of information to specific targets. In order to deliver information, the server requests the FCM to deliver the information to several destinations.

3.2 Database structure for healthcare and emergency response service platform

Figure 3 shows the proposed database structure for the service platform. The database consists of four tables. The *Healticesv* table stores users' information (i.e., user name, encrypted password, sex, birth date, phone number, and push server token information). Based on this table, the motion table stores user's motion data that is connected to describe a source of data. The *motion* table stores user name, timestamp, movement status and phone number which uses as an Identification (ID) as a key value. The calendars table stores calendar information contains phone numbers, calendar id, title of the schedule, and timestamp. Health calendar function is provided based on this data. The *locationData* table stores the name, timestamp, latitude, and longitude and phone number as a key value. This location data is used to provide activity reports or guardian mode.

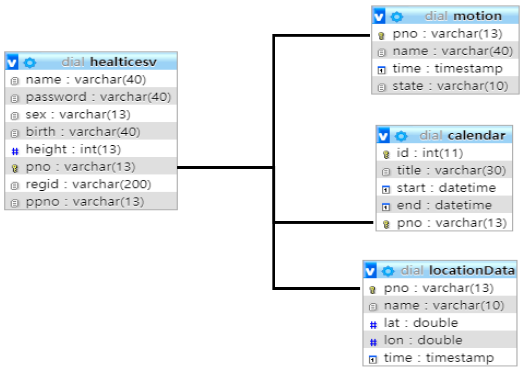

Figure 3. Relational database structure for healthcare and emergency response service

3.3 FCM based message delivery procedure

If there are many users who want to access information of specific target, traditional one-to-one messaging has the problem that servers repeatedly send messages. To solve this problem, various message delivery PUSH methods are being utilized. Generally, the messaging server generates and delivers a sender's message instead to many subscribers who want to receive certain information. Thus, a sender can easily deliver a message to hundreds and thousands of very large subscribers through a single message transmission. A user who want to receive certain information should send subscription request to the messaging server. Therefore, we utilize messaging server (FCM server) based on three procedures in the proposed healthcare and emergency response service.

1. User registration procedure: In order to send/receive messages, all user must be registered to the FCM server as shown in Figure 4. First, a user sends the registration request message to the FCM server. It includes sender's ID, API key and App ID for token issuing. When a token issued by the FCM server is received, it is forwarded to the HEALTICE server to store the token of a user.

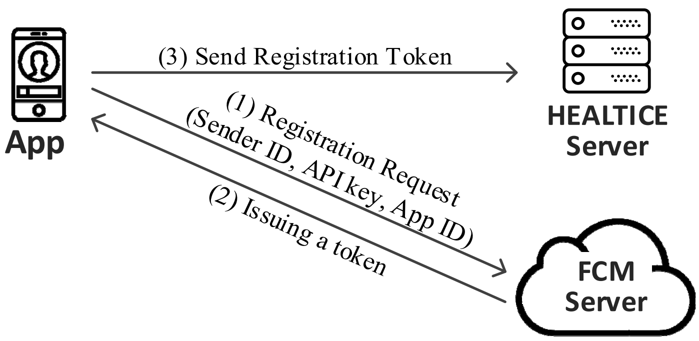

Figure 4. User registration procedure

2. Guardian registration procedure: Like the user, guardians (e.g., family, medical personnel, etc.) request the token and store it on the HEALTICE server. For a guardian to subscribe information about the ward, we must know the sender (ward)'s topic [18]. To do this as shown in Figure 5, subscribers (guardians) request a specific user (target ward)'s topic to the HEALTICE server. The HEALTICE server replies to the topic request according to determining the authority to acquire the information (ward's topic). The subscribers (guardians) request subscription of the ward's topic to the FCM server.

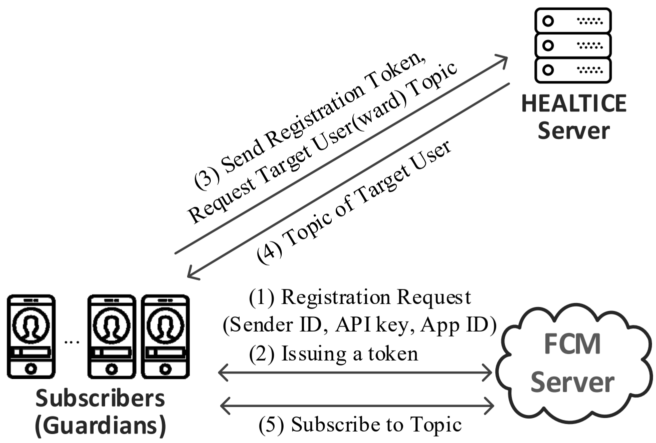

Figure 5. Guardians registration procedure

3. Message delivery procedure: When user registration and topic setting (subscription request) are completed, message can be delivered. Figure 6 shows this procedure. When service data needs to be delivered (e.g., emergency situation detected, activity data requested), user's App sends message to the HEALTICE server. Then, the HEALTICE server requests to the FCM server for sending a message using the user's topic. Then, the FCM server sends a message to all subscribers based on the subscriber's token of the topic. These procedure enables the efficient delivery of message from a sender (ward) to number of subscribers (guardians).

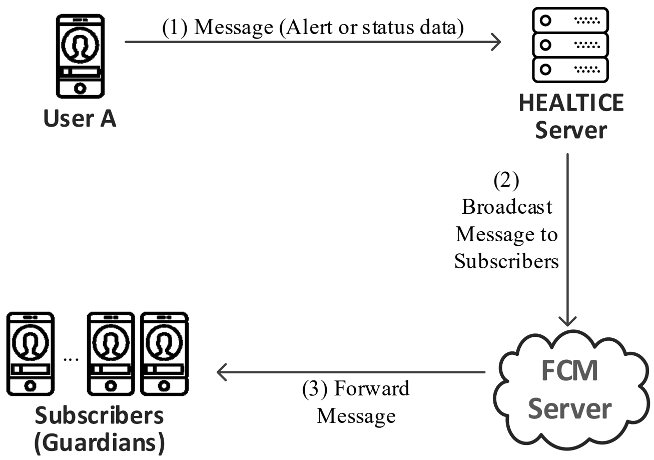

Figure 6. Message delivery procedure

3.4 Activity recognition mechanism

Generally, for motion recognition of target user, one or more motion sensors or devices which contains multiple sensors are attached to the target. Through this sensors or devices, the target motion data are aggregated. Also, [19, 20] proposed multi sensor-based recognition methods which aggregates data from different types of sensor such as camera and acceleration sensor. Based on the collected information, various analysis techniques, such as pattern analysis and numerical analysis [21], machine learning and deep learning, are used to extract the characteristics of motion.

This chapter introduces the activity recognition mechanism based on collected motion data. This mechanism proposed in the previous research work [16] which allows users to classify the types of activity regardless of the angle or position of the user's smartphone. It consists four components as shown in Figure 7. First, the user's movement data is collected once every 0.1 second through the sensor API of smartphone. The collected movement data are pre-processed to remove redundant distribution areas, depending on the data characteristics of the target activity. The preprocessing function extracts Local Maximum Value (LMV) from the collected data. LMV is the maximum value of period of data, which extracts the upper level of the movement data distribution area. Natural movements of user consist of combinations of different activities and transitions between activities. Therefore, the method to recognize a stable motion area and activity transition areas are required. To this, [16] proposed the LMV adaptive weighting method. This method calculates new weighted LMV based on the newly extracted LMV and the existing values in the movement data weighting function. Activity recognition function classifies current activity status using weighted LMVs. To recognize complex situations, such as driving or fall and dangerous situations, the activity status is determined using the previous recognition results. As a result, the proposed platform provides healthcare and emergency response services based on these recognition results.

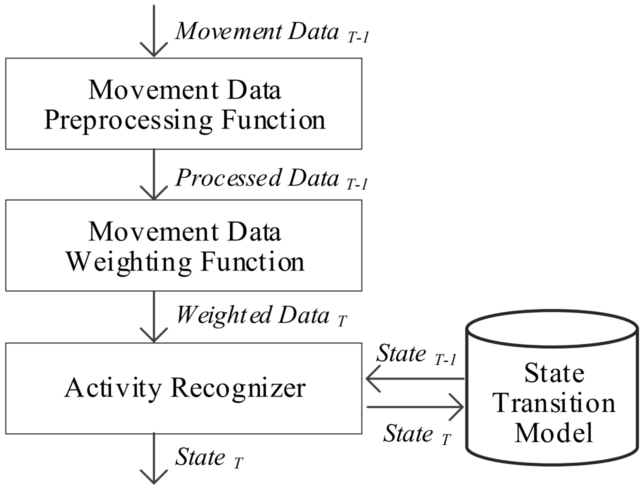

Figure 7. Activity recognition mechanism

4. Implementation Results

This chapter describes the results of implementation of the proposed healthcare and emergency response services. As mentioned in chapter 3, the proposed service was implemented as Android App. App development should be developed on a framework dependent on the mobile platform such as IOS, Android, blackberry, etc. But These platforms require overlapping development costs to provide service for each platform. Therefore, in this paper, the hybrid framework Cordoba [15] is used to develop the proposed services.

Cordoba [15] is a representative hybrid App development framework that provides integrating Software Development Kit (SDK)s for multiple mobile platforms. It creates application source code with HyperText Markup Language 5(HTML5), Cascading Style Sheets 3(CSS3), jQuery, and JavaScript. The source code is converted to the appropriate language for each mobile platform through the Cordoba SDK to create the App. Cordoba provides APIs for using various functions of smartphones. The APIs are implemented by JavaScript objects to utilize acceleration, cameras, audio, compass, network, contacts, files, events, GPS and storage which are built into smartphone. In this paper, acceleration, location, and gait data are collected by Cordoba API. It also used file APIs to process and store data.

Figure 8 shows the main screen of the HEALTICE service App. It shows the user's current status, weather information, schedule, and exercise report graphs in a comprehensive manner. If the menu button is selected at the top, the detailed menu is displayed as shown the right side of Figure 8. First, there is the user membership signup and login menu. And if the wards are set, it shows a menu button to check the status of the target wards. The activity recognition menu shows the real-time status of the current movement. The health calendar menu provides a variety of health-related schedule. The activity report menu provides analysis results of historical and daily movement information based on activity recognition result about user self or ward. The hospital search menu provides information about surrounding hospitals based on the current user's location. Lastly, the emergency alarm sending menu notifies current emergency situation to the guardian.

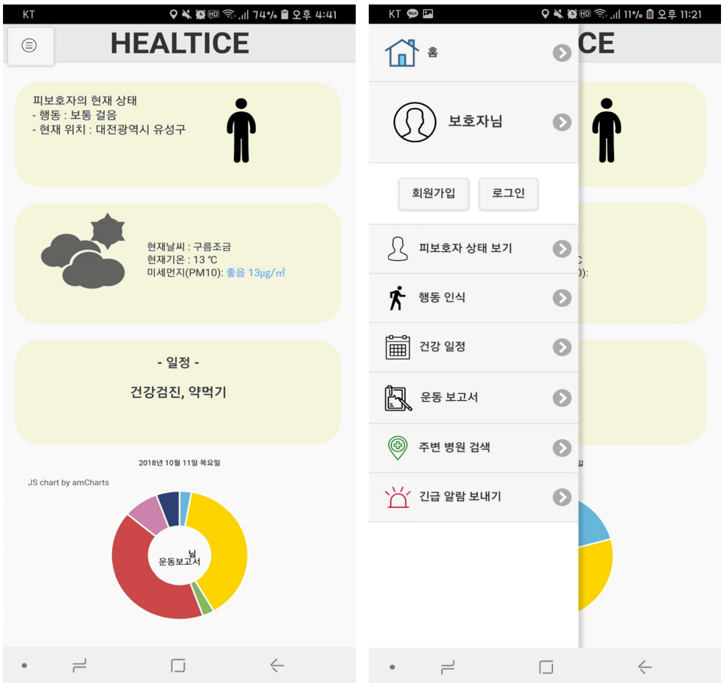

Figure 8. HEALTICE service App main screen

After the user is registered as a member, the FCM server issues a token for message transmission as described in Chapter 3.3. Figure 9 is a sample data of user information in *healticesv* table of database after three users are registered. It includes user name, password, sex, birthday, height, phone number, and FCM tokens. Some areas of captured image were blinded to protect personal information.

name	password ▲ 1	sex	birth	height	pno	regid
한[illegible]	[illegible]	여	199[illegible]5	172	010[illegible]	cSpsGz1GfIU:APA91bFacKMaX
김[illegible]	[illegible]	여	199[illegible]1	160	010[illegible]	fwxKs1WAuik:APA91bE46lcj0PI
이[illegible]	[illegible]	여	199[illegible]9	180	010[illegible]	seklfjowjgllslla45-4kRjrWQ7HN

Figure 9. Sample data of user information database (*healticesv* table)

User self or ward's current location and activity reports can be accessed by selecting the ward status and activity report menu. Figure 10 shows the activity report and current location service view about ward. Exercise reports provide a daily exercise graph by recognizing the ward's status in real time. It can also show the activity of a particular period of time. Through this, users can check their or their ward's activity history and they (guardians) can change the pattern of activity or detect unusual patterns for wards. The right side of Figure 10 shows the current location of the ward. In the case of children or a person with poor mobility, guardian needs to periodically check the target's location and to take appropriate action. Therefore, the service platform shows the location of the target on Google Maps based on the location information of the wards.

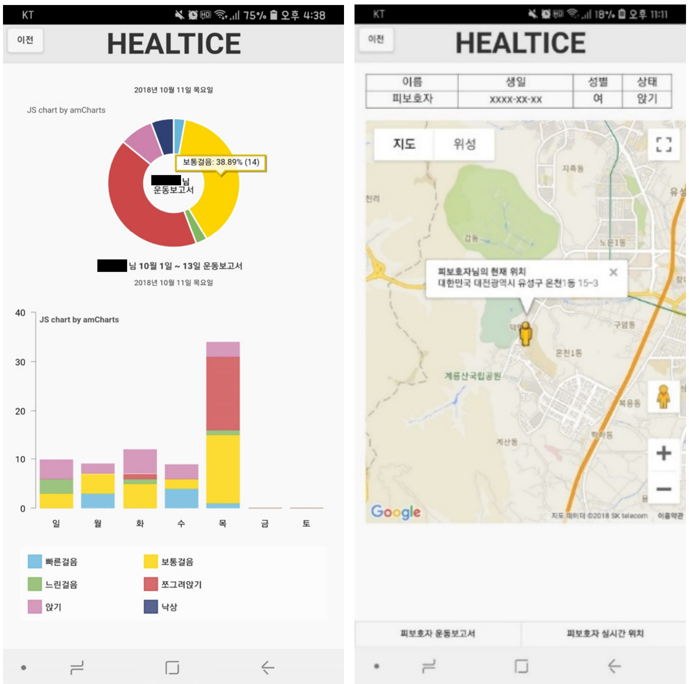

Figure 10. Activity report and location view

The status information detected based on the motion data collected in real time is continuously stored in the database. And this data utilizes to make an activity report. Figure 11 shows a sample of the status database which is stored in real time. It includes the measured time, status value, name and phone number. Based on this data, the activity report is provided by statistical calculations. In the event of an emergency situation, such as a fall, an emergency notification is given to the predetermined user (e.g., family, guardian, medical personnel).

time	state	name	pno
2018-10-11 16:33:37	squat	한	010
2018-10-11 16:33:38	squat	한	010
2018-10-11 16:33:40	squat	한	010
2018-10-11 16:33:41	squat	한	010
2018-10-11 16:33:42	squat	한	010
2018-10-11 16:33:43	fall	한	010
2018-10-11 16:33:44	squat	한	010
2018-10-11 16:33:46	squat	한	010
2018-10-11 16:33:47	squat	한	010
2018-10-11 16:33:48	squat	한	010
2018-10-11 16:33:49	squat	한	010
2018-10-11 16:33:50	squat	한	010
2018-10-11 16:33:52	fall	한	010
2018-10-11 16:33:53	squat	한	010
2018-10-11 16:33:54	squat	한	010
2018-10-11 16:33:55	squat	한	010
2018-10-11 22:45:59	normal	한	010

Figure 11. Sample data of user status database (*motion* table)

As an additional function, HEALTICE provides hospital information located nearby based on the current location as shown the Figure 12. First, user can choose the type of hospital, such as the left side of the Figure 12. Because this function implemented with Google Maps API to provide geographic information, it provides six types of hospital based on categories provided by Google Maps. If the user selects an orthopedic hospital, the App provides information about the orthopedic hospital located nearby current location, and the map displays hospital icon. If user selects a specific hospital icon, App shows the hospital's detailed information (address, phone number, and homepage) as shown on the right side of the Figure 12. This function allows users to quickly find hospital information around them.

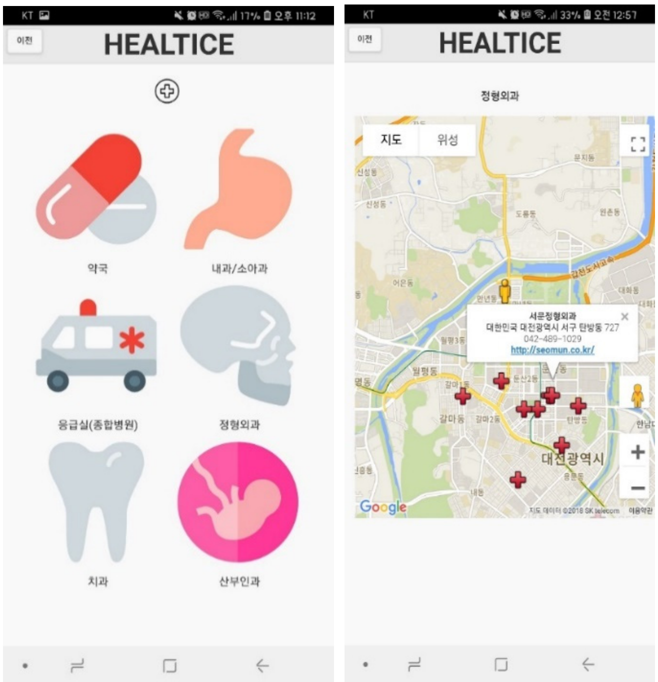

Figure 12. Location based hospital information

To manage a medical schedule, such as regular medication or medical checkups, the proposed App provides a health calendar as shown in the Figure 13. The left side of the Figure 13 shows the ward's basic information and exercise report graph. Also, today's schedule is provided simply. When user selects a schedule, the calendar is provided as shown on the right side. And then you can choose a specific date to register an event need to notify.

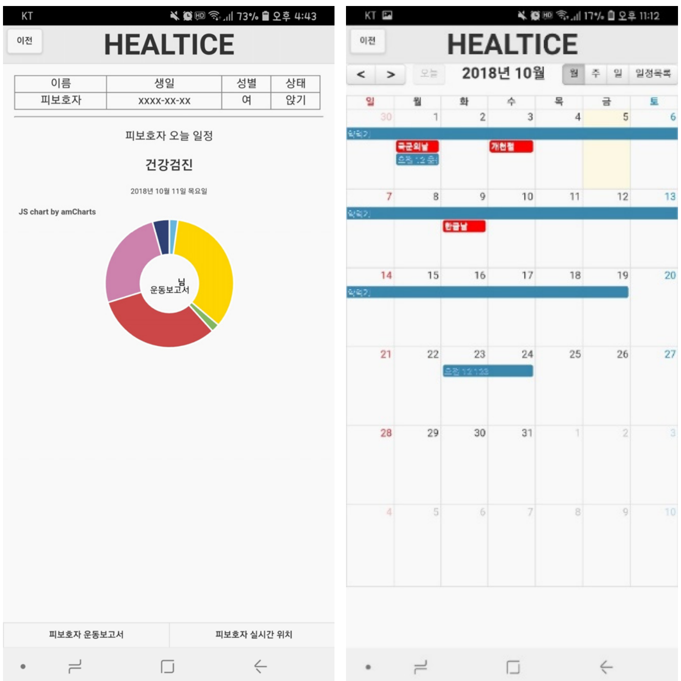

Figure 13. Health calendar

Figure 14 shows a schedule data sample of the *calendar* table. When a new schedule is added, one record which contains five tuples (i.e., title, start and end time, id and phone number of a user) is created.

id	title	start	end	pno
96	약먹기	2018-09-28 00:00:00	2018-10-20 00:00:00	010[illegible]
109	운동하기	2018-10-01 00:00:00	2018-10-02 00:00:00	010[illegible]
117	건강검진	2018-10-09 00:00:00	2018-10-12 00:00:00	010[illegible]
119	회의	2018-10-10 00:00:00	2018-10-11 00:00:00	010[illegible]
124	건강검진	2018-10-11 00:00:00	2018-10-12 00:00:00	010[illegible]

Figure 14. Schedule data sample of *calendar* table

In addition, user can send an emergency message to the guardian by Short Message Service (SMS), and if the ward is falling and not movable condition, the proposed App notifies dangerous situation to the guardian automatically via push message.

5. Conclusion

With the advent of an aging society, the importance of healthcare increases continuously. Especially for single-person households, an immediate response is difficult when an accident occurs. Therefore, in this paper, we proposed the smartphone-based healthcare and emergency response service platform. To supporting healthcare of users, the proposed service platform provides real-time status monitoring, activity report, health calendar, location-based hospital information and efficient notification to several subscribers. Also, it supports emergency situation detection of the ward and notifies the detected situation to guardians such as family and medical personnel. This paper described the functional architecture of the proposed healthcare service platform. It consisted of a smartphone App for a user, HEATICE server and messaging server (FCM server). The App aggregates user motion data and recognizes current status based on activity recognition mechanism in real-time. Also, through the recognized result the proposed App provides activity reporting and health calendar. All information processed by App is sent to the HEALTICE server. The HEALTICE server provided user management, authority management, alert management and repository. Therefore, when detecting the dangerous situation, the preregistered persons (guardians: family, medical personnel) can know the situation immediately. And, they can take appropriate action (response) in a short time. We implemented the proposed App through Cordova SDK, and described the implementation result with database example of HEALTICE server.

As a further study, we are going to conduct a study of machine learning based situation recognition method which utilizes contextual data as well as motion data of target user.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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