A Daily Activity Monitoring System for Internet of Things-Assisted Livingin Home Area Networks

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Article Info	ABSTRACT
	In this paper, a daily activity monitoring system for Internet of Things (IoT)-assisted living in home area networks is proposed in order to provide care for elderly people who live alone. The proposed system consists of two main parts: an IoT-assisted living space with contactless activity sensors, a help trigger, and an emergency gateway and a daily activity monitoring server witha range of components including data collection, event and user management, activity analysis and reporting, and so on. The contactless activity sensors can be placed any where in the home, and the emergency gateway collects data from them, detects emergency situations reported through the help trigger, and communicates with the daily activity monitoring server. The server analyzes and reports the daily activities and activity patterns of elderly users using a predefined activity index. In addition, unexpected emergency situations can be estimated and prevented through analysis of the activity information.

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1.   INTRODUCTION

In 2013, the Korean Ministry of Health and Welfare reported that 1.12 million households consisted of elderly people living alone. A 2011 report of Statistics Korea estimated that the proportion of the total population comprised by the elderly (people over the age of 65) would reach 12.2% in 2013 and continuously increase to 24.3% in 2020 and 37.4% in 2050. The elderly over the age of 85 were expected to significantly increase to 2.5% of the population in 2030 and 7.7% in 2050, from 0.9% in 2013. Aging still presents many challenges to the elderly due to limitations in their physical activity, age-related diseases, and cognitive decline, although advances in medicine have enabled people to live longer [1]. In fact, the elderly who live alone face many limitations in terms of recognition and response to their daily activities and risks. They require full-time care provided by families or home health aides, but most of them suffer from family disorganization, low income, and/or poor living conditions.

In order to address the serious social problems related to the care of the elderly and other vulnerable groups, increasing research has been devoted to telecare systems and activity monitoring techniques [2]-[6]. In first-generation telecare systems, alarms were directly generated in response to user-generated emergency notifications. In other words, the user had to recognize an emergency situation and physically operate an alarm generator, because sensor technology was not utilized in first-generation telecare systems. The user was required to always wear the alarm generator, which communicated with equipment linked to the wired or wireless phones in a home. In contrast, second-generation telecare systems exploited sensor technology to monitor the user and recognize emergency situations. Even if the user is unconscious and helpless, the alarm

generator is able to work automatically in cooperation with sensors. At that point, predefined procedures related to the alarm can check the user's condition, make contact with the designated guardian and emergency agencies, and so on. Third-generation telecare systems are expected to use smart home and ambient assisted living technologies with advanced sensors, and they will be improved to monitor and manage the user's living environment. Second-generation systems provide elder care services using only data from the sensors attached to the user and the areas near the user, whereas third-generation systems provide intelligent elder care services that estimate and deal with potential dangers through the monitoring of abnormal environmental changes, and by using data from advanced sensors and information from ambient networks.

In recent years, Internet-of-Things (IoT) services have attracted much attention in the context of smart homes that integrate healthcare technologies [7]-[11]. The IoT refers to a global infrastructure for the information society that enables advanced services by interconnecting physical and virtual things, based on existing and evolving interoperable information and communication technologies. This paper presents a daily activity monitoring system based on the IoT concept as a third-generation telecare system for providing intelligent care to the elderly. The proposed system can analyze and report the daily activities and activity patterns of the elderly living alone by using a predefined activity index for the purpose of estimating and preventing unexpected emergency situations. The rest of the paper is organized as follows. Section 2 presents the proposed activity monitoring system in detail, and Section 3 describes the implementation results of the feasibility verification of our proposal. Section 4 presents conclusions.

2. PROPOSED ACTIVITY MONITORING SYSTEM

The proposed daily activity monitoring system is illustrated in Figure 1, and consists of two main parts: an IoT-assisted living space with contactless activity sensors, a help trigger, and an emergency gateway, and a daily activity monitoring server with the following components: data collection, event and user management, activity analysis and reporting, system configuration and management, and an external service interface.
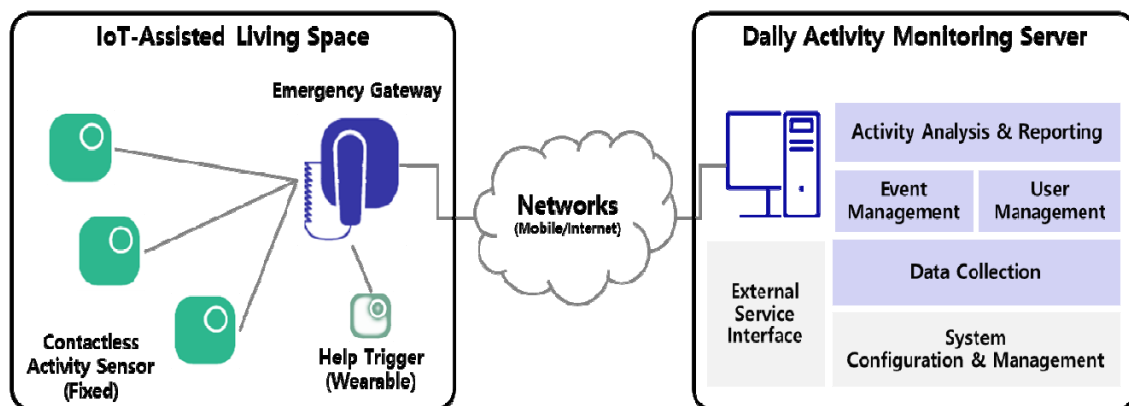

Figure 1. Block diagram of the proposed daily activity monitoring system

In the IoT-assisted living space, contactless activity sensors using passive infrared detection are located in the living room, bathroom, kitchen, and bedroom to measure the activity of the elderly at set intervals, and they send the activity data to the emergency gateway via ZigBee communication at set times. In addition, the operating status of the contactless activity sensors, including configuration information, battery level, and transmission cycle, can be checked and controlled by the emergency gateway. The emergency gateway is an important central unit for gathering activity data, detecting emergency situations, and communicating with the daily activity monitoring server via mobile networks and the Internet. It consists of an internal speaker, a microphone, and a handset. It supports various communication modules, such as 4G LTE (800 MHz), ZigBee, Bluetooth 3.0/4.0, and WiFi (2.4GHz 802.11b/g/n). The help trigger with a push button is a wearable device, such as a necklace or a wristband that sends an emergency notification message to the emergency gateway via ZigBee communication. When an elderly person leaves the home with the help

trigger, the emergency gateway automatically sets his or her status to "Going Out" in order to avoid false alarms or the absence of detected activities.

The daily activity monitoring server has various components, including data collection, event and user management, activity analysis and reporting, system configuration and management, and an external service interface. The system configuration and management component deals with the installation, setup, updates of the emergency gateway, contactless activity sensors, and help triggers. It supports remote checks on the operating conditions of the sensors and the firmware over the air in the emergency gateway in order to conveniently manage the IoT-assisted living space without requiring user intervention. The data collection component gathers activity data from the emergency gateway and then sends them to the corresponding components according to data communication and command protocols based on the categories of messages in Table 1. In Table 1, the activity monitoring and reporting function has fourteen message types, and the function of system configuration and management has four message types. The event management component is in charge of event detection and alerts, and the user management component is responsible for user registration and updates.

Table 1. Message types for data communication and command protocols

Category	#	Message Type
	1	Activity detection status
	2	Activity detection report (periodic)
	3	Voice call for predefined phone number 1
	4	Voice call for predefined phone number 2
	5	Voice call for emergency phone number
	6	Voice call for call/service center
Activity Monitoringand Reporting	7	User cancellation report sound alarm
	8	Reserved for other sensors
	9	Reserved for other sensors
	10	Reserved for other sensors
	11	Away status report
	12	Help trigger push and status report
	13	Heartbeat alarm report
	14	Voice call cancellation report
	15	Emergency gateway power status change report
System Configurationand Management	16	Emergency gateway configuration details
	17	New sensor installation result report
	18	Sensor test result report

The activity analysis and reporting component computes the activity index defined in Equation (1) from the activity data of an elderly person and tries to find the normal activity pattern based on daily (AI_day), weekly (AI_week), monthly (AI_month), and yearly (AI_year) average activity information derived by the activity index.

$$A_{index} = \frac{A_s}{A_m} \times Q_c = A_s \times A_d \times \frac{1}{A_t} \times Q_c \tag{1}$$

where A_s denotes the sum of the activity data measured from the activity sensors, A_m denotes the maximum activity data of an elderly person, and Q_c denotes the constant for quantification (here, $Q_c = 1000$). Note that A_m can be obtained through the activity data sending period A_t (seconds) and the activity sensing period for the activity data A_d (seconds/activity data). Also, by comparing the activity index and activity information with the normal activity pattern stored in a database, the activity analysis and reporting component can proactively estimate and prevent unexpected emergency situations. As an illustration of Equation (1), if contactless activity sensors measured activity data twice each in the living room, the bathroom, and the kitchen, the sum of the activity data is six ($A_s = 6$). If the activity data sending period is 600 seconds ($A_t = 600$) and the activity sensing period for the activity data is two seconds/activity data ($A_d = 2$), the maximum activity data value is 300 ($A_m = 300$). Thus, the activity index is 20 ($A_{index} = 20$).

Finally, the external service interface component provides a user interface based on a web browser that interfaces with the database and applications for the designated guardian and family, the emergency

agencies, counselors, managers of home care services, and so on. It also provides network security to protect personal information from hacking, DDoS attacks, and other threats.

3. IMPLEMENTATIONRESULTS AND ANALYSIS

This section describes the implementation results of the proposed daily activity monitoring system, primarily focusing on the activity analysis and reporting component of the daily activity monitoring server. Figure 2 illustrates a web browser-based user interface for analyzing and reporting daily, weekly, and monthly average activity information. The brief user information of an elderly person is shown at the top, and the date appears in the upper right corner. If the icons representing the day, week, and month in the upper left corner are clicked, the daily, weekly, and monthly average activity information will be graphically visualized. As shown below, the monthly average activity information intuitively indicates normal and abnormal activity patterns, which likely occur due to unexpected emergency situations. If the elderly person's activity remains very low for more than four hours, "Emergency Check" will be shown in red as an automatic announcement for the designated guardian and family, the emergency agencies, counselors, managers of home care services, or other designated users. Similarly, when activity remains very low for more than two hours, a yellow warning sign will be shown to proactively alert them. In all other cases, normal findings will be shown in gray. For example, in Figure 2, it can be seen that almost no activity took place over the course of three days, from the 22nd to 24th of the month. On the basis of this activity information, the daily activity monitoring server will send the "Emergency Check" message to the designated guardian and family, the emergency agencies, and so on for the purpose of contacting the elderly person and checking on his or her state of health. This may result in a simple visit to the elderly person, but it is important to verify whether a potentially fatal emergency has taken place.
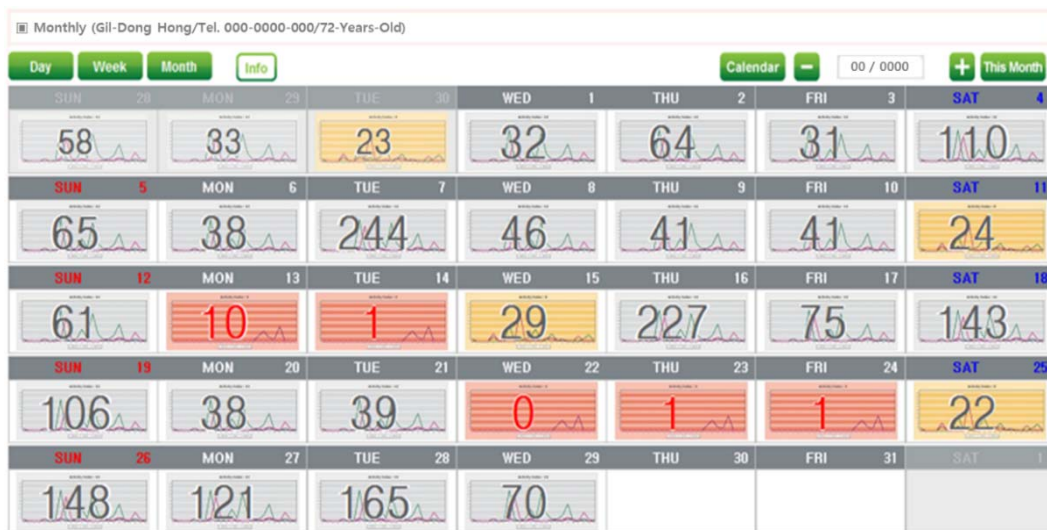

Figure 2. Implementation results of the proposed daily activity monitoring system

Figure 3 illustrates monthly activity information according to the age groups monitored by the proposed system. The group of people in their 90s demonstrated a very low state of activity, whereas the groups of people in their 70s and 80s showed more activity. In Figure 4, the monthly activity information of users in their 70s is presented according to gender. Elderly women were generally found to be more active in their homes than elderly men.
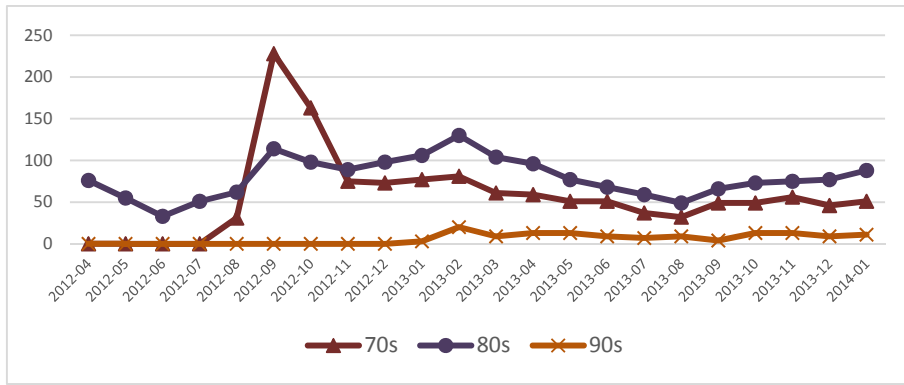
Figure 3. Monthly activity information according to age groups : 70s, 80s, and 90s
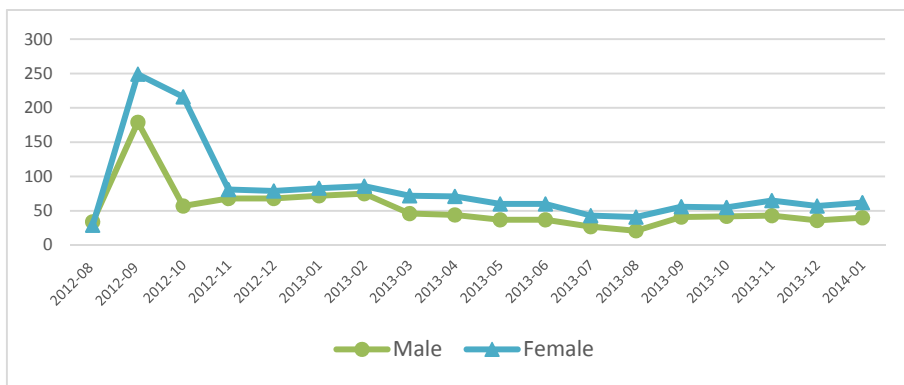

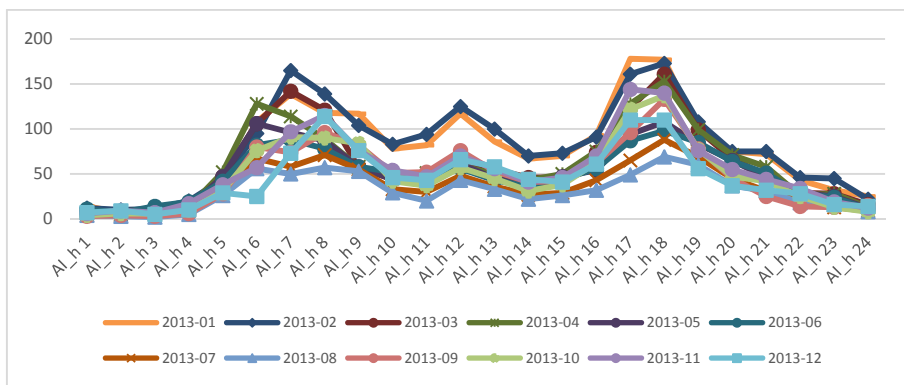Figure 4. Monthly activity information in users in their70s according to gender

Figure 5. Daily activity information in users in their70s over the course of 24 hours

Figure 5 presents the daily activity information of users in their 70s over the course of 24 hours. Generally, elderly users woke up at approximately five AM and then spent more than three hours predominantly in the bathroom and kitchen. At noon, their activity in the kitchen increased. The maximum level of physical activity was observed from six to seven PM. By using the average activity information shown in Figures 3–5, it is possible to determine normal activity patterns according to age group, gender, time interval (daily, weekly, and monthly), and potentially other parameters. These normal activity patterns could be applied to the development of various health and wellness service applications.

4.   CONCLUSION

This paper presented an intelligent daily activity monitoring system for realizing IoT-assisted living for the elderly who live alone and may suffer from family disorganization, low income, and/or poor living conditions. The proposed daily monitoring system was shown to be able to gather the activity data of the elderly from the emergency gateway in cooperation with contactless activity sensors and a help trigger. The system analyzes and reports normal and abnormal patterns of activity defined in reference to the average activity information derived using the predefined activity index. The average activity information can be used to estimate and prevent unexpected emergency situations, including sudden deaths, and utilized in various health and wellness applications.

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