International Journal of Electrical and Computer Engineering (IJECE)
Vol. 6, No. 1, February 2016, pp. 399~405
ISSN: 2088-8708, DOI: 10.11591/ijece.v6i1.9339

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

Hyun-Sik Kim*, Jong-Su Seo*, Jeongwook Seo**
* School of Electrical and Electronic Engineering, Yonsei University, Korea
** Department of Information and Communication Engineering, Namseoul University, Korea

Article Info

Article history:

Received Aug 21, 2015
Revised Nov 15, 2015
Accepted Dec 3, 2015

Keyword:

Activity monitoring
Elderly people
Healthcare
Home care network
Internet of things

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.

Corresponding Author:

Jeongwook Seo,
Department of Information and Communication Engineering,
Namseoul University,
91 Daehakro, Seonghwan-eup, Seobuk-gu, Cheonan-si, Chungnam, South Korea.
Email: jwseo@nsu.ac.kr

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.

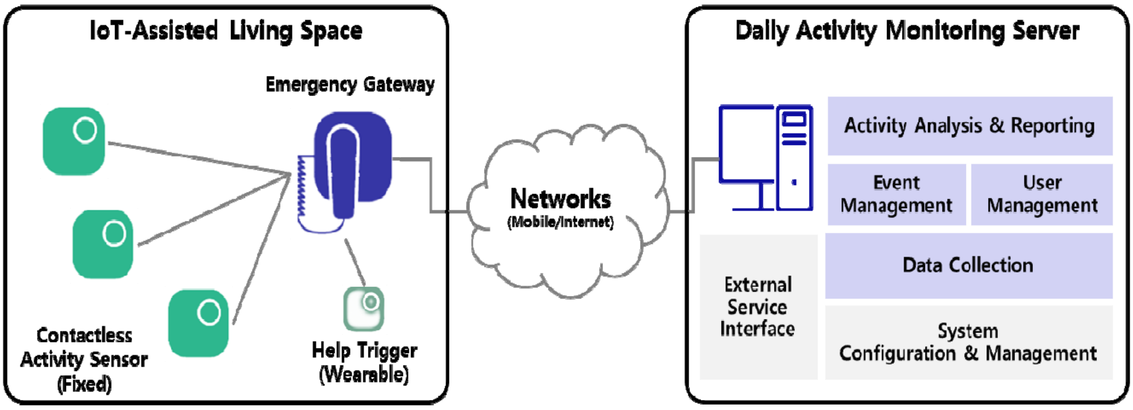

Figure 1. Block diagram of the proposed daily activity monitoring system

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
Activity Monitoringand Reporting	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
	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
System Configurationand Management	15	Emergency gateway power status change report
	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.

$$A_{index} = \frac{A_s}{A_m} \times Q_c = A_s \times A_d \times \frac{1}{A_t} \times Q_c \quad (1)$$

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.

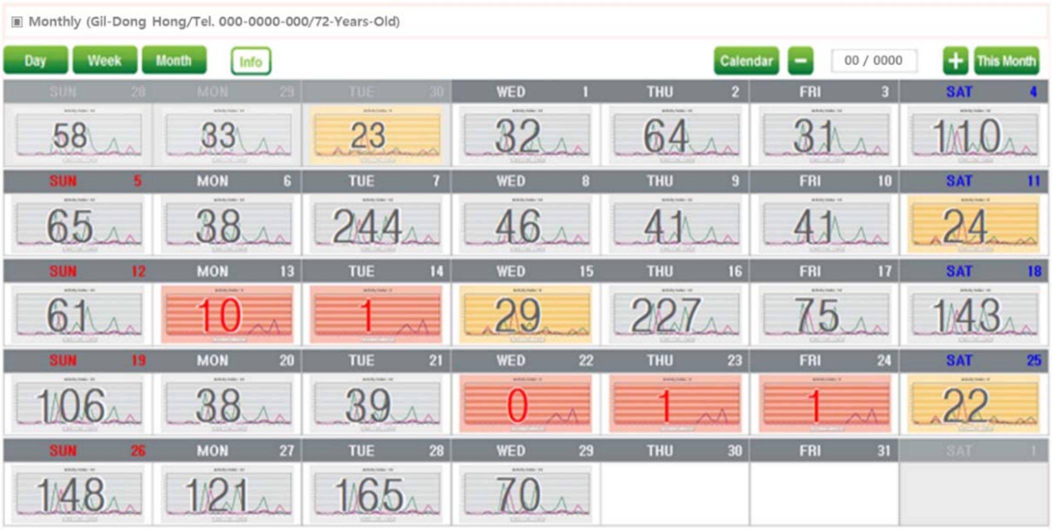

Figure 2. Implementation results of the proposed daily activity monitoring system

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.

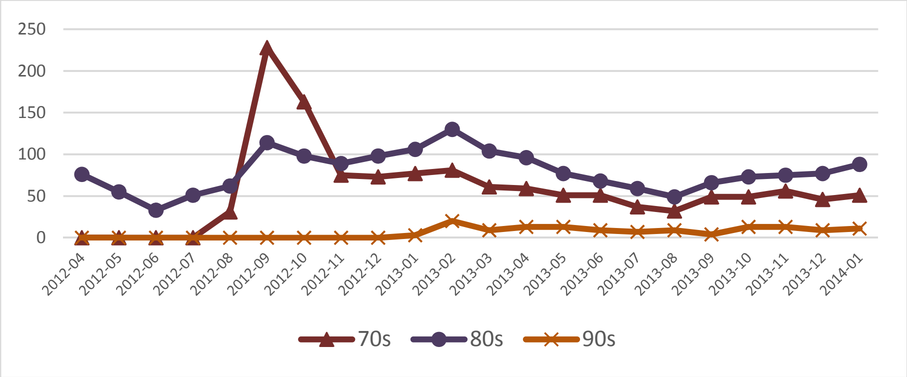

Figure 3. Monthly activity information according to age groups : 70s, 80s, and 90s

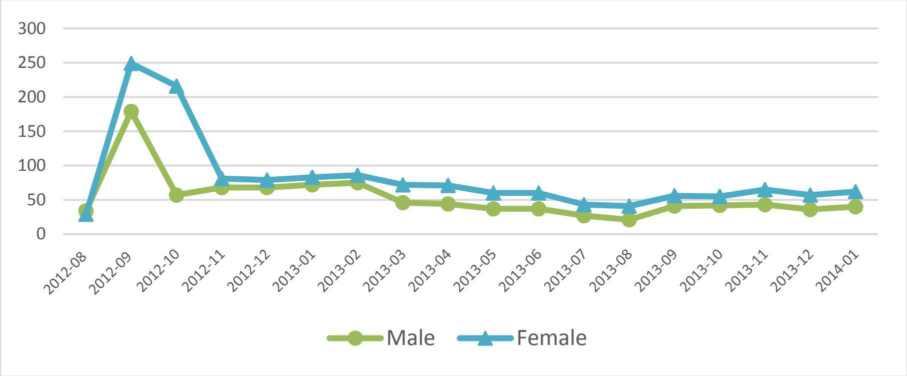

Figure 4. Monthly activity information in users in their70s according to gender

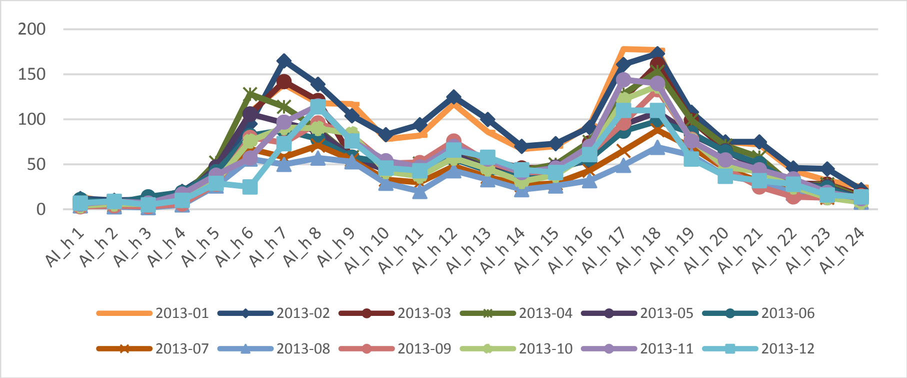

Figure 5. Daily activity information in users in their70s over the course of 24 hours

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.

ACKNOWLEDGEMENTS

Funding for this paper was provided by Namseoul University.

REFERENCES

[1] P. Rashidi and A. Mihailidis, "A survey on ambient-assisted living tools for older adults", *IEEE Journal of Biomedical and Health Informatics*, vol. 17, no. 3, pp.579-590, May 2013.

[2] G. Demiris, M. Skubic, M. Rantz, J. Keller, M. Aud, B. Hensel and Z. He, "*Smart home sensors for the elderly: A model for participatory formative evaluation*", in Proceeding of the IEEE EMBS International Special Topic Conference on Information Technology in Biomedicine, Loannina: Greece, pp. 1-4, 2006.

[3] Ö. Bozo and C.A. Guarnaccia, "Activities of daily living, social support, and future health of older Americans", *Journal of Psychology*, Vol. 144, No. 1, pp. 1-14, Jan. 2010.

[4] H. Pirsiavash and D. Ramanan, "*Detecting activities of daily living in first-person camera views*", in Proceeding of the IEEE Conference on Computer Vision and Pattern Recognition, Providence, pp. 2847-2854, 2012.

[5] P. Rashidi and D.J. Cook, "COM: A method for mining and monitoring human activity patterns in home-based health monitoring systems", *ACM Transactions on Intelligent Systems and Technology*, vol. 4, no. 4, article no. 64, pp.1-20, Sept. 2013.

[6] B. Nandhini and R. Janani, "A smart home monitoring system for elderly people", *International Journal of Emerging Technologies in Computational and Applied Sciences*, vol. 7, no. 4, pp. 444-447, Feb. 2014.

[7] A. Dohr, R. Modre-Opsrian, M. Drobics, D. Hayn, and G. Schreier, "*The Internet of Things for ambient assisted living*", in Proceeding of the International Conference on Information Technology: New Generations, Las Vegas: NV, pp. 12-14, April 2010.

[8] D. Bandyopadhyay and J. Sen, "Internet of Things: Applications and challenges in technology and standardization", *Wireless Personal Communications*, vol. 58, no. 1, pp. 49-69, May 2011.

[9] R.S.H. Istepanian, A. Sungoor, A. Faisal, and N. Philip, "*Internet of m-health Things*", in Proceeding of the IET Seminar on Assisted Living, London, pp. 1-3, April 2011.

[10] S. Husain, A. Prasad, A. Kunz, A. Parageorgiou, and J. Song, "Recent trends in standards related to the Internet of Things and Machine-to-Machine communications", *Journal of Information and Communication Convergence Engineering*, vol. 12, no. 4, pp. 228-236, Dec. 2014.

[11] C.W. Tsai, C.F. Lai, M.C. Chiang, and L.T. Yang, "Data mining for Internet of Things: A survey", *IEEE Communications Surveys & Tutorials*, vol. 16, no. 1, pp. 77-97, Feb. 2014.

BIOGRAPHIES OF AUTHORS

Hyunsik Kim received B.S. and M.S. degrees in information and communication engineering from Inha University, South Korea, in 2002 and 2004, respectively. Currently, he is a Ph.D. candidate in electrical and electronic engineering at Yonsei University, South Korea. He has also worked as a senior researcher in the Contents Convergence Research Center at the Korea Electronics Technology Institute, South Korea since 2004. His research interests are in content sharing, wearable computing, human-computer interaction, and machine-to-machine communication/the Internet of Things.

Jong-Soo Seo received a B.S. degree in electronics engineering from Yonsei University, Seoul, Korea, in 1975, and M.S. and Ph.D. degrees from the University of Ottawa, Ottawa, ON, Canada, in 1983 and 1988, respectively. He was employed with IDC and CAL, Canada for six years, where he was engaged in research on digital satellite communications and data broadcasting systems. In 1995, he joined the Department of Electrical and Electronic Engineering, Yonsei University, where he is currently a Professor. Prof. Seo is an IEEE Fellow and an Associate Editor of the IEEE Transactions on Broadcasting. His current research interests include next-generation broadcasting and 5G radio systems.

Jeongwook Seo received B.S. and M.S. degrees from the Department of Telecommunication and Information Engineering, Korea Aerospace University, Gyeonggi, Korea, in 1999 and 2001, respectively, and a Ph.D. degree from the School of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea, in 2010. He is currently an Assistant Professor in the Department of Information and Communication Engineering, Namseoul University, Cheonan, Korea. From 2001 to 2013, he worked at the Network Convergence Research Center in the Korea Electronics Technology Institute, Seoul, Korea. His research interests include statistical signal processing for communications and networking, machine learning, machine-to-machine communications and the Internet of Things.