Human Factors and Systems Interaction, Vol. 52, 2022, 491–497
https://doi.org/10.54941/ahfe1002193

Reviews on Existing Sensors of Tracking the Activities of Daily Living

Hyung Nam Kim

North Carolina A&T State University, Greensboro, NC 27411, USA

ABSTRACT

Today, various sensor technologies are available for users to keep track of their daily living activities for self-care. However, there has been a lack of attention paid to comprehensive reviews, valuable especially for young, early-career scholars who just developed research interests in this area. This paper aims at reviewing the existing sensor technologies by considering various contexts such as sensor features, data of interests, locations of sensors, and the number of sensors. This comprehensive reviews for sensor technology implementations can help researchers and professionals to design, develop, and use sensor technology applications adequately in the target user's contexts by promoting safety, usability, and accessibility.

Keywords: User-centered design, System requirements, Activities of daily living

INTRODUCTION

As it is important for individuals to promote health, prevent disease, and cope with illness, the active engagement in a self-care routine is considered critical. To facilitate it, various sensor technologies are introduced in the market, and they aim to keep track of human behaviors on a daily basis and accurately analyze them to offer recommendations to improve or alter one's daily routines. Those sensors technologies are often integrated in ambient intelligence systems. Ambient intelligence comprises several components in computing areas (Shadbolt, 2003). For example, it uses portable, low-cost computing devices/sensors that support learning algorithms and pattern machers, speech and gesture recognition, and situation assessment. Ambient intelligence equipped with sensors is invasively incorporated in an individual's everyday life (Debes et al., 2016) to identify users' needs, customize services, and forecast behaviors (Ramos et al., 2008). A smart home is, for instance, built based on such ambient intelligence systems that install various sensors throughout the home and consumer appliances to monitor residents' behavior (Ni et al., 2015). Other applications using sensor technologies include a recommender system for promoting a healthy lifestyle (Ali et al., 2015), a mobile emergency response system (Lloret et al., 2015), and a fall detection system (Yu et al., 2018). Sensor technology could also be helpful in clinical settings, such as an early sign or onset of Alzheimer's diseases (Lyons et al., 2015), dementia (Moore et al., 2013), abnormal sleep disorder (Ravichandran et al., 2017) and heart rate problems (Elliot et al., 2017).

There have been a relatively fewer number of published articles discussing the importance of using sensors for monitoring human behaviors especially among vulnerable populations (Shi, 2015; Totter et al., 2011; Wolbring & Leopatra, 2013). Many previous studies were limited to general populations over those with disabilities or special needs; for example, assistive robots to support the elderly's daily living activities (Chen et al., 2013), a sit-to-stand assistive chair (Lu et al., 2013), and a fall alert detector (Cagnoni et al., 2009). However, systems that meet the needs of general populations may not be compatible for other populations such as people with disabilities or special needs as the two user groups are likely to have different performance abilities, limitations, and preferences (Dormal et al., 2016; McDonald & Rodrigues, 2016; Pigeon & Marin-Lamellet, 2015). Today's sensor technologies have the potential to contribute to enhancing the quality of life in a variety of ways for everyone regardless of ability and disability. To better support various user groups, there is an immediate need to investigate how sensor technologies have been used. This paper aims to review the use of sensor technologies in general.

USING SENSORS TO KEEP TRACK OF DAILY LIVING ACTIVITIES

The following reviews will help researchers and professionals in implementing sensor technologies by considering various relevant aspects, such as sensor features, data of interests, sensor placement, and number of sensors.

Sensor Features

There are different types of sensors available with various features to monitor human motion (e.g., walking speed), use of household goods (e.g., door open/close and switch on/off of home appliances), sounds (e.g., sounds in a particular room), and surrounding environments (e.g., temperature and humidity).

Human Motion

Many motion-tracking studies have been using a passive infrared (PIR) sensor that can measure infrared light radiating from objects within its field of view (Basu et al., 2013; Cook et al., 2012; Dawadi et al., 2014; Fanti et al., 2017; LeBellego et al., 2006; Michel et al., 2010; Skubic et al., 2009; Thomas et al., 2016). The PIR sensor is reliable in day/night, small, inexpensive, low-power, and easy to use (Pawar et al., 2018) although it has several shortcomings. Some of its limits include lower sensitivity and less coverage as compared to microwave sensors, reduced operability at greater than 35 degrees Celsius (°C), and insensitivity to very slow motion (Pawar et al., 2018; RF Wireless World, 2018). Besides the PIR sensors, video-based sensors (e.g., Microsoft Kinect) are also often used to obtain a deep understanding of human behaviors and to calculate biomechanical variables such as gait speed and stride length (Konstantinidis & Bamidis, 2015; Rantz et al., 2015; Skubic et al., 2009; Stone & Skubic, 2011; Thomas et al., 2016). Other sensors include pulse-doppler radars and webcams (Rantz et al., 2015).

Use of Household Goods

The sensor technology can also monitor how residents use their household goods via a light switch sensor, a door sensor, a water flow sensor, a stove sensor, and a bed mattress sensor (Dawadi et al., 2014; Krishnan & Cook, 2014; Michel et al., 2010; Thomas et al., 2016). For example, a motion sensor is triggered whenever a person opens or closes a door. A dry contact sensor can be connected to various appliances such as a toaster, a kettle, or radio shack equipment so that the sensor can monitor an electric current and determine whether the appliance is in use (Basu et al., 2013).

Sound

Sensors are capable of monitoring not only physical activities of objects and humans, but also sound. For instance, a sensor is equipped with a microphone to detect human presence in a particular room through footsteps, dishes sound, door closing, glass breaking, speech, scream, phone ring, and object fall (Michel et al., 2010).

Surrounding Environment

Indoor and outdoor contexts can be monitored with, for example, a humidity and temperature sensor (Basu et al., 2013; Krishnan & Cook, 2014; LeBellego et al., 2006; Michel et al., 2010; Thomas et al., 2016). Those sensors can virtually be interconnected and managed over Wi-Fi, Bluetooth, or the ZigBee protocol, an openly available wireless communication standard to control home automation devices (Lee et al., 2009; Soliman et al., 2013; Wang et al., 2016).

Data of Interests

As sensor technologies have a variety of capabilities to detect, discover, and react to different matters, sensors are widely used to investigate various aspects of daily living activities, such as healthcare-related factors such as sleep, pulse, and respiration levels (Dawadi et al., 2014; Krishnan & Cook, 2014; Skubic et al., 2009), medication adherence (Cook et al., 2012; Krishnan & Cook, 2014), dietary habits such as cooking, eating, and washing dishes (Huang et al., 2017; Vu et al., 2017), leisure activities such as listening to music, watching TV, and playing a card game (Cook et al., 2012; Dawadi et al., 2014; Tapia et al., 2004), hygiene status such as personal and household cleaning (Cook et al., 2012; Krishnan & Cook, 2014), motion tracking (Dawadi et al., 2014; Fanti et al., 2017; Konstantinidis & Bamidis, 2015; Krishnan & Cook, 2014; Michel et al., 2010; Rantz et al., 2015; Skubic et al., 2009; Stone & Skubic, 2011; Tapia et al., 2004), weather (Michel et al., 2010), and other activities such as getting dressed and paying bills (Cook et al., 2012; Michel et al., 2010).

Location

Sensors can be installed in various locations to cover wide-open area (e.g., ceilings, wall, and hallway) (Cook et al., 2012; Dawadi et al., 2014; Fanti et al., 2017; Konstantinidis & Bamidis, 2015; Krishnan & Cook, 2014;

Michel et al., 2010; Rantz et al., 2015; Skubic et al., 2009; Stone & Skubic, 2011; Thomas et al., 2016), specific area (e.g., a bedroom, a dining room, a living room, a bathroom, and a kitchen) (Basu et al., 2013; Cook et al., 2012; Konstantinidis & Bamidis, 2015; Krishnan & Cook, 2014; Stone & Skubic, 2011; Tapia et al., 2004), and specific objects (e.g., mattresses, windows, cabinets, light switches, lamps, drawers, doors, DVDs, stereos, washing machines, dish washers, and coffee machines) (Basu et al., 2013; Cook et al., 2012; Dawadi et al., 2014; Krishnan & Cook, 2014; LeBellego et al., 2006; Rantz et al., 2015; Skubic et al., 2009; Stone & Skubic, 2011; Tapia et al., 2004).

Number of Sensors

Different sets of sensors can be used to keep track of activities of daily living, which range from a single sensor to multiple sensors to cover throughout the home (Cook et al., 2012; Fanti et al., 2017; Krishnan & Cook, 2014; LeBellego et al., 2006; Michel et al., 2010; Rantz et al., 2015; Stone & Skubic, 2011; Tapia et al., 2004). An empirical study (Nambiar et al., 2016) reported that at least three sensors – minimally obtrusive sensors – would be recommended to accurately detect physical activities of daily living in older adults who transition between rooms.

DISCUSSION

This paper provided a general review of different types of sensors that are recently used to monitor a wide array of activities of daily living and environmental factors. Researchers and professionals are recommended to consider comprehensively different determinants to design, develop, and use sensor technology applications. Such determinants include the area to cover, the data of interests, the location of sensors, and the target to detect. Yet, our reviews found that there is lack of consideration of macroergonomics — e.g., interactions of the sensor technologies with both a user and relevant user contexts such as an individual's living environment, tools, and tasks. Although there have been research efforts to review the use of sensors (Ando et al., 2015), the reviews focused on technology advancement over macroergonomics. Future research will be devoted to exploring how macroergonomics can influence the implementation of sensor technologies in monitoring various activities of daily living, especially for people with different needs.

ACKNOWLEDGMENT

This work was supported by the Natural Science Foundation grant number 1831969.

REFERENCES

Ali, R., Siddiqi, M. H., Kang, B. H., & Lee, S. (2015). KARE: A hybrid reasoning approach for promoting active lifestyle. Proceedings of the 9th International Conference on Ubiquitous Information Management and Communication,

Ando, B., Lombardo, C., & Marletta, V. (2015). Smart homecare technologies for the visually impaired: recent advances. *Smart Homecare Technology and TeleHealth, 3*, 9–16.

Basu, D., Moretti, G., Gupta, G. S., & Marsland, S. (2013). Wireless sensor network based smart home: Sensor selection, deployment and monitoring. Sensors Applications Symposium (SAS), 2013 IEEE,

Cagnoni, S., Matrella, G., Mordonini, M., Sassi, F., & Ascari, L. (2009). Sensor fusion-oriented fall detection for assistive technologies applications. ISDA'09. Ninth International Conference on Intelligent Systems Design and Applications,

Chen, N., Tee, K. P., & Chew, C.-M. (2013). Assistive grasping in teleoperation using infra-red proximity sensors. RO-MAN, 2013 IEEE,

Cook, D. J., Thomas, B. L., & Crandall, A. S. (2012). Exploring Smart Home Sensor Placement Algorithms. https://research.libraries.wsu.edu/xmlui/bitstream/handle/2376/3531/WSU-AS-2012-Poster.pdf?sequence=1

Dawadi, P., Cook, D. J., & Schmitter-Edgecombe, M. (2014). Smart home-based longitudinal functional assessment. Proceedings of the 2014 ACM international joint conference on pervasive and ubiquitous computing: Adjunct publication,

Debes, C., Merentitis, A., Sukhanov, S., Niessen, M., Frangiadakis, N., & Bauer, A. (2016). Monitoring activities of daily living in smart homes: Understanding human behavior. *IEEE Signal Processing Magazine, 33*(2), 81–94.

Dormal, V., Crollen, V., Baumans, C., Lepore, F., & Collignon, O. (2016). Early but not late blindness leads to enhanced arithmetic and working memory abilities. *Cortex, 83*, 212–221.

Elliot, C. A., Hamlin, M. J., & Lizamore, C. A. (2017). Validity and reliability of the Hexoskin® wearable biometric vest during maximal aerobic power testing in elite cyclists. *Journal of strength and conditioning research*.

Fanti, M. P., Roccotelli, M., Faraut, G., & Lesage, J.-J. (2017). Smart placement of motion sensors in a home environment. Systems, Man, and Cybernetics (SMC), 2017 IEEE International Conference on,

Huang, Q., Wang, W., & Zhang, Q. (2017). Your glasses know your diet: Dietary monitoring using electromyography sensors. *IEEE Internet of Things Journal, 4*(3), 705–712.

Konstantinidis, E. I., & Bamidis, P. D. (2015). Density based clustering on indoor kinect location tracking: A new way to exploit active and healthy aging living lab datasets. Bioinformatics and Bioengineering (BIBE), 2015 IEEE 15th International Conference on,

Krishnan, N. C., & Cook, D. J. (2014). Activity recognition on streaming sensor data. *Pervasive and mobile computing, 10*, 138-154.

LeBellego, G., Noury, N., Virone, G., Mousseau, M., & Demongeot, J. (2006). A model for the measurement of patient activity in a hospital suite. *IEEE Transactions on information technology in biomedicine, 10*(1), 92–99.

Lee, H. J., Lee, S. H., Ha, K.-S., Jang, H. C., Chung, W.-Y., Kim, J. Y., Chang, Y.-S., & Yoo, D. H. (2009, 2009/03/01/). Ubiquitous healthcare service using Zigbee and mobile phone for elderly patients. *Int J Med Inform, 78*(3), 193–198. https://doi.org/https://doi.org/10.1016/j.ijmedinf.2008.07.005

Lloret, J., Canovas, A., Sendra, S., & Parra, L. (2015). A smart communication architecture for ambient assisted living. *IEEE Commun. Mag, 53*(1), 26–33.

Lu, H., Li, D., Oyekan, J., & Maple, C. (2013). A survey on assistive chair and related integrated sensing techniques. Manipulation, Manufacturing and Measurement on the Nanoscale (3M-NANO), 2013 International Conference on,

Lyons, B. E., Austin, D., Seelye, A., Petersen, J., Yeargers, J., Riley, T., Sharma, N., Mattek, N., Wild, K., & Dodge, H. (2015). Pervasive computing technologies to continuously assess Alzheimer's disease progression and intervention efficacy. *Frontiers in Aging Neuroscience, 7*, 102.

McDonald, C., & Rodrigues, S. (2016). Sighted and visually impaired students' perspectives of illustrations, diagrams and drawings in school science. *Wellcome open research, 1*.

Michel, V., Anthony, F., Francois, P., Jean-Francois, S., & Norbert, N. (2010). *Complete Sound and Speech Recognition System for Health Smart Homes: Application to the Recognition of Activities of Daily Living*. INTECH Open Access Publisher. http://www.intechopen.com/articles/show/title/complete-sound-and-speech-recognition-system-for-health-smart-homes-application-to-the-recognition-o

Moore, P., Thomas, A., Tadros, G., Xhafa, F., & Barolli, L. (2013). Detection of the onset of agitation in patients with dementia: real-time monitoring and the application of big-data solutions. *International Journal of Space-Based and Situated Computing, 3*(3), 136–154.

Nambiar, S., Nikolaev, A., Greene, M., Cavuoto, L., & Bisantz, A. (2016). Low-cost sensor system design for in-home physical activity tracking. *IEEE Journal of Translational Engineering in Health and Medicine, 4*.

Ni, Q., García Hernando, A. B., & de la Cruz, I. P. (2015). The elderly's independent living in smart homes: A characterization of activities and sensing infrastructure survey to facilitate services development. *Sensors, 15*(5), 11312–11362. https://doi.org/10.3390/s150511312

Pawar, Y., Chopde, A., & Nandre, M. (2018). Motion Detection Using PIR Sensor. *International Research Journal of Engineering and Technology, 5*(4), 4753–4756.

Pigeon, C., & Marin-Lamellet, C. (2015, Feb). Evaluation of the attentional capacities and working memory of early and late blind persons. *Acta Psychol (Amst), 155*, 1–7. https://doi.org/10.1016/j.actpsy.2014.11.010

Ramos, C., Augusto, J. C., & Shapiro, D. (2008). Ambient intelligence—the next step for artificial intelligence. *IEEE Intelligent Systems, 23*(2), 15–18.

Rantz, M., Skubic, M., Abbott, C., Galambos, C., Popescu, M., Keller, J., Stone, E., Back, J., Miller, S. J., & Petroski, G. F. (2015). Automated in-home fall risk assessment and detection sensor system for elders. *The Gerontologist, 55*(Suppl 1), S78-S87.

Ravichandran, R., Sien, S.-W., Patel, S. N., Kientz, J. A., & Pina, L. R. (2017). Making Sense of Sleep Sensors: How Sleep Sensing Technologies Support and Undermine Sleep Health. Proceedings of the 2017 CHI Conference,

RF Wireless World. (2018). *Advantages of PIR Sensor and Disadvantages of PIR Sensor*. Retrieved December 1 from http://www.rfwireless-world.com/Terminology/Advantages-and-Disadvantages-of-PIR-sensor.html

Shadbolt, N. (2003). Ambient intelligence. *IEEE Intell. Syst., 18*(4), 2–3.

Shi, W. V. (2015). Recent Advances of Sensors for Assistive Technologies. *Journal of Computer and Communications, 3*(05), 80.

Skubic, M., Alexander, G., Popescu, M., Rantz, M., & Keller, J. (2009). A smart home application to eldercare: Current status and lessons learned. *Technology and Health Care, 17*(3), 183–201.

Soliman, M., Abiodun, T., Hamouda, T., Zhou, J., & Lung, C.-H. (2013). Smart home: Integrating internet of things with web services and cloud computing. 2013 IEEE 5th International Conference on Cloud Computing Technology and Science (CloudCom).

Stone, E. E., & Skubic, M. (2011). Evaluation of an inexpensive depth camera for passive in-home fall risk assessment. 2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops, Dublin.

Tapia, E. M., Intille, S. S., & Larson, K. (2004). Activity recognition in the home using simple and ubiquitous sensors. International conference on pervasive computing,

Thomas, B. L., Crandall, A. S., & Cook, D. J. (2016). A Genetic Algorithm approach to motion sensor placement in smart environments. *Journal of reliable intelligent environments, 2*(1), 3–16.

Totter, A., Bonaldi, D., & Majoe, D. (2011). A human-centered approach to the design and evaluation of wearable sensors-Framework and case study. Pervasive Computing and Applications (ICPCA), 2011 6th International Conference on,

Vu, T., Lin, F., Alshurafa, N., & Xu, W. (2017). Wearable food intake monitoring technologies: A comprehensive review. *Computers, 6*(1), 4.

Wang, X., Yang, L. T., Feng, J., Chen, X., & Deen, M. J. (2016). A tensor-based big service framework for enhanced living environments. *IEEE Cloud Computing, 3*(6), 36–43.

Wolbring, G., & Leopatra, V. (2013). Sensors: views of staff of a disability service organization. *Journal of personalized medicine, 3*(1), 23–39.

Yu, S., Chen, H., & Brown, R. A. (2018). Hidden Markov Model-Based Fall Detection With Motion Sensor Orientation Calibration: A Case for Real-Life Home Monitoring. *IEEE journal of biomedical and health informatics, 22*(6), 1847–1853. https://doi.org/10.1109/JBHI.2017.2782079