

Author's copy.

First Online: 23 June 2019 (© Springer Nature Switzerland AG 2020)

P. Novais et al. (Eds.): ISAmI 2019, AISC 1006, pp. 153–161, 2020.

https://doi.org/10.1007/978-3-030-24097-4_19

Cite as:

Almeida A.H. et al. (2020) Real-Time Low-Cost Active and Assisted Living for the Elderly. In: Novais P., Lloret J., Chamoso P., Carneiro D., Navarro E., Omatu S. (eds) Ambient Intelligence – Software and Applications –, 10th International Symposium on Ambient Intelligence. ISAmI 2019. Advances in Intelligent Systems and Computing, vol 1006. Springer, Cham <https://doi.org/10.1109/ISDA.2009.106>

Real-Time Low-Cost Active and Assisted Living for the Elderly

António Henrique Almeida¹, Ivo Santos¹, Joel Rodrigues¹,
Luis Frazão¹, José Ribeiro¹, Fernando Silva¹ and António Pereira^{1,2}

¹ School of Technology and Management, Computer Science and Communication
Research Center, Polytechnic Institute of Leiria, 2411-901 Leiria, Portugal
{2160827, 2160837, 2090715}@my.ipleiria.pt,

{luis.frazao, jose.ribeiro, fernando.silva, apereira}@ipleiria.pt

² Information and Communications Technologies Unit, INOV INESC Innovation, Delegation
Office at Leiria, Leiria, Portugal

Abstract. The aging of population in recent years and the increase in life expectancy is raising challenges for finding new ways to guarantee healthy and controlled activities for the elderly. Most of them prefer living in their houses than in a community center, even if they live alone or isolated from their family; at home, their normal routine activities and comfort makes them feel well. In this paper, an Active and Assisted Living (AAL) solution to detect irregular situations in everyday life of the elderly living alone is presented. By using low-cost sensors in an Internet of Things (IoT) architecture we aim to gather data in specific areas of an elderly's house in order to give the system enough input to detect abnormal behavior. These sensors are non-intrusive to the elderly, do not disturb them, and do not force them to wear a device at all times. These sensors can also send information to edge computing devices that analyze the data in real time using machine learning algorithms and alert family or caretakers when an unusual situation arises. The proposed solution provides a system that monitors the main activities performed by the elderly and creates patterns based on that activity to achieve its results and is scalable in terms of sensors and data input.

Keywords: Active and Assisted Living, Edge Computing, Internet of Things, Ambient Intelligence, Machine Learning, Low Cost, Real Time.

1 Introduction

Modern societies are facing a fast growth of aging population. Improved health and social care over recent years has increased life expectancy worldwide. Nearly 7% of the world's population is now over 65 years of age and the predictions indicate that older people will rise to approximately 20% by 2050 worldwide [1]. The number of elderly people living alone is increasing every day and typically they prefer to stay in their homes, which makes it even more difficult for family members to make sure that they are okay. The concept of AAL is understood as the use of Information and Communication Technologies (ICT), a means of prolonging time, people can live in their preferred environment (usually their home), avoiding social isolation, giving them due support and promoting a better and healthier lifestyle. In this context, the concept of IoT can be used to support elders, particularly those who live alone in their homes.

The resulting data from IoT services can be processed by Machine Learning (ML) mechanisms that will extract knowledge from it in real time to create patterns about elderly's behavior. The proposed solution goals involve surveying the current state of the art related to the theme. To begin, an identification of low-cost and non-intrusive sensors, adequate to the proposed problem, is done. A survey of tools and mechanisms concerning the use Artificial Intelligence (AI) / ML to extract knowledge from IoT data in real time is also presented. A prototype of sensory nodes for acquisition and transport of information and subsequent storage in the Platform is built. Concluding, a module of real-time knowledge extraction of IoT data using a studied algorithm is applied.

In this work, we present a system that aims to apply state of the art concepts, in order to provide an AAL solution for elders, which includes low-cost equipment and offers real-time communication with caregivers. The specific contributions of our work include a system that is available anytime and anywhere for family and caregivers, uses low cost devices to be affordable by anyone, applies machine learning algorithms for the data being gathered by the IoT sensors which allow the system to detect unusual behavior, and finally, it is adapted for elders that live alone in their homes.

The rest of the paper is organized as follows. Section 2 presents the fundamental concepts and some works related to assistive home systems. The general architecture of the proposed solution is described in section 3. In section 4, the implementation of a functional scaled model of a smart home for the elderly is presented. In section 5, Analysis and Discussion are presented. Finally, in section 6, the conclusions are drawn and some ideas for future work are presented.

2 Background

The work presented by Parisa Rashidi et al. [2] states that, in recent years, we have witnessed a rapid surge in assisted living technologies due to a rapidly aging society. AAL encompasses technical systems to support elderly people in their daily routine to allow an independent and safe lifestyle for as long as possible. The main goal of AAL is to maintain and foster the autonomy of those people and, thus, to increase safety and quality in their lifestyle and in their home environment. AAL applications include services, products and concepts that allows achieving that goal.

The work presented by Remagnino et al. [3] indicates that **Ambient Intelligence** (AmI) was introduced by the European community ([4], [1]) to identify a paradigm to equip environments with advanced technology and computing to create an ergonomic space for the occupant user. An AmI system requires the use of distributed sensors and actuators to create a pervasive technological layer, able to interact transparently with a user, either passively by observing and trying to interpret what the user actions and intentions are, or actively by learning the preferences of the user and adapting the system's parameters to improve the quality of life and work of the occupant.

The work presented by Kotsiantis, Zaharakis and Pintelas et al. [5] says that there are several applications for ML, the most significant of which is data mining. People are often prone to making mistakes during analyses or, possibly, when trying to establish relationships between multiple features. This makes it difficult for them to find solutions to certain problems. ML can often be successfully applied to these problems, improving the efficiency of systems and the designs of machines. Every instance in a dataset used by ML algorithms is represented using the same set of features. The features may be continuous, categorical or binary. If instances are given with known labels (the corresponding correct outputs) then the learning is called supervised, in contrast to unsupervised learning, where instances are unlabeled. By applying these unsupervised (clustering) algorithms, researchers hope to discover unknown, but useful, classes of items. Another kind of ML is reinforcement learning. The training information provided to the learning system by the environment (external trainer) is in the form of a scalar reinforcement signal that constitutes a measure of how well the system operates. The learner is not told which actions to take, but rather must discover which actions yield the best reward, by trying each action in turn.

Considering the work presented by Gazis et al. [6], **IoT** is a socio-technical phenomenon with the power to disrupt our society such as the Internet did before. IoT promises the (inter-) connection of myriad of things providing services to humans and machines. In [7], IoT is described as a technology that can provide a large amount of data about human, objects, time and space. Recent IoT development on existent Internet technologies create large opportunities to innovative existing services based on low-cost sensors and wireless communication.

The work from Yu et al. [8] states that nowadays millions of sensors and devices are continuously producing data and exchanging important messages. **Edge computing** will approximate data computation and storage to the end users. That way, the nodes installed in a network can significantly reduce the latency in message exchange, relieving the computational stress aggregated to the data center (cloud). Furthermore, transferring the computation process from nodes that have limited resources to others that are more powerful, can extend system lifetime.

The work presented by Blackstock and Lea [9] describes **Node-RED** as a web-based tool for connecting hardware devices and Application Programming Interfaces (API). It uses the concept of flows that are constituted by nodes connected by wires. The user interface consists of a flow editor with node templates on the left that can be dragged and dropped into a flow canvas. All users accessing Node-RED manage a single flow, which may be shown on multiple pages.

According to Manandhar [10], **Message Queuing Telemetry Transport** (MQTT) is a lightweight protocol, data-centric and specially designed for resource constrained

The proposed system implements a solution where multiple houses can coexist. Each house has a local area network (LAN) and a set of non-intrusive sensors that will be responsible for measuring the most important variables of the quotidian. Sensors such as temperature meter, carbon dioxide meter, energy or water consumption meter, door opening detection and movement detection can be used to gather important information about elder habits. These sensors are connected to resource constrained IoT devices with communication capabilities that are programmed to control and read values from sensors. The IoT device sends information from the sensors through an 802.11 network to a single-board computer (SBC) on the same network (as shown in Fig. 1 as Edge A.I). This SBC device acts as an Edge Hub, which is an intermediary device responsible to implement edge computing solution. The parcel of data that was not discarded by the Edge Hub in the process of edge computing will be sent to a cloud-based platform to be used in a supervised AI algorithm. In order to achieve this connectivity between an Edge Hub and the cloud platform, all LANs connect to an Internet provider.

The communication between devices use the MQTT protocol, and the Edge Hub has the function of a MQTT broker. The broker is responsible for receiving and filtering the messages, determining who is subscribed to each message, and sending the message to these subscribed clients. Each LAN device sends MQTT publish messages with information about data gathered in its house sensors, while the cloud platform receives MQTT subscribe messages from all LAN devices. At the platform, a supervised mechanism is applied to all data received, in order to create patterns regarding the elder's behavior, detect unusual actions and warn family and caregivers.

In summary, the proposed system and architecture are based on edge computing. In this concept, some processing of the data is accomplished using one of the edges of the system. The relevant data is produced on devices modules at the edge of the network, making it more efficient, in terms of required system communication bandwidth, to process this data in the end devices rather than in cloud servers. However, this solution will also be using cloud computing, because the edge devices do not have the computational power to solve some of the more difficult tasks. Whenever an abnormal situation is detected the system activates its corresponding support services. This solution aims to help elders that live all by themselves, since it gives them a better quality of life with real comfort and security as well as to their relatives and caregivers.

4 Implementation and Testing

This section presents and describes the development and implementation of a functional prototype in order to demonstrate the technical and economic feasibility of the communication system. Fig. 2 presents the diagram of the implemented prototype system. The elders are expected to present similar behavior in some common actions. Examples of such common actions include leaving the house at the same time every day to take care of their garden, buying bread, drinking their coffee at a local shop or visiting and feeding their livestock animals. In order to detect whenever the elder leaves the house a magnetic door sensor is used in order to detect when a door opens or closes. The sensor used for this purpose is a magnetic reed switch (see Fig. 3) which is installed at the door of the house. Each half of the sensor contains a magnet, so that when they are separated (doors opening), its value is different to when they are close together (door closed).

Other sensors are used to acquire information about the weather. In days of bad weather, the elder may change his/her behavior. To be able to correlate this information, a temperature meter and a rain sensor are also used to gather data and to send it to the cloud platform, as showed in Fig. 3. All of the sensors are connected to two NodeMCU ESP8266 (IoT Device).

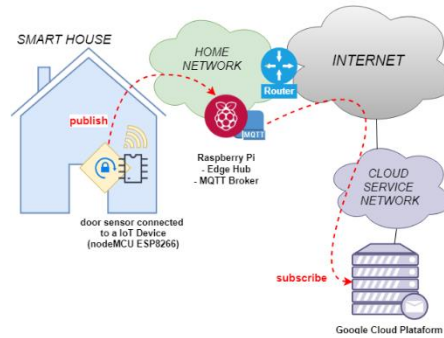


Fig. 2. Implemented Prototype System

One microcontroller is continuously gathering data from the door sensor and when a change of state happens, it sends that event to the Edge Hub, via Wi-Fi communication, using a MQTT publish message to a specific topic about the state of the door. The other microcontroller is acquiring information about temperature and rain and sending it periodically to the Edge Hub, via Wi-Fi communication using a MQTT publish message to a specific topic about weather. A RaspberryPi3 model B is responsible to serve as a MQTT broker. An instance of a local Node-RED server (node.js) is also executing on this device. The platform being used is the Google's Cloud Platform. Google develops modules for Node-RED and receives data using MQTT subscribe messages.

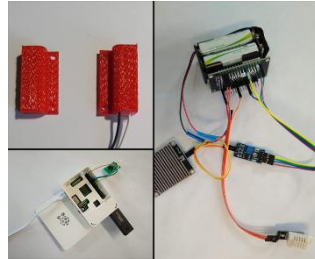


Fig. 3. Magnetic reed switch(top-left), SBC (bottom-left) and weather sensors

This chapter demonstrates the necessary software and hardware that can be used to consort the elder's behavior. A simple set of non-intrusive sensors is used in order to test the communication between sensors and platform. Node-RED is a great tool to help in terms of management because of its graphical interface.

5 Analysis and Discussion

Several tests were performed to achieve the communication between a sensor and Google's Cloud Platform. Considering that a publish/subscribe mechanism is used, scalability is secured. The local network can grow in number of sensors and IoT devices without a significant increase in cloud processing costs, given that the Edge Hub present at the edge of each LAN reduces the data sent to the cloud platform regardless of its processing power and storage. This way, through the Edge Hub, each LAN possesses a small part of the responsibility of the AI process, discarding the most unprecedented values. Taking into consideration that the information gathered is received from only non-intrusive sensors, elder's everyday life is not affected by the proposed system. The sensors are "passive" in its method of interaction, and so, elders do not have to interact directly with them. This is important, since this type of technology is not of the common knowledge for the elder. The concept "low-cost" is assured given that communication to the cloud is established with very low-price hardware components and low energy consumption. One set of hardware that includes a magnetic reed switch, an ESP8266 and a RaspberryPi3, can be obtained by values under \$50.

A significant amount of data is needed for the algorithm to work at the required precision, so while this data is being generated by the sensors, we are also generating data manually by asking elders to write down their own habits of exiting and entering their homes. Whenever the amount of data needed is fulfilled by sensors themselves, the algorithm will be capable of predicting elder actions in their quotidian life. e.g. "It is usual that the person leaves every day during the week at 3 pm. Given that information, he should leave today as well. If he does not, maybe something is wrong".

In summary, a publish/subscribe mechanism is used to connect the sensors to the platform. Each sensor publishes to a different topic. The broker of this mechanism is the edge hub (RaspberryPi3) which is responsible by handling the communication. In our implementation and testing this device is also responsible for processing information using the Edge A.I. module. When the data reaches the cloud, further AI processing takes place with the aim of understanding and creating patterns of the elder's behavior. Additionally, the elders are asked to provide written information about their habits, given that this type of algorithm requires a large amount of data in order to reach reliable results.

6 Conclusions and Future Work

This paper presents a system being developed with the purpose of helping elders that live alone; this work pretends to provide a high level of security, comfort and tranquility to the person in question, as well as to his/her family and caregivers. The means by which communication between a sensor and a cloud platform is established is detailed; a low-cost and real time communication system is implemented, allowing the platform to receive data from its sensors anytime and anywhere. Data is transmitted through an IoT device, an Edge Hub, and finally to a cloud-based platform. The communication is possible by means of the MQTT protocol. The Edge Hub is presented as the broker, while the IoT device and the platform are its clients as publisher and subscriber.

As future work, it is intended that Edge AI will be on the edge of each LAN (Edge Hub), in order to reduce the amount of data that is sent to the Google Cloud Platform. Considering that a RaspberryPi3 has little processing capabilities, a light algorithm of AI will be presented, in order to discard the most obvious flaws in the data collected regarding elder behaviors. At the platform, a supervised AI algorithm will be developed for achieving more precise results. A security layer will be added to the communications with the purpose of protecting the private and sensitive data that travels through the Internet. At this point, the data travels through the Internet without any encryption. One of the most important/necessary modules to implement is encryption of communication. Very sensitive data is being sent to the cloud. If accessed, a malicious person could have important information about the behavior patterns of the elder. Sensors and houses distinctiveness is not yet tested. However, it could be achieved in a few ways, e.g., by providing each sensor with a unique identification, or by associating each house to a specific topic from the publish/subscribe mechanism.

ACKNOWLEDGMENTS

This publication is funded by FCT - Fundação para a Ciência e Tecnologia, I.P., under the projects identified by UID/CEC/04524/2016 and UID/CEC/04524/2019.

References

- [1] G. Rica and . et al, "Being There: Concepts, Effects and Measurements of User Presence in Synthetic Environments (Emerging Communication: Studies in New Technologies and Practices in Communication, Vol. 5)," IOS Press, 2003, pp. 59–82.
- [2] P. Rashidi and A. Mihailidis, "A survey on ambient-assisted living tools for older adults," *IEEE J. Biomed. Heal. Informatics*, vol. 17, no. 3, pp. 579–590, 2013.
- [3] P. Remagnino, H. Hagrais, S. Velastin, and N. Monekosso, *Ambient intelligence: a gentle introduction*. Springer, 2005.
- [4] N. Shadbolt, "Ambient Intelligence," *IEEE Intell. Syst.*, pp. 2–3, 2003.
- [5] S. B. Kotsiantis and . et al, "Machine learning: A review of classification and combining techniques," *Artif. Intell. Rev.*, vol. 26, no. 3, pp. 159–190, 2006.
- [6] V. Gazis *et al.*, "Short Paper : IoT : Challenges , Projects , Architectures."
- [7] A. Gurjar and N. Sarnaik, "Heart Attack Detection By Heartbeat Sensing using Internet Of Things : IoT," *Int. J. Mod. Trends Eng. Res.*, vol. 5, no. 4, pp. 212–216, 2018.
- [8] F. Liang *et al.*, "A Survey on the Edge Computing for the Internet of Things," *IEEE Access*, vol. 6, pp. 6900–6919, 2017.
- [9] M. Blackstock and R. Lea, "Toward a Distributed Data Flow Platform for the Web of Things (Distributed Node-RED)," pp. 34–39, 2015.
- [10] S. Manandhar, "MQTT based communication in IoT," no. May, 2017.
- [11] O. Aran, D. Sanchez-Cortes, M. T. Do, and D. Gatica-Perez, "Anomaly detection in elderly daily behavior in ambient sensing environments," *Lect. Notes Comput. Sci.*, vol. 9997 LNCS, pp. 51–67, 2016.
- [12] E. Demir, E. Köseoğlu, R. Sokullu, and B. Şeker, "Smart Home Assistant for Ambient Assisted Living of Elderly People with Dementia," *Procedia Comput. Sci.*, vol. 113, pp. 609–614, 2017.

- [13] R. Dawadi, Z. Asghar, and P. Pulli, "Internet of Things Controlled Home Objects for the Elderly," no. Biostec, pp. 244–251, 2017.