Societal Impact of Technology: A Survey and Ethics critique on IoT for the Elderly Healthcare

Samir Farhat Dominguez

November 27, 2021

1 Introduction

This work will serve as an exploration of the rise of IOT devices as a solution to elderly healthcare, and the resulting ethical ramifications arising from this trend. As a result of advancements in medicine the developed world has seen median age rise significantly, leading to a larger elderly populous. This has led to an increased demand technology to allow the elderly to be cared for and lead independent lives. This had occurred along the of IoT systems has led to several pieces of academic literature and research into building IoT systems to allow for consistent and accessible observation and treatment of the elderly.

People at the end of their life may need constant monitoring and attention. The viability of having a healthcare professional accessible at all times only occurs for the wealthiest of people. Moreover, older adults still wish to lead independent lives no matter their physical condition. As a result, the much more affordable use of IoT systems becomes a good way to bridge the gap of care providing and demand for care. The ultimate prerogative of IoT devices for the elderly is to improve quality of life, activity recognition, and measuring vital signs. A generalized depiction of this system style can be seen below.

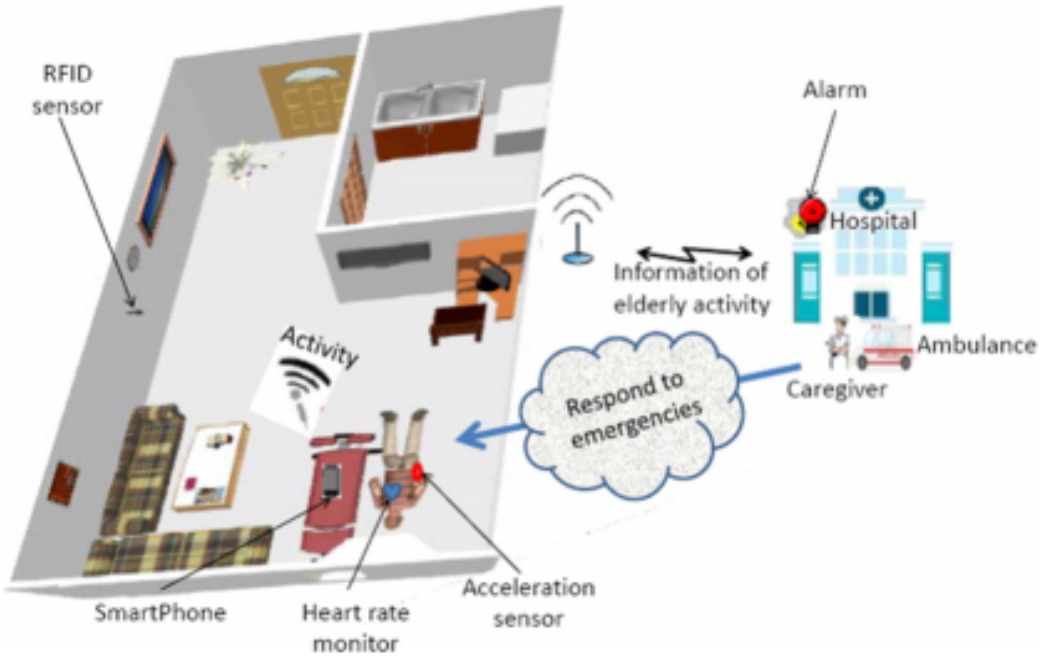


Figure 1: General IoT in healthcare for the elderly proposal

Interaction with devices is generally delivered as user interfaces on a mobile phone, tablet, or television. These usually display reminders and give information such as what medication the elderly person needs to take, when they need to take it. Activity recognition takes place through wearable devices, cameras, and sensors placed on furniture. The monitoring

of vital signs occurs through specialized equipment such as ECGs, LMIs and many others. In this paper we will evaluate and critique 3 different systems that have been implemented in the real world. These will then be compared against each other from a perspective of ethics and morality.

2 Propositions

2.1 H2U

The Help to You healthcare system is an intensive service management platform. The system implements many devices in order to streamline the monitoring and treatment of the elderly. It is a heterogeneous system, allowing nurses to service patients while being easy to use and cheap to setup. Additionally, a user friendly mobile application forms a part of the system in order to connect patients to doctors on demand from the comfort of their home. This is done through video calls, audio calls and direct messages. As seen above, the system begins by allowing the patient to interact through their

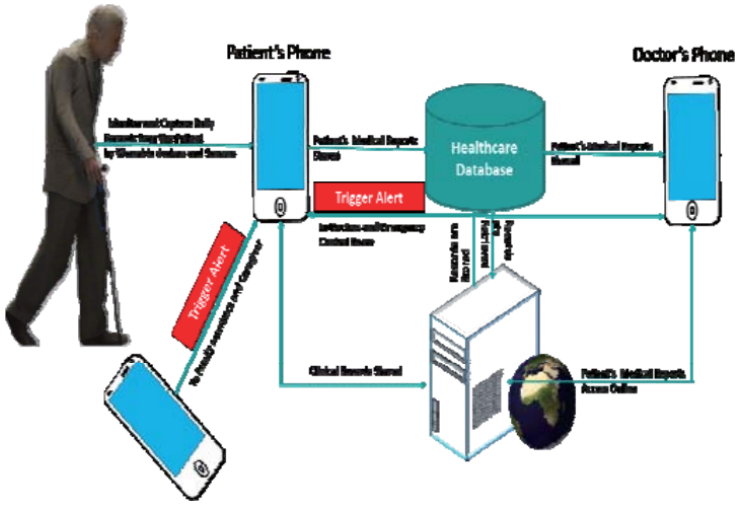


Figure 2: H2U architecture

mobile phone. The actuators and sensors placed around the home of the patient are allowed to network together in the patient's home. The system overcomes the issue of low power processors in IoT devices, by sending the raw unprocessed data packets to the phone app. From there the mobile phone performs a relatively low intensive processing before distributing this processed data to an H2U hosting data centre, where further processing and compilation is performed and dispatched to a doctor or overseer.

The system also has an emergency mechanism whereby if vitals received are past a certain threshold, all overseers and emergency services are contacted. The specific thresholds are set by the doctor at the initial H2U assessment, but normally meet extreme thresholds of cardiac arrest, pulmonary failure, or dangerously low blood pressure and air-flow levels.

2.2 H3IoT

Home Health Hub Internet of Things ($H3IoT$) is a platform designed to monitor elderly people. It employs biosensors, comms channels, microcontrollers and applications; all of which are interconnected in the patient's internet provider. The system focuses on affordability and mobility. It is composed of a 5-layer hierarchy, consisting of the following items.

1. Physiological Sensing
2. Local Communication
3. Information Processing
4. Internet Application
5. User Application

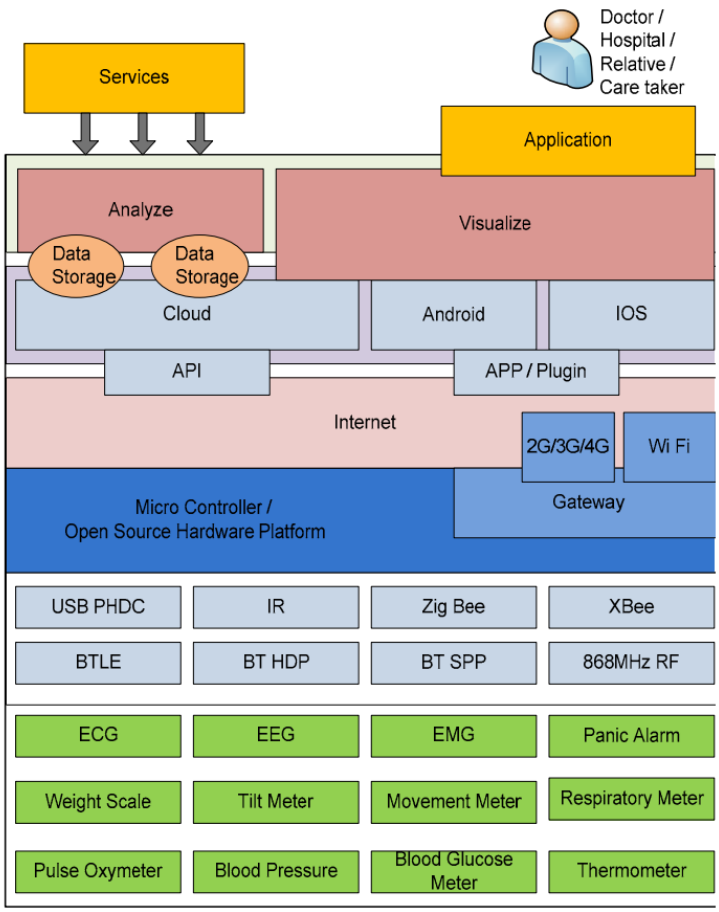


Figure 3: $H3IoT$ Architecture

The PSL can be found at the bottom-most layer of the system. As one might assume from its label, this part has the role of detection and processing of bio-metric data. This stage is defined by devices taking in raw data and eventually passing this along to steps higher in the system. The devices can include ECGs, which observe electrical heart activity, Electroencephalograms (EEG) which look at activity relating to brainwaves and Electromyograms, which characterise muscular function. This layer also includes panic alarms, stadiometers, blood pressure sensing, respiration observers and many other smart devices that caretakers use to virtually examine the health of an elderly person.

The local communication layer describes the network composed of the systems in the PSL. It consists of networking protocols such as BLE and Zigbee. This layer ensures communication in the PSL. The IPL receives the raw data . Here, it is processed into data structures that which can be used by the algorithms such that it can be outputted to humans for interpretation.

From here, the IAL is necessary. The useful data from the IPL is siphoned through an API, allowing for the data to be uploaded where caretakers are able to observe the state of the elderly person. This could be to an external server in a hospital or a storage system hosted on the cloud.

Finally, there is the UAL which is the user interface. This allows for caretakers and family members to quickly disseminate the current medical profile of the elderly person. This is effevtive as a monitoring system, and also allows for the quick distribution of info that would make human intervention a necessity.

2.3 HABITAT

HABITAT or Home Assistance Based on the Internet of Things for the Autonomy of Everybody (HABITAT) was constructed by a team of network engineers, hardware engineers, and medical professionals. Its design prerogative is to be user centric and accessible at every user interface level. It accomplishes this by performing a qualitative benchmarks and surveys for the particular devices and systems needed on a user by user basis. Th system is highly flexible and regimented to specific users. A figure showing its architecture is observed below.

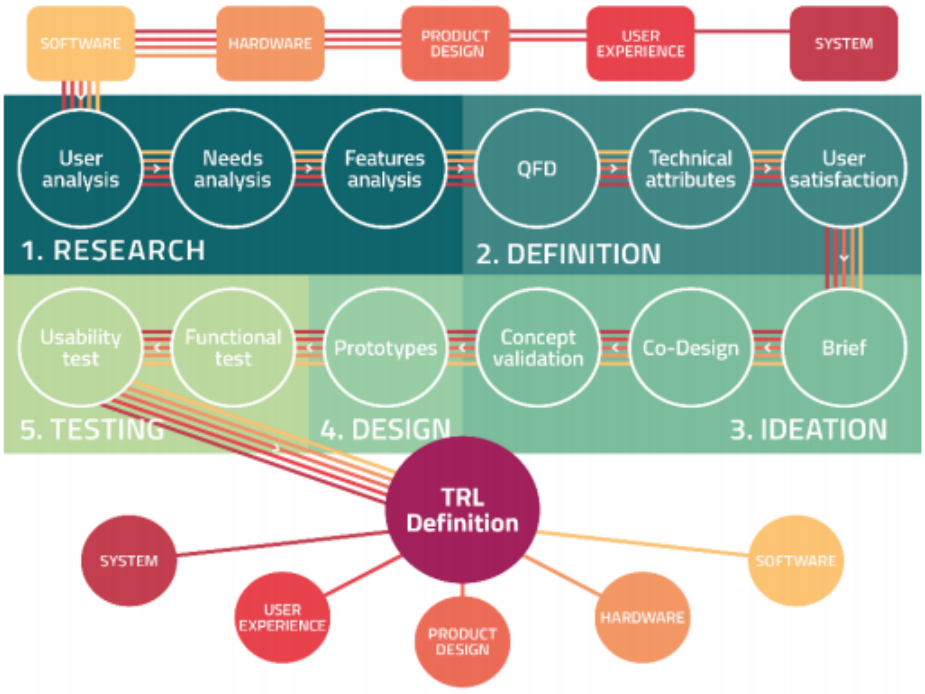


Figure 4: Depiction of User-centered Design Methodology

The system varies on a user by user basis, but in general terms there is an initial assessment made by a medical professional, and a checklist of devices and systems is constructed from this by a commitee of engineers. The system is dependent on sensors and actuators that can be placed in every day household items. These include, armchairs, belts, monitors and wall panels. From there, a module dubbed SPARQL Event Processing Architecture takes in the raw network packets from all these actuators and dispatches them to processing centre to be evaluated relative to the user profile in order to establish a current health profile of the user.

H3IoT and H2U use sensors and actuators for the purpose of monitoring activities and vitals of its users to keep tabs on their safety and health. HABITAT differentiates itself by employing a middleware artificial intelligence engine, which implements a random forest decision tree network to make health profile deliberations. An ORM communication module then sends its interpretation of data to a central database, which caretakers and family members will have access too. This is depicted in the figure below.

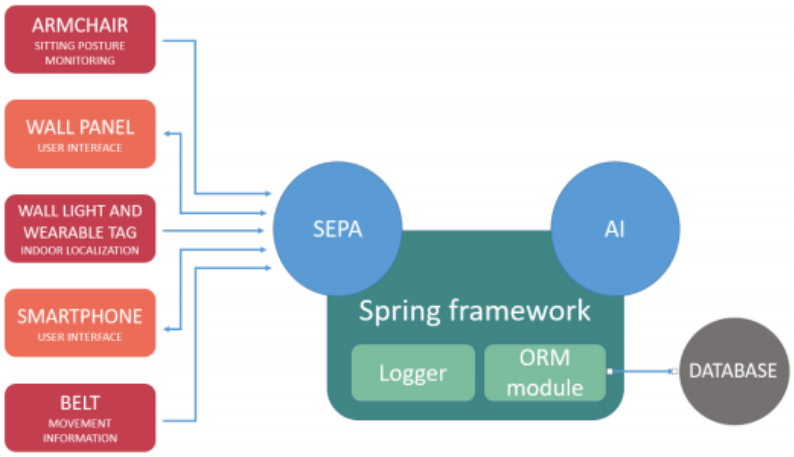


Figure 5: HABITAT architecture

3 Strengths and Weaknesses

3.1 $H3IoT$

3.1.1 Pros

1. Available to a wide range of potential elderly users. This can range to the very active and relatively healthy to those in vegetable states or in bad straits.
2. Easy to use for patients and caretakers with an intuitive and accessible UX and UI architecture.
3. Implements comprehensive array of devices, allowing the observation of every aspect of the a day in the life of an elderly person.

3.1.2 Cons

1. There exist encryption and anti data-leakage measures at all architecture levels. But, there is a concern over privacy. Users can be made uncomfortable about constant monitoring. This is exacerbated as monitoring can occur while on the restroom or during sleep.
2. System is expensive.
3. There have been several reports of inaccurate data when compared to state of the art sensors that are independent of the system.

3.2 H2U

3.2.1 Pros

1. The system implements mechanisms that allow for emergency routing, medication reminders and symptom checkers.
2. This system wields a mobile phone to collect data allowing for the reduction of costs on the hypothetical users who adopt it.
3. This system engages directly with common occurrences in the elderly person's health issues. This occurs through analysis of family history used in conjunction with sensor data and a symptom matrix evaluation structure. This is shown below.

	Diabetes	Cardiac	Ortho	Dental	Eye	Skin
Diabetes	0.48	0.48	0.23	0.38	0.51	0.61
Cardiac	0.08	0.08	0.09	0.05	0.10	0.08
Ortho	0.10	0.04	0.05	0.02	0.03	0.03
Dental	0.12	0.16	0.27	0.09	0.05	0.05
Eye	0.10	0.08	0.14	0.19	0.10	0.08
Skin	0.12	0.16	0.23	0.28	0.20	0.15

Figure 6: Matrices and weights system example used to find correlates between diseases

4. Intuitive and user friendly interface.

3.2.2 Cons

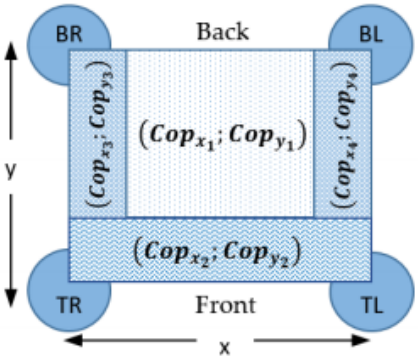
1. Limited hardware mans it is the least adaptable of the discussed systems.
2. Only well suited to the relatively active
3. Privacy concerns exist to a greater extent then the others.

3.3 HABITAT

3.3.1 Pros

1. User-centric design means the system is highly flexible, and allows for supplementary mechanisms to be built around the precise needs of its individual elderly users.

2. The system is remarkably good at maximizing quality of life whilst staying out of the way of its users. Users are less inconvenienced then when compared to the other systems in this report. This can be exemplified in the system's armchair design, which appears to be a common armchair despite its sophisticated design depicted below.



Coordinates	Message
$(Cop_{x_1}; Cop_{y_1})$	"Upright sitting"
$(Cop_{x_2}; Cop_{y_2})$	"Front sitting"
$(Cop_{x_3}; Cop_{y_3})$	"Right sitting"
$(Cop_{x_4}; Cop_{y_4})$	"Left sitting"

Figure 7: Depiction of sensors and actuators placed in normal domestic appliances

3. The wall panel appliance allows users to be reminded of their medicine dosages, exercise routine, and other tidbits regarding improving health and quality of life.

3.3.2 Cons:

1. Setting up the system will have varying costs for different users. However, it is almost always more expensive than the alternatives reported in this work.

2. As with all the other systems, their is an issue with privacy concerns as a whole.

4 Conclusion and Analysis

It would be naive to try and designate a "best" system out of the 3. All of these have elements in common as well as different negatives and positives. Therefor, it would be wiser to elaborate on the extent to which each system achieves its explicit goals, and how they may reach them more effectively should they be found wanting.

The IoT systems this work has discussed are well funded, fully backed, and represent serious attempts to build viable systems which a relatively wealthy public could afford. These systems have several strengths and weaknesses that can be compared to ascertain a better idea of what an optimal architecture would look like.

The most imperative weakness found in all the systems are the concerns of privacy. As should be expected, all of them possess strong encryption and secure networking algorithms to stop malicious parties accessing sensitive data. Despite this, many elderly people are skeptical of being constantly observed by machines, especially when they are engaging in highly private activities. Unfortunately, this seems to be an unavoidable trade-off, as monitoring entails some sort of renouncement of privacy.

Another important issue to address is H2U being created solely for active people. It is important to clarify that this could be seen as a strength, as it has a more niche focus on active elderly people, allowing it to specialize.

Another trend to to look at is that all of the reported implementations have user friendly interfaces and have a strong focus on accessibility. This is a phenomenal strength, as the elderly are, and will most likely continue being the most illiterate demographic when it comes to technology.

Finally, all 3 systems have yet to undergo significant use in the real world. Only time will tell how they develop and disseminate through society. The ever shifting developments of IoT and smart devices will almost certainly find some sort of balance with the stagnant needs of the elderly.

Bibliography

[1] Al-Khafajiy, Mohammed, et al. "Remote health monitoring of elderly through wearable sensors." Multimedia Tools and Applications 78.17 (2019): 24681-24706.

[2] Sebbak, F., Benhammadi, F. Majority-consensus fusion approach for elderly IoT-based healthcare applications. Ann. Telecommun. 72, 157–171 (2017). https://doi.org/10.1007/s12243-016-0550-7

[3] P. P. Ray, "Home Health Hub Internet of Things (H3IoT): An architectural framework for monitoring health of elderly people," 2014 International Conference on Science Engineering and Management Research (ICSEMR), Chennai, 2014, pp. 1-3, doi: 10.1109/ICSEMR.2014.7043542.

[4] Toh, Xiaoping, et al. "Elderly medication adherence monitoring with the Internet of Things." 2016 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops). IEEE, 2016.

[5] H. Basanta, Y. Huang and T. Lee, "Intuitive IoT-based H2U healthcare system for elderly people," 2016 IEEE 13th International Conference on Networking, Sensing, and Control (ICNSC), Mexico City, 2016, pp. 1-6, doi: 10.1109/ICNSC.2016.7479018.

[6] Tun, S.Y.Y., Madanian, S. & Mirza, F. Internet of things (IoT) applications for elderly care: a reflective review. Aging Clin Exp Res (2020). https://doi.org/10.1007/s40520-020-01545-9

[7] Gkouskos, Dimitrios, and Jonathan Burgos. "I'm in! Towards Participatory Healthcare of Elderly through IOT." Procedia Computer Science, Elsevier, 19 Sept. 2017, www.sciencedirect.com/science- /article/pii/S1877050917317350

[8] Borelli, E.; Paolini, G.; Antoniazzi, F.; Barbiroli, M.; Benassi, F.; Chesani, F.; Chiari, L.; Fantini, M.; Fuschini, F.; Galassi, A.; Giacobone, G.A.; Imbesi, S.; Licciardello, M.; Loreti, D.; Marchi, M.; Masotti, D.; Mello, P.; Mellone, S.; Mincolelli, G.; Raffaelli, C.; Roffia, L.; Salmon Cinotti, T.; Tacconi, C.; Tamburini, P.; Zoli, M.; Costanzo, A. HABITAT: An IoT Solution for Independent Elderly. Sensors 2019, 19, 1258

[9] Rath, Mamata. "Big data and iot-allied challenges associated with healthcare applications in smart and automated systems." Data Analytics in Medicine: Concepts, Methodologies, Tools, and Applications. IGI Global, 2020. 1401-1414.

[10] P. Gope and T. Hwang, "BSN-Care: A Secure IoT-Based Modern Healthcare System Using Body Sensor Network," in IEEE Sensors Journal, vol. 16, no. 5, pp. 1368-1376, March1, 2016, doi: 10.1109/JSEN.2015.2502401

[11] A. T. Thakar and S. Pandya, "Survey of IoT enables healthcare devices," 2017 International Conference on Computing Methodologies and Communication (ICCMC), Erode, 2017, pp. 1087-1090, doi: 10.1109/ICCMC.2017.8282640.

[12] G.S, Karthick P.B, Pankajavalli. (2020). A Review on Human Healthcare Internet of Things: A Technical Perspective. SN Computer Science. 1. 10.1007/s42979-020-00205-z.

[13] Fendrich, Konstanze, and Wolfgang Hoffmann. "More than just aging societies: the demographic change has an impact on actual numbers of patients." Journal of Public Health 15.5 (2007): 345-351.

[14] Bengtson, Vern L., et al., eds. Aging in East and West: Families, states, and the elderly. Springer Publishing Company, 2000.

[15] Iqbal, Naeem, Shabir Ahmad, and Do Hyeun Kim. "Health Monitoring System for Elderly Patients Using Intelligent Task Mapping Mechanism in Closed Loop Healthcare Environment." Symmetry 13.2 (2021): 357.

[16] Sokullu, Radosveta, Mustafa Alper Akkaş, and Eren Demir. "IoT supported smart home for the elderly." Internet of Things 11 (2020): 100239.

[17] Ahmadi, Hossein, et al. "The application of internet of things in healthcare: a systematic literature review and classification." Universal Access in the Information Society 18.4 (2019): 837-869.

[18] Mainetti, Luca, et al. "An IoT-aware system for elderly monitoring." 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI). IEEE, 2017.

[19] Misbahuddin, Syed, et al. "IoT framework based health care system for elderly and disabled people." International Conference on Recent Advances in Computer Systems (RACS 2015). 2015.