Human Data Model: An Approach for IoT Applications Development for Elderly Healthcare

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Abstract. Nowadays, the number of devices connected to the Internet is growing at an unstoppable rate. This, added to the amount of information these devices produce, makes new techniques necessary to take advantage of their potential. New devices are continually being introduced in the daily life of people, and they are already producing an unprecedented amount of data related to people's well-being. However, taking advantage of such information to create innovative solutions heavily relies on manually gathering the needed information from several sources. In this paper, we present a Human Data Model to combine personal data, perform related computations, and proactively schedule computer-human interactions. The model's main aim is to improve the development of IoT applications by means of reusing the interactions detected in order to meet the sensation or abstractions inferred from the stored information.

Keywords: Internet of Things · IoT · Human Data Model · People · Well-being

1 Introduction and Motivations

Today, an increasing number of interoperating systems produces a flood of sensitive and intimate data. In the cyber world, human data is generated by our actions in social media and various types of cloud services. In the physical world, the data is now generated by the ever-growing amount of data pumps (wearables, sensors, mobile devices, etc.) next to us, on the network edges, where we and our devices are located.

To facilitate the daily life of elderly smart devices are developed. However, these devices also have some limitations and are not always useful if they are not combined with services that include the exchange and processing of the data they generate [1]. Also, the elderly may require frequent and immediate medical intervention, so it is necessary to know information about their routines

J. García-Alonso and C. Fonseca (Eds.): IWoG 2020, LNBE, pp. 111–120, 2021.
https://doi.org/10.1007/978-3-030-72567-9_11

and preferences [2]. This leads to remote health monitoring on an intelligent home platform allowing people to remain in their comfortable home environment rather than expensive and limited nursing homes or hospitals, ensuring maximum independence of the occupants [3,4]. This highlights the importance of smart devices and the information they produce in the elderly lives and how by processing their information, their day-to day life can be simplify and quality of life can be improved.

People use smart devices that continuously capture information. In this sense, the data provided by people posses plenty of potential for both new types of software applications as well as for improving conventional applications. Particularly important, said data is considered as data collectively gathered from our surroundings being directly related to our well-being from a smart healthcare perspective [5,6]. Nonetheless, by making use of this data with current approaches can be a complicated task. The access to this data and the usage requires that an IoT device sends the data to a smartphone, central devices, or a backend service. This setting has serious inconveniences, such as the Internet companies swamp personal data gathered from their customers is a privacy nightmare, and transferring the data to and from the cloud is intolerable for latency-sensitive systems [7]. It can only be fixed by reconsidering the way the data is utilized, calling for coordination between the Edge, the Fog, and the Cloud [8].

In this paper, we propose applying a new model based on people's data and wearable devices, Human Data Model (HDM) [9], in the context of the elderly. In addition, this model is complemented with an API that allows developers for accessing and interacting with it. The main objective of this model is to collect data concerning elderly lives and then processing the data into an actionable form. With this proposal it is also possible to build applications that proactively schedule computer-human interactions to allow the computing infrastructure to take the initiative to serve the users better.

The rest of the document is structured as follows. Section 2 shows the background of this work and some related work. Next, Sect. 3 details a use-case based on a elderly people to show the detected problem. In Sect. 4 we show our proposal HDM. Finally, in Sect. 5 the discussion and conclusions are detailed.

2 Background and Related Work

The rise of mobile and web apps have lead the way for digitization and define how people embrace technology [10]. While there are established approaches for mobile and web app development, there currently is no such approaches for developing solutions based on wearable devices.

Using Healthcare APIs, developers can integrate their healthcare applications with complex ecosystems that capture, store, and process data about people's health, e.g., Apple's HealthKit[1] with ResearchKit and CareKit provide an excellent opportunity to conduct studies and to build apps that leverage health

[1] https://developer.apple.com/health-fitness.

and wellness data. However, this approach still allows room for technological improvements. First, data processing and capture are separated, so data has to be sent from one device to another. Second, the approach does not offer solutions for connecting and leveraging different services for data processing. Finally, it is limited to Apple-compatible devices, but it also offers advantages, as the devices are homogenized and it is easier to exchange information among them.

The most direct alternative to Apple's HealthKit is Google Fit[2]. Google Fit allows people to discover different types of sensors and devices from connected applications through the sensor APIs. This makes it easy to create an ecosystem where different devices or sensors can be used by users. These devices can collect data about people's activities, which is really useful to know their needs, preferences or interactions with other people. In addition, this data also serves to create a history of routines or activities of people so that they can know their progression. Google Fit allows developers to work with different types of manufacturers such as Adidas, Nike or Asus, among others, creating a relatively large ecosystem. As with Apple's HealthKit, Google Fit is subject to those manufacturers that support its integration. In terms of security, Google Fit cannot be used by a service that is certified as a medical device. This is because Google Fit should not be considered a medical service and therefore does not require security measures to protect user information.

The integration of these APIs can also be done with intelligent devices, that allow a versatile placement and provide flexibility and comfort to monitor elderly health status. Many of these devices can be worn or placed on clothing, or under the skin, and on almost any part of the body. These devices can detect a plethora of different variables, the number of steps, activity performed, etc. There are works devoted entirely to the analysis of these types of sensors for monitoring human activity such as [11], where many of the most relevant works on wearables for healthcare domain are analyzed. The authors reaffirm challenges yet in current solutions to be addressed such as energy consumption, privacy and security of information or standardization of protocols. Also, most of the systems analyzed require validation by healthcare personnel to certify that the devices effectively fulfill their function. Our proposal addresses many of these aspects, such as supporting a wide variety of devices regardless of communication protocols, that the devices are mainly low consumption, that users are the ones who have their data and are not in external sources and that the model is easy to use, both for developers and for users themselves. Also, Kim et al. provide in [12] an interesting review on the advances in wearable sensors where they also discuss their potential, alternatives or how invasive they are for people. This study result quite useful to highlight the potential that wearables have in the daily life of people and the limitations they have. The work [13] studies different types of sensors that can be used for monitoring health status from the biomedical-technological perspective. Here, the authors analyze wearable devices, sensors, wireless technology, and real-time tracking devices in the home and their application to physicians. Besides, they point out that these devices are

[2] https://developers.google.com/fit.

generally underused and should be further exploited through different systems that are capable of both managing them and relating them to each other.

The following section presents a use case detailing an ecosystem of different wearable devices, and how HDM can be used to improve the health care of an elderly person.

3 Use-Case: New Healthcare and Well-Being Services for Elderly People

Today, great efforts are being made to bring technology closer to older people. This is why older people are becoming increasingly familiar with intelligent devices, which enhance their quality of life and help them in their daily lives. The following use case shows the importance of this:

Helen is a 74-year-old woman. Recently, she incorporated smart devices that facilitate her daily life and monitor her activity. These devices are a bracelet that monitors her heart rate, slippers that track the number of steps taken during the day or the type of physical activity performed, and even pyjamas that allow her to detect movements while she is sleeping. The advantage of these devices is that they are perfectly integrated into Helen's clothing, so there is no disruption to her daily life nor usage barriers.

In addition, Helen takes part in physical sports activities in the company of other people, which are organised by an association in her neighbourhood. This helps her to stay active and meet new people. Also, the association is responsible for adapting people's exercises and activities, based on information collected from the different participants. This is why the information captured by the different sensors that Helen carries are useful, not only for monitoring her daily life, but also to find out more about her hobbies, interests and sensations. These sensations are stored locally on Helen's devices and are continuously synchronised with each other on her wearable cloud. In addition, some data may be accessible to third parties when connected to the Internet. Sensations can therefore be shared and synchronised with family, friends or health care experts, so that, Helen can be proactively advised to improve her quality of life.

In addition, introducing new smart health monitoring devices into Helen's environment is a simple process, since Helen's existing devices automatically detect when a new data source is available and, then, Helen simply grants access to that information. In addition, an application can be download onto her smart phone to access the data provided by the new source device or service. In terms of data privacy, Helen can decide what information is shared and with whom. Also, this information is processed and stored on her devices locally, so it does not travel to external servers.

This use case shows how one person, Helen, can improve her lifestyle by using wearables that allow her to interact with other people. However, the most important aspect is the processing of the information that these devices generate about Helen's routines. For this reason, the following section presents the HDM, a data model for the intelligent processing of information captured through wearables that allows information to be easily exchanged with other devices and encourages developers to develop applications easily.

4 Human Data Model for Elderly and Wearable Technologies

The above scenario where elderly people, devices and services work as seamlessly as described above requires solutions that go beyond the current state of the art development approaches.

In this paper, we introduce HDM and its architecture. The motivation for HDM is to allow applications running on the devices around the elder's environment to anticipate the relevant sensations, and then to adapt the device behavior so that the environment can serve the elder in a more personalized way. In this sense, the HDM design follows some of the main principles of the User-Centred Design methodology as it is based on an explicit understanding of the users, environment conditions are driven and refined by a user-centred assessment and it addresses the entire user experience [14]. The Fig. 1 shows globally the concept of HDM and how, through data captured using different types of devices, applications or services can be used that take advantage of this data to obtain information from people's routines. By combining external services, intelligent devices, specific IoT devices or information from social networks, a data model of a person can be created. In order to enrich the model, contextual information such as location, date and time, climate or identify other people nearby through sensors located in the environment can be included. This model is then used by developers to create new IoT applications that are easy for people to use.

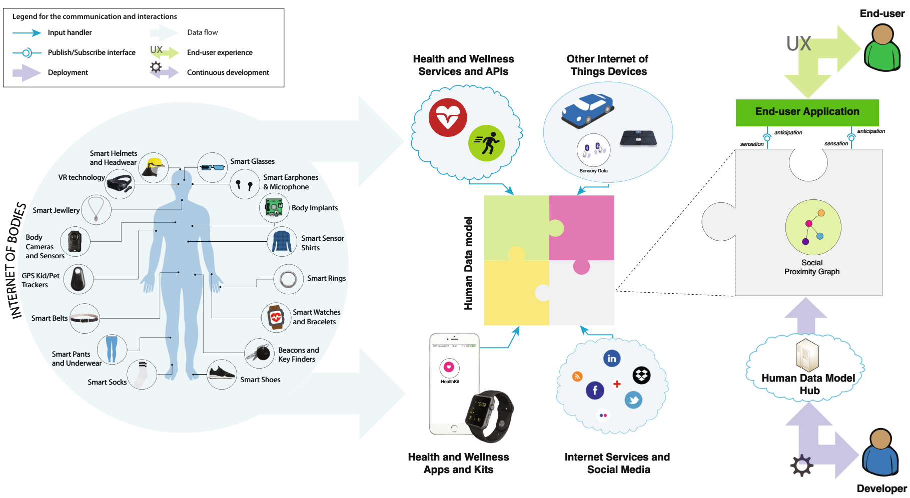

Fig. 1. Design of the Human Data Model.

In addition, Fig. 2 describes the HDM architecture and its different components. HDM collects the data related to our digital and physical elderly lives, and then refines this data into more abstract sensations. In addition, it offers an API for accessing and interacting with the now more meaningful data, but the abstractions can also be used for proactively scheduling computer-human interactions. The HDM is composed of three main layers: **Unified Communication Layer**, **Human Data Model Instance Manager** and **Human Data Model Programming Interface**. Each layer feeds on the sensations generated in the previous layer to perform its functions. The following paragraphs explain the HDM architecture (Fig. 2), from the *Unified Communication Layer* that is in charge of connecting with different types of devices; to the *Instance Manager* whose job is to ensure that each device can get its seed that allows it to be identified with its owner and related to other devices; and, finally, the *Programming Interface* that allows developers to create applications easily.

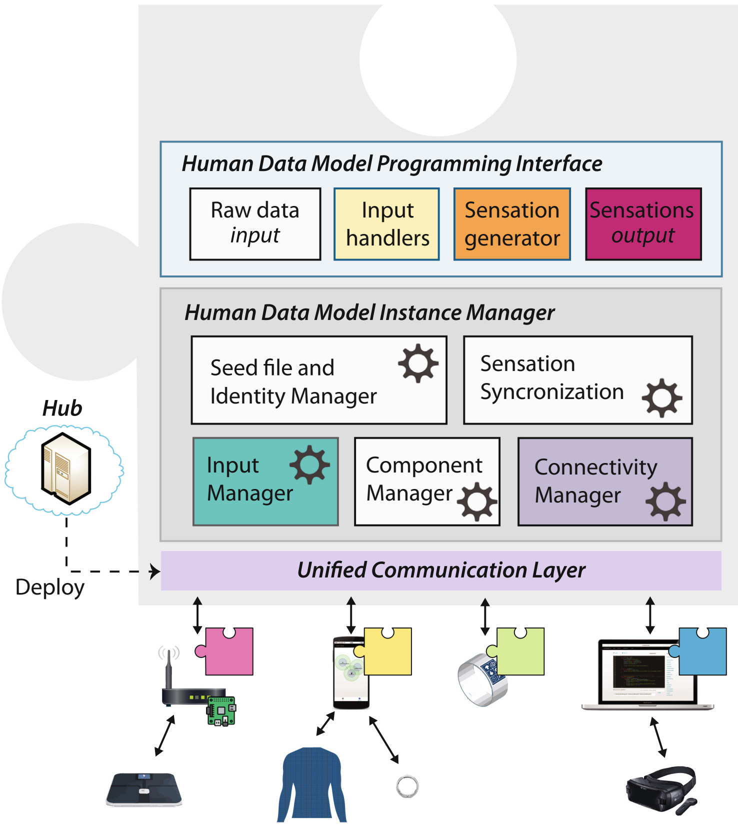

Fig. 2. Human Data Model architecture.

Regarding the first layer, the use of elements from both physical and cyber worlds such as smart devices, social networks, or any application that makes use of people's information, generates a large amount of raw data that allow to detect perceptions and sensations about people to generate a data model. In HDM this perception is enabled by collecting raw data from the physical and cyber worlds (*Unified Communication Layer*).

Once the perception are enabled, they are used as a feed to define people's data model in the second layer. As social relationships are also fundamental in how entities interact, we have defined how the relationships from the so-called "social world" can be reflected in the sensations. In the presented scenario, HDM allowed us to detect the *sensations* that took place in Helen's daily life, e.g., to help anticipating possible health problems and to help discovering routines that lead to healthier and better life quality. An example sensation in the above scenario could be describing that Helen's heart rate was a bit high in contrast to her typical heart rate after a heavy lunch while she was making some activity with her friends in the association. Such a sensation is intuitive and helps Helen to understand better her health condition and what kind of habits and choices may affect her health in a concrete way.

Different people have different needs that are in constantly changing and must be satisfied to facilitate their daily life [15]. Additionally, people use different devices. However, not all of their devices can process all types of data. For instance, the most common wearable devices at the moment can be difficult to program. One of the critical challenges with wearable technology seems to be usability and user experience. So, this can be difficult for elderly who may lack technical knowledge or not be familiar with this type of devices. Imagine how hard it could be for an elderly person to start interacting with a smartwatch, for this reason, one essential quality of HDM is that it can improve the interaction with types of devices, like on a mobile phone, cloud service, or even on a web page and provide access to the up-to-date data for easy-to-use applications. For example, imagine when Helen goes to the association. She could log in to a single application, and this would create a new HDM instance (*HDM Instance Manager*) where all Helen's preferences data would start synchronizing. Helen would then grant the system access to the data she feels comfortable sharing. This would allow to perform the data, the HDM instance would die, and all Helen's data would vanish from that system and services it is using.

Finally, the third layer is able to elaborate new sensations from the data provided for the previous layer. In this sense, our aim with HDM is that it can run on different Edge devices. Not all Edge devices are able to percept or process all types of data [16]. Hence, HDM is also allows modifying an instance dynamically and flexibly with processing capabilities while it is running. As depicted in Fig. 2, developers are expected to define new types of sensations with *Sensation generators* continuously – methods that analyze and combine data from various sources and existing sensations (*HDM Programming Interface*). In addition, developers define how the data is used by the model instance when it receives the data as well as how the data should be preprocessed or refined before relaying it further by implementing new *input handler* methods. Finally, developers can implement *Dispatchers* – a specific type of apps or processes – that can access data sources that have not been previously supported.

In the real world, the entities around elderly people may continually change, and the need to interact can be over shortly. To protect the developers from implementing poorly working interactions and false scheduling, we designed HDM to have a quality of ephemeral sensations, which means that the sensation generated and stored by the model become invalid within a relatively short period – time that can be defined by the developer. Next, the sensations are also being removed from the instances to protect the user privacy. In the scenario above, if Helen takes off her smart pyjama or any other wearable, HDM removes sensations that are based on the data provided by that device in order to prevent relaying false or outdated information to the apps.

5 Discussion and Conclusions

The development of applications based on wearable technologies requires certain features such as data collection, synchronization, combining it with data from other sources, and carrying out the necessary processing to make the most out of it. It has been demonstrated that the data provided by intelligent devices on elder's routines and lives are particularly useful for achieving ecosystems that make their daily lives easier. This ranges from automating simple tasks such as adding reminders to take medication, to sharing information with other devices to promote group activities. All the data processing can be done locally on wearable devices, taking advantage of the great computing capacity they may have. One more advantage is that the Internet connection does not have to be permanent. As a trade-off, edge devices' computing capacity cannot be compared to the Cloud servers', so processing takes longer. Also, adaptability is one of the advantages of the proposed model, since new devices can be added to the ecosystem, and data can be easily obtained and associated with discovering new sensations to improve the behavior of wearable technologies applications for elderly people in smart environments.

In addition to this, wearable devices are becoming fundamental elements in people's daily lives, whether it's to perform activities, communicate with others, report data, improve quality of life, or aid in health care. Due to that, new tools are required to simplify the gathering, relating, and processing of this information to perceive the peoples' environment and act to anticipate possible problems, moods, or needs accordingly. Also, it was mentioned that data privacy is an important aspect to take into account and that only the user should have his/her data and decide with whom (s)he shares it. HDM contemplates this aspect and therefore it must be integrated with security protocols. As future work, we are working to define a security mechanism that guarantees the privacy and security of data in HDM to be evaluated.

In this work, a novel model has been presented allowing one to capture the personal information related coming from heterogeneous sources for its later processing and promoting proactive interactions among smart devices and people.

So, we think that such facilities are essential for the wearable devices technologies as well as other related approaches where data related to individuals is processed.

The HDM implementation can be checked at: https://humandatamodel.github.io/.

Acknowledgments. This work was supported by (0499_4IE_PLUS_4_E) funded by the Interreg V-A España-Portugal (POCTEP) 2014-2020 program, by the project RTI2018-094591-B-I00 (MCIU/AEI/FEDER, UE) and FPU17/02251 grant, by project IB18030 funded by the Government of Extremadura. The work of N. Mäkitalo was supported by the Academy of Finland (project 328729). We would especially want to thank Professor Yevgeni Koucheryavy from Tampere University for his contributions and insight.

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