Measuring Vital Signs for Virtual Reality Health Application

Leonel D. Deusdado, Rui P. Lopes, Alexandre F. J. Antunes, and Júlio C. Lopes

Abstract Smart devices are extremely useful nowadays and incorporate a variety of tools. Their advanced technology allows them to multitask on the same device, being because of this and due to the convenience, agility, and accuracy they bring, they are becoming increasingly popular. Taking advantage of this, it is possible to use this technology to assist in many areas and for a variety of objectives. In areas such as the health sector, new devices are increasingly being used to aid in the treatment of patients in a preventive way, such as with degenerative mental diseases. This research explores the use of a smartwatch to capture heart rate, store it in a database, and display it on a web page, all in real time. The future significance of such a development is based on its connection with another segment of research that attempts to employ virtual reality to aid in the treatment of schizophrenia with a serious game, being able to perceive schizophrenics' body behavior for health analysis.

Keywords Health · Vital sign · Measurement · Storage · Real time · Virtual reality

1 Introduction

People are increasingly measuring their vital signs, whether for exercise or body analysis for health monitoring. This is due to the increasing use of smart devices that can quickly provide such data and a solid assessment of what is being read as

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X.-S. Yang et al. (eds.), *Proceedings of Eighth International Congress on Information and Communication Technology*, Lecture Notes in Networks and Systems 693,
https://doi.org/10.1007/978-981-99-3243-6_50

well. The smartwatch is a popular technology these days. It is commonly used by athletes to conduct thorough measures of calorie consumption, blood oxygen level, and several others, including heart rate, which is the focus of this research.

It is also beneficial in a medical context and offers various advantages for ongoing and extensive analysis. It is usual for data to be stored and utilized for behavioral verification as technological gadgets become more integrated. The project's purpose is to better understand how schizophrenics act by measuring their heartbeats while using a virtual reality serious game application and with this also aid in their treatment. The next sections will go over such applications in further detail as well as present the use of a smartwatch for heartbeat rate measurement.

2 State of the Art

Digital technology is becoming more prevalent in everyday life and more accessible to everyone. Its evolution has been so rapid over the decades that humanity is constantly learning to reinvent it for new purposes. With devices that integrate multiple features, commonly referred to as smart devices, it is crucial to consider the quality and security they provide in order to make them usable. With this in mind, each branch in which they are used will necessitate various tests and analyzes to ensure their accuracy and effectiveness, whether for an external or internal body part.

It is essential for the medical sector to have ongoing scientific studies, such as the one conducted by Winiarski et al., who used inertial sensors attached to the body of an automotive multinational corporation worker to determine whether there is a relationship between ergonomic risk measures and health diseases via motion analysis in several routine tasks [1]. Also with the research of Alsaade et al., which used facial recognition and deep learning techniques in photos from social media to detect children with autism, in order to aid in their treatment, reintegrating them into society through early detection of the mental illness [2].

Measuring data for the inside of the human body is indispensable for detecting diseases and viruses, as well as assisting in the treatment of people who are already ill. A number of social changes and habits have resulted from the (COVID-19) pandemic. People were required to have body temperature check, either infrared temperature detectors or forehead thermometers [3], on most countries and most of commercial premises to ensure that the virus was not present. Rahaman et al. conducted a project estimating a person's calorie burn while doing certain types of activity without the use of a wearable device and then tested with results from those ones [4]. Basjaruddin et al., on the other hand, designed a device to measure the level of stress, based on the joint reading of vital signs such as body temperature, oxygen saturation, galvanic skin response, and heart rate, captured through sensors, as a way to solve the problem of low capture effectiveness of current medical devices that read each body information separately [5].

When it comes to schizophrenia treatment, which is the ultimate goal of the current project's development assistance, there is an increasing amount of technology-driven research. Abbas et al. conducted a research with schizophrenic and healthy individuals to assess motor functioning as a characteristic of schizophrenia over a two-week period, being trained by the study team to use a smartphone application that asked simple questions and captured a video of the participant's response, using the front-facing camera, making an analysis of their head movement by machine learning and computing vision [6].

It is then noticeable the increasing in the use of mobile devices to support medical treatment and public health, referred to nowadays as mHealth, but awareness is required not only for regular smart device users but also for doctors and other associated professions. Gupta et al. conducted a review with this approach, analyzing potential benefits of smartwatches in the clinical area, given their wide range of capturing metrics of the human body, whether with heartbeat rate, amount of oxygen, steps count, sleep tracking, (ECG or EKG), (HRR), or (HRV), realizing the great value and good results coming from the use of this technology [7]. The heart rate is one of the most frequently used features on smartwatches. This feature has a huge advantage in that it can be combined with many various purposes and provide support for other analyses. It also has the ability to tell how a person feels while performing an action. As in Nielsen's research, which uses a smartwatch to measure the heartbeat of children who have issues integrating and interpreting sensory information, that can lead to learning difficulties, then a haptic vest is used for sensory stimulation [8].

Another example would be in relation to (VR), such as the research of Hirzle et al. into this interaction, or the work of Salekin et al. on creating a tool for visualizing enormous and complex medical datasets, which uses the watch as an input method [9, 10]. Furthermore, Quintero et al. discussed the effectiveness of this use with physiological computing system for mental health therapies in their master thesis, analyzing (HRV) during slow-breathing relaxation exercises using a smartwatch and recognizing that medicine can benefit from mobile technology but emphasizing the need to be cautious of technical instabilities [11]. Another intriguing research was conducted by Dolu et al., which investigated how (VR) affects isometric muscle strength. They discovered that participants experienced less pain while using (VR) compared to the traditional exercise were capable of pushing themselves more and felt the time pass more quickly, and there was no difference in their (HRV), which is a metric measured using a smartwatch [12].

The current project uses a smartwatch to monitor the heart rate, as described in greater details in the following sections., with the intention of later integrating it with a (VR) application, sometimes in conjunction with the usage of a haptic vest, to aid in the treatment of schizophrenics [13–15].

3 Heart Rate

The capability to collect information directly from the user is essential for the operation of many smart device systems, especially when the application's objective is to monitor or examine bodily behavior metrics. Although they are not medical devices,

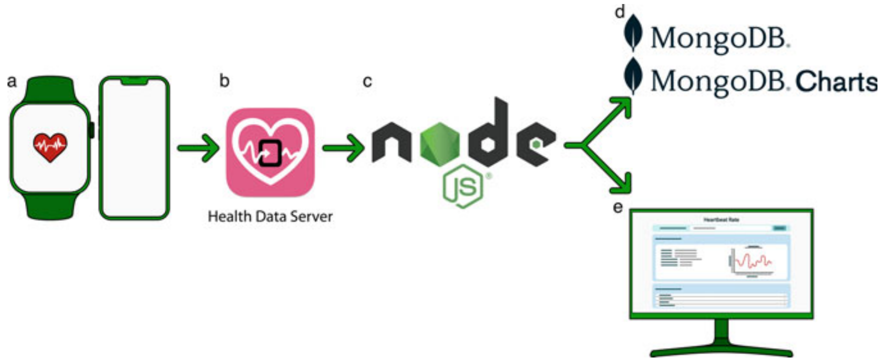

Fig. 1 Heart rate steps. **a** Smartwatch and smartphone. **b** Health data server. **c** Node.js. **d** MongoDB and MongoDB chart. **e** Webpage

smart devices are highly accurate nowadays and can provide a satisfactory estimate to the user, so there is no need to perform numerous medical tests in order to obtain basic information. Smartwatches, for example, that measure with good precision, are not overly intrusive, and do not require calibration.

With that in mind, the project's goal is to employ a smartwatch to capture metrics from user's heartbeat while they are using a (VR) application which focuses on supporting those who suffer from schizophrenia, a progressive mental disorder for which there is yet no cure [14, 16]. Such information will be recorded in a database for analysis of how people feel and when it happens, enabling analysts to determine in what way the (VR) application affects heart rate variations. Additionally, another branch of the study uses a haptic device to try to make the (VR) experience more immersive, which the data will also be used to analyze user's body feedback [13].

To accomplish this, it was essential to use and configure a smartwatch that could, as illustrated in Fig. 1, record heartbeats (connected with a smartphone) (Fig. 1a) and connect it to an application that could gather this information and send it to a desktop computer for which the Health Data Server Application [17] (Fig. 1b) was chosen. Those steps will be explained in Sect. 4.

The information was taken by coding with Node.js (Fig. 1c) [18], that will be discussed in Sect. 5, and then stored in a MongoDB (which provides MongoDB Charts) (Fig. 1d) [19] database, as it can be seen explained in Sect. 6, being all platforms used to generate the desired result. The last step was to display the data on a webpage (Fig. 1e), and it will be explained in the Sect. 7.

4 Heartbeat Rate Measurement

For the heartbeat rate measurement, it was chosen to use a smartwatch that could capture the heart rate quickly and reliably, and this is the first step of the process as it can be seen in Fig. 1a.

The Apple Watch Series 6 [20], from Apple Inc. [21], was selected as the smartwatch for the research because it includes advanced technology and a third-generation optical heart sensor in addition to an electrical heart sensor [22], besides being light and having a small area of contact with the user's body, it does not cause much discomfort; in other words, it is not quite intrusive. The watch contains an optical heart sensor for measuring heart rate, which can also use infrared light, green (LED) lights, and it has "built-in electrodes in the Digital Crown and the back of Apple Watch, which can measure the electrical signals across your heart" [23–25]. A disadvantage of adopting Apple's system is that in order for the watch to operate, you must always have the iPhone around, connected to the internet, and paired with the same Apple account.

The Health Data Server Application [17], created by Rexios, was used for heart rate capture because it effectively transmits the heartbeat rate fastly and is simple to use, and this is the second step of the process as it can be seen in Fig. 1b. It was installed on the iPhone and the watch itself. Figure 2 exhibits the application being used on the smartwatch while capturing the user's heartbeat (a), an user testing it with a haptic vest and our (VR) application displayed in Oculus Meta Quest 2 [26] (b). Part (c) of the image corresponds to what the user is experiencing in the Oculus, which is another branch of the project that has developed a (VR) serious game application [14] to aid in the treatment of schizophrenia, which will be tested with schizophrenics afterward. For such objective, the developer makes available the executable of various systems in a page on GitHub [27] that has instructions for using and downloading files [28].

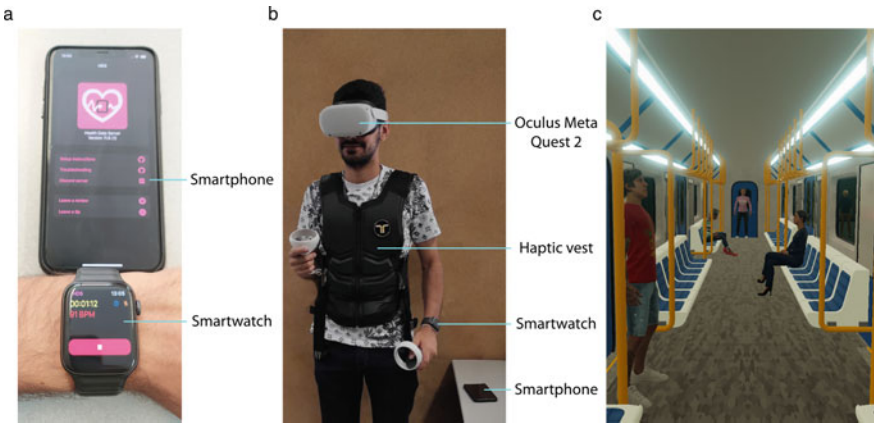

Fig. 2 Smartwatch usage process. **a** Smartwatch and smartphone with health data server. **b** Smartwatch, VR application and haptic vest. **c** VR application

5 Data Acquisition

The data acquisition from the smartwatch had to be received via an (IPv4) connection to the computer. In order to do this, programming code was required to obtain it and used to manage the entire data flow, starting with collecting it from the application until storing and displaying it, and this is the third step of the process as it can be seen in Fig. 1c.

For each user, it is started a new section on the website, followed by a new measurement within the smartwatch application, which starts recording each heartbeat. Our project's GitHub page hosts the open-source application code and also provides additional details on how to use and install the project [29]. The final step was to display the data on a webpage in a more simplified format. This page is being created locally on port 3000 on localhost. More information about the website will be provided in the Sect. 7.

6 Data Storage

It was necessary to use a database in a cloud for data storage that would allow for simplicity and agility, with the goal of transmitting data in real time, in addition to an online connection that would allow data transmission from a device. It was chosen a (NoSQL) oriented database which stores data in (JSON) [30, 31] format and was used to store user's heartbeat data from the smartwatch application, among other things, and this is the fourth step of the process as it can be seen in Fig. 1d.

Figure 3a exhibits the database for saving user data in MongoDB Atlas [32], MongoDB's cloud management. Several elements considered necessary to save were defined for this, such as the user's name, an identifier of the measurement section they are in, the start and final date and time of that section, and the section's duration in

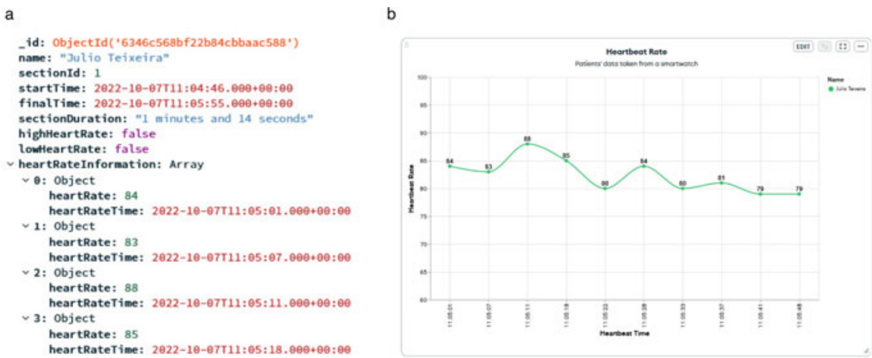

Fig. 3 Database configuration and display. **a** MongoDB storage. **b** MongoDB real-time chart

minutes and seconds. It also saves the possibility of the user surpassing the safe upper or lower limit of the heart rate, as specified by a doctor in a user analysis. Furthermore, the heartbeats are recorded along with the moment they were collected.

For Fig. 3b, a graph built on MongoDB Chart [33] is displayed with the same data as in Fig. 3a. Its configuration is determined by the heartbeat rate on the vertical Y axis and the time of each beat on the horizontal X axis, besides from the number of heartbeats represented on the graph line for each time. The time gap between each heartbeat is around 5 s.

7 Website for Management Control

To manage the application and present the gathered heartbeat data in a simple manner, a webpage was designed that enables the user to manage a new data entry (a), or view previously obtained data (b) while being in real-time connection, as shown in Fig. 4, and this is the last step of the process as it can be seen in Fig. 1e.

To begin a new heartbeat acquisition, it is necessary to provide the current user's name and begin the capture process by clicking on the start button, followed by the need to begin the capture by smartwatch application, as previously described. After that, the page displays information about the data for this new analysis, such as the

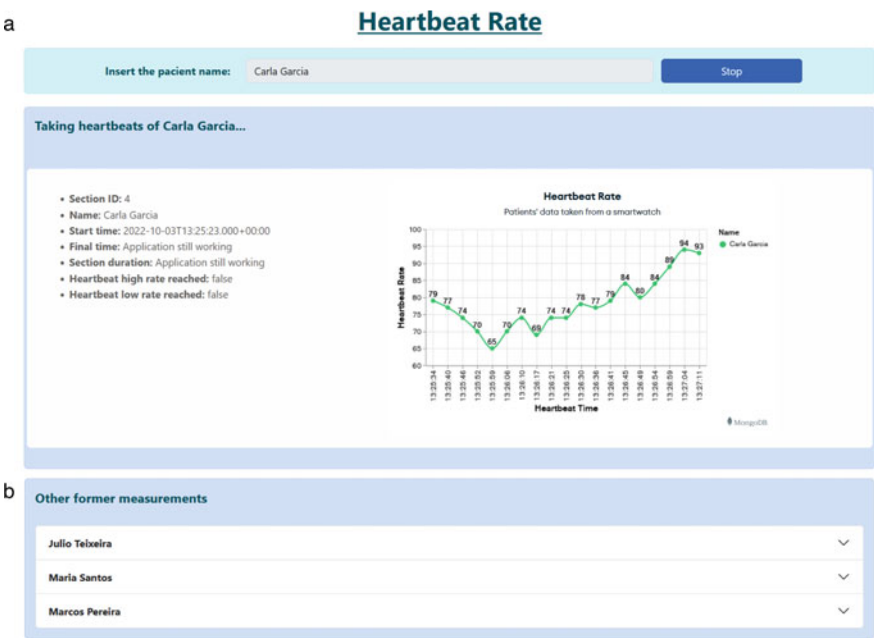

Fig. 4 Webpage exposure. **a** New entrance. **b** Old measurements

section identifier, name, start, finish, and duration of the capture section, and if the high or low limiting heartbeat rate was reached during application operation, showed on Fig. 4a. Along with this data, the chart automatically generates a real-time graph, displaying the heartbeat rate on the vertical Y axis and the time of each beat on the horizontal X axis, and the time gap between each heartbeat is approximately 5 s. Figure 4b displays the old measurements data, which is presented in the same manner as Fig. 4a.

8 Conclusions and Future Works

This research investigated the use of a smart device to capture heartbeats, saving data in a database and displaying it on a web page, all in real time and in a simple manner. Even though they are not medical devices, they perform very well in measuring vital signs and are able to aid in health sector in a way cheaper methodology compared to conventional medical equipment. It was realized that the cloud connectivity was quite useful, with the ability to record and visualize data in a few seconds, as well as transfer information by connecting devices to the database. With this implementation, the medical analysis of a schizophrenic can happen instantly while using the (VR) application.

The future of this implementation will enhance its database configuration, bringing in additional vital data such as health and national ID, as well as its presentation and features. Despite the good integration between the platforms used in the project's development, a limitation is the requirement to have the smartphone close to the watch and on the same account, which if not connected makes using the system impossible. Using outsourced services may also result in issues resulting from system updates or changes to privacy policies. This determines a potential change in the platforms used when focusing on the future growth of obtaining and displaying detailed vital signs of schizophrenics.

It will also be integrated with the other branches of the project that employ a (VR) serious game application in conjunction with a haptic vest to aid in the rehabilitation of schizophrenics and their reintegration into society. Heartbeat analysis will be crucial in determining how the patient feels during this treatment.

Also of interest are the additional possibilities for capturing vital signs that a smartwatch affords, which, if feasible, will be included to the project. Ideally, all the data obtained will be used to make our (VR) serious game application adapt to each single user, by the use of (AI), being possible to make the application take attitudes and change its approach based on the schizophrenic's body behavior.

Acknowledgements This work is funded by the European Regional Development Fund (ERDF) through the Regional Operational Program North 2020, within the scope of Project GreenHealth—Digital strategies in biological assets to improve well-being and promote green health, Norte-01-0145-FEDER-000042.

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