A Real-time m-Health Monitoring System: An Integrated Solution Combining the Use of Several Wearable Sensors and Mobile Devices

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Abstract: Nowadays the upsurge in the prevalence of chronic diseases represents an increasing burden on individuals and society. Chronic diseases can require repeated and frequent hospital treatment to control vital parameters of interest. The use of automatic instruments for a real-time monitoring of biological parameters constitutes a valid instrument to improve the patient's quality of life. The integration of mobile communications with wearable devices has facilitated the shift of healthcare assistance from clinic-centric to patient-centric monitoring. In this paper, a real-time monitoring system is proposed. The system is conceptualized to provide an instrument for patients, by means of which they can easily monitor, analyse and save their own vital signs using wearable sensors and an Android device such as a smartphone or tablet, offering an efficient solution in terms of a decrease in time, human error and cost.

1 INTRODUCTION

During the recent decade the demographic changes in developed countries resulting in a more elderly population and the increasing prevalence of chronic diseases have contributed to the need for a constant monitoring of the state of patients' health.

According to the World Health Organization (World Health Organization, 2016), chronic diseases such as coronary heart disease, cancer, chronic obstructive pulmonary disease and diabetes mellitus type 2 constitute the leading cause of mortality in the world, representing about 60% of all deaths. Chronic diseases are primarily attributable to heart failure, currently the main cause of death in most western countries. The 2016 Heart Disease and Stroke Statistics update of the American Heart Association (AHA) reported that 15.5 million people in the USA suffer from cardiovascular disease, this prevalence increasing with age for both women and men (Sanchis-Gomar et al., 2016). In Europe, in the last 12 months the prevalence of people reporting heart problems was 9.2% for both sexes (Townsend et al., 2016). In particular, in Italy cardiovascular diseases are the main cause of death, responsible for 44% of all deaths (Centro nazionale di epidemiologia, sorveglianza e promozione della salute dell'Istituto superiore di sanità, 2016).

Chronic diseases also have a negative impact on the quality of people's life. Patients suffering from these pathologies must, often, carry out a monitoring of physiological parameters such as heart rate and blood pressure as well as take control of the main risk factors that can aggravate their state of health. In less dangerous cases, it is convenient to monitor patients outside the hospital. On the one hand,in fact, such patients can face their illness in a family context that helps to speed up their recovery time. On the other, this strategy implies a considerable saving of resources, allowing social health facilities and personnel to be assigned to patients with more severe diseases.

Therefore, an efficient solution for the monitoring of a patients' state of health is required, which is able to collect, record and analyse vital signs, and so support preventive care, diagnosis and rehabilitation planning. Moreover, the automation of physiological data capture and its visualisation on a device

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reduces the risk of errors in manual harvesting. This lower risk of error results in increased efficiency, reduced costs and improved vital qualities in an area such as healthcare one where human error can really make the difference between life and death. The most innovative aspect of the adoption of a tele-monitoring system is represented by the means by which patients and healthcare professionals communicate and interact. Patients are directly involved in managing their health and wellness.

Mobile devices, such as smartphones or tablets, constitute the perfect instrument to monitor the vital parameters of a patient. Thanks to the use of appropriate wearable sensors, it is possible to collect and analyse the data coming from these devices to monitor the patient's state of health.

In this work we present a real-time m-health monitoring system for people suffering from chronic diseases that enables the collection, sharing and exchange of physiological data, such as blood pressure, heart and respiration rate and ECG signals. The system is not limited only to the acquisition of such data but also enables the analysis of vital signs. The physiological data are captured using wearable systems compliant and not to Continua Health Alliance guidelines (Carroll et al., 2007), one of the most respected communication standardization protocol.

2 RELATED WORK

Mobile healthcare applications constitute an instrument for individuals to keep track of their health condition, to take more responsibility for their lifestyle and to improve the efficiency of care by providing high quality data to health professionals. Such medical data are often acquired by means of the use of wearable devices. Interest in the research and development of smart wearable systems is increasing in both the academic world and industry, to promote the realization of devices that comply with the required standards of effectiveness, interoperability, cost, privacy and ethics (Lmberis and Dittmar, 2007; Konstantas, 2007; Chan et al., 2012). These systems are able to measure vital signs, such as body and skin temperature, heart rate, blood pressure, blood oxygen saturation (SpO2), electrocardiograms (ECG), electroncephalograms (EEG) and respiration rate.

To implement an m-health solution a level of standardization is necessary to ensure an easy and quick integration between the wearable device (e.g. a blood pressure monitor or pulse-oximeter) and the gateway device (e.g. a smartphone). The interoperability among all devices that compose a telehealth system is regulated by the guidelines of the Continua Health Alliance.is necessary which describe a set of internationally established standards and frameworks to ensure interoperability of devices (Carroll et al., 2007).

Several examples of monitoring systems are described in literature useful for the monitoring of physiological data taken from wearable devices. Unfortunately, not all the presented systems use devices that follow the Continua Health Alliance guidelines. Kakria et al. (Kakria et al., 2015), for example, propose a real-time monitoring system to collect data about heart rate, blood pressure and body temperature using wearable devices non-compliant with the Continua Health Alliance guidelines. The same limitation applies to the device used by PhysioDroid (Banos et al., 2014), a mobile system to monitor heart rate, body temperature and respiration rate, and to the system realized by Forastiere et al.(Forastiere et al., 2016) for a monitoring of a patient's own wellness. The proposed system, instead, supports devices compatible with the Continua Health Alliance design Guidelines. In addition, the open architecture of our framework allows an integration with wearable devices that use other communication and data access protocols to provide a system that can monitor patients integrating data coming from several medical devices, unlike the system proposed by (Park et al., 2016). They develop an m-health application limiting the integration to only certified devices. While, Szydlo et al (Szydło and Konieczny, 2016) present a data acquisition module, implemented as a mobile application to integrate several medical devices, whether or not compliant or not with the Continua Health Alliance guidelines, but without analysing the acquired data.

Many mobile healthcare systems are aimed at patients with cardiac diseases, diabetes, hypertension, or hyperthermia, limiting the acquisition and monitoring to only one set of physiological data, and sometimes providing an analysis such as (Gay and Leijdekkers, 2007; Lv et al., 2010; Rodrigues et al., 2014; Guo et al., 2013; Lee et al., 2016), SenseView (http://www.senseview.mobi/), and SimpleEye (https://simpleeye.com/platforms/android/bluetooth-pulse-oximeter/). Our proposed system, however, is not limited to capturing and monitoring in real time vital signs but also to allows data processing and analysis locally, to better evaluate whether health activities have been performed planned and to assess whether the desired results are being achieved.

Moreover, in literature there are platforms that collect the physiological data and send it to a care center for processing and analysis. These solutions do not process the medical data locally on mobile de-

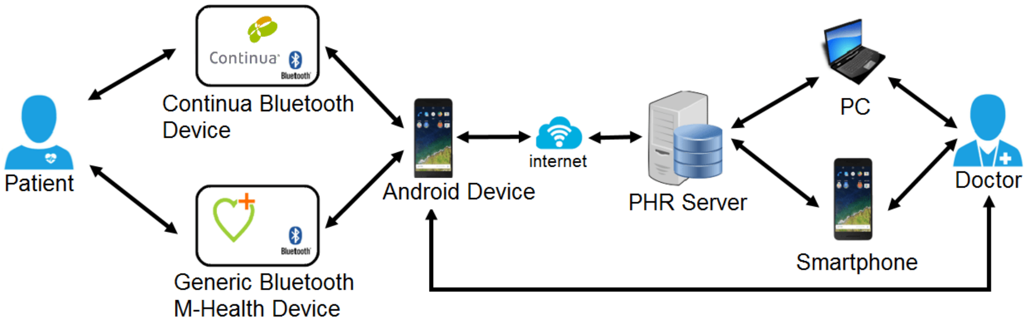

Figure 1: System Structure.

vice, but the signal needs to be continuously transferred to a health center. For example, the European Union-funded research project AMON (Anliker et al., 2004) has an objective realizing a wrist-worn medical monitoring and alert system. The data are transmitted via GSM to a medical center. Unfortunately, for heart monitoring the system is technically limited by the noisy ECG signal that is acquired on the wrist through the realized device and is not appropriate for the diagnosis of cardiac abnormalities. The Epi-medics project (Rubel et al., 2005) is another project for ECG monitoring that records and analyses ECG signals and generates alarms. In this case, also, the monitoring system uses its own sensor device, not interfaced with other sensor devices. Bisio et al. (Bisio et al., 2015), instead, proposed a platform for patients suffering from a heart failure, able to monitor data coming from the pulse oximeter to measure the saturation of peripheral oxygen and a weighting scale to measure the body weight, using devices compliant with the Continua Health Alliance standards. Moreover, Al-Taee et al.(Al-Taee et al., 2015) present a platform to support the self-management of diabetes using several medical sensors which are not compliant the guidelines.

3 MONITORING SYSTEM

The proposed system is able to monitor several health parameters using multiple sensors. The acquired physiological data are processed and analysed locally on a mobile device. A report of the analysis and the original files are saved, can be visualized whenever the user wants and are sent to the medical specialist.

The scheme in the figure 1 shows the structure of the system, a set of interconnected blocks in which the data flows start from the patient and arrive at the medical specialist. A patient can monitor his/her own vital signs using an Android device, which is easy to use and able to capture and store the data from the wearable sensors. Once the acquisition has been completed, the Android device sends the data to a remote Personal Health Record (PHR) server, which the doctor can access to monitor the patient's health state. In the following section the system architecture is explained in detail.

3.1 System Architecture

The system has a modular structure, in which every module performs a specific set of operations, as shown in the figure 2.

The *Health Device Profile (HDP) module* is responsible for the transmission of data from the wearable devices to the mobile devices using the Bluetooth protocol. Moreover, it is possible to connect the proposed system with an external PHR, as shown in the figure 1, and/or Decision Support Systems. In the interaction with these systems, the adoption of the Continua Alliance standard, using an appropriate wrapper, allows a fast and accurate data translation in accordance with the two Health Level 7 standards (http://www.hl7.org/implement/standards): Fast Healthcare Interoperability Resources (FHIR) and Personal Healthcare Monitoring Report (PHMR). The FHIR Standard (Bender and Sartipi, 2013) is useful to represent and exchange information between several types of monitoring devices, for a correct syntactic and semantic interoperability and appropriate efficiency between information systems and biomedical devices. Moreover, in order to improve the data dissertation in a tele-monitoring application, the PHMR (Wolf et al., 2009) was introduced, which is able to translate personal healthcare monitoring information into electronic medical record systems including a representation of the measurements captured.

The data, that are received by the HDP module, will be forwarded to the other modules connected with it, the *Storage module* and the *Signal Analysis* module. The first one is used to save physiological data and a patient's analysis report in the device in-

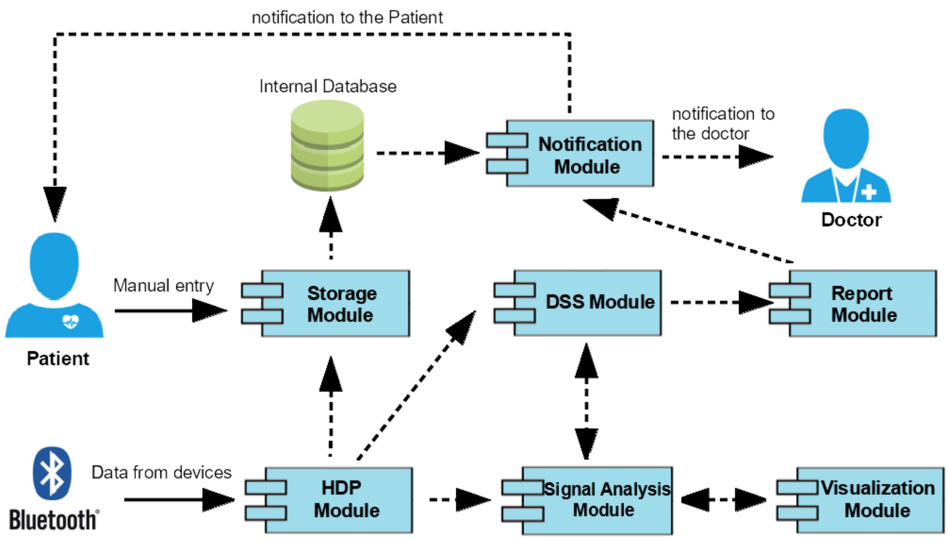

Figure 2: System Architecture.

ternal memory. SQLite database is used to store measurement data acquired from the mobile health device and/or data from manual measurement that the patient performs with devices not equipped with a Bluetooth connection. In the first case, the Storage Module receives data from the HDP Module, while in the second the data are directly inserted by the user. Collected and analysed data, during the monitoring, constitute the Personal Health Record (PHR) of the patient (Tang et al., 2006). To access the data contained in the PHR the doctor, through appropriate devices, must interact with a remote server to visualize any desired data. This operation is fundamental when there are anomalies that generate an alert. In this situation the specialist visualizes all the patient's measurements and can decide to change the therapy, perform in depth examinations or modify the monitoring plan.

The monitored data, besides being saved, can be analyzed, using the *Signal Analysis Module*. In detail,such analysis can include:

- Filtering data to remove the additive noise that can distort the signal and the resulting interpretation. It is possible to choose between four types of filter: high-pass and low-pass (Chen and Chen, 2003), recursive (Cuomo et al., 2016) and Hanning filters (Verde et al., 2015). The implemented filters are characterized by appropriate parameters such as the cut-off frequency that the user can set indicating the desirable value;
- Data processing, whereby the signals can be analysed to extract characteristic parameters, useful to evaluate the patient's health state.

Data obtained from the HDP and Signal Analysis modules are sent to the *DSS Module*. This module constitutes the Decision Support System, apable of supporting and improving the real-time monitoring and analysis using "the medical specialist's knowledge". The data are, in fact, compared with selected threshold values to check the patient's state of health. If the module discovers a warning situation, it asks the Report Module to generate a message to be sent to the doctor via the Notification Module.

All acquired data and analyses are saved in the appropriate reports, realized by the *Report Module*. The system saves a report with all measurement data once a day, which is then sent to the medical specialist at the time scheduled by the user. Moreover, the system can create a warning report message, attaching the report files, if an analysis of the data using the DSS Module reveals an abnormal situation in the patient's state of health.

The *Notification Module* is the part of the software that is responsible for notifying messages generated by the system to the doctor and the patient. The messages can be of two types:

- Alerts, that instructs the user to perform the desired measurements at scheduled time;
- E-mail messages, sent to the medical specialist indicated by the user. Such messages include any report of the patient's measurements.

Finally, the *Visualization Module* is the interface between the system and the users. It shows the real time measurements acquired from the wearable devices, the analysis data and the report files, whenever the user chooses.

4 USE-CASE

The realized monitoring system can be used with patients suffering from cardiovascular diseases. These patients have to constantly monitor characteristic phisiological data, such as blood pressure and heart rate. Therefore, they must report these data, very often collected manually over several days, to their medical specialists during rountine follow-up visits.

The manual collection of physiological data can increase the risk of errors, and the recording of erroneous values can change the evaluation of patient's state of health. To avoid this problem it is possible to automate the process for capturing and monitoring vital signs, as performed by the proposed system. Moreover, this system allows the patients to monitor their own physiological data at home using appropriate wearable devices without the necessity of going to a hospital center, providing a complete clinical picture to the medical specialist.

The fundamental vital signs, in order to perform a monitoring of a patient suffering from cardiovascular disease, are the heart rate, respiration rate, ECG signal, blood pressure and oxygen saturation. Therefore, the patient, using an appropriate wereable device, such as Zephyr Bioharness BH3, A&D Medical UA-767PBT-C and Nonin 9560 Onyx 2 (described in the following subsection), can capture and monitor the relevant parameters, by means of a mobile device, such as a smartphone or tablet, on which the tele-monitoring application has been installed.

4.1 Medical Devices

The measuring accuracy of the sensor has a direct impact on the accuracy of the heart parameter measurement in real-time monitoring systems. Therefore, the selection of an accurate heart parameter monitoring device plays an important role in the early detection of any possible heart disease.

Zephyr Bioharness BH3 is a multisensory belt used to monitor heart rate, breathing rate and posture in real-time. The selection of the Zephyr Bioharness BH3 device was made on the basis of the accuracy of the acquired physiological data, low cost and comfort for patient comfort. This instrument is able to capture the vital signs in three different ways: with an elastic belt in which the sensors are integrated, with a shirt with the sensors integrated inside or with a and holder connected with common cardiac electrodes, as shown in the figure 3.

The second measurement parameter in our monitoring system is the evaluation of blood pressure. Blood pressure is an index of the force of the blood pushing against the walls of the arteries as the heart pumps blood. It is measured as both the pressure when the heart beats pump blood (the systolic pressure) and the pressure when the heart is at rest between beats (the diastolic pressure). To monitor the patient's blood pressure the realized system uses the *A&D Medical UA-767PBT-C* blood pressure monitor.

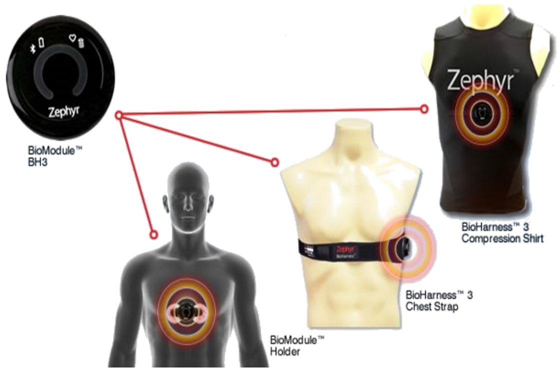

Figure 3: Zephyr Bioharness BH3.

An acute rate of these parameters is considered as an early indicator which supports medical specialists in the diagnosis of serious diseases. Additionally, the blood oxygen saturation and pulse rate can be indices of possible alterations, monitored in our system by using the *Nonin 9560 Onyx 2*. The blood pressure monitor and the pulse oximeter are illustred in the figure 4.

Figure 4: A&D Medical UA-767PBT-C and Nonin 9560 Onyx 2.

These three devices uses the Bluetooth protocol to communicate with the monitoring software installed on the Android device. The communication between the realized system and the Nonin 9560 Onyx 2 and the UA-767PBT-C follows the Continua Health Alliance guidelines. Although the Zephyr Bioharness BH3 is not certified for this standard, a dedicated library is available enabling its connection with the mobile devices.

4.2 Mobile Application

The system was implemented for mobile devices, such as a smartphone or tablet, developed by using the Java Programming Language through the use of

Eclipse IDE and the Android Software Developer Kit (SDK). The mobile system offers several functionalities. At the first access the user must complete a Registration form, in which he/she inserts personal information such as name, surname, date of birth, gender, email address. In detail, the e-mail address is both that of the user and that of the medical specialist who will receive the user's report containing the measurement of the physiological data and the analysis of the estimated values. Such an e-mail will be sent at the time indicated in the registration phase.

After the registration, the user can choose any of the operations in the main menu shown in the screenshot in the figure 5.

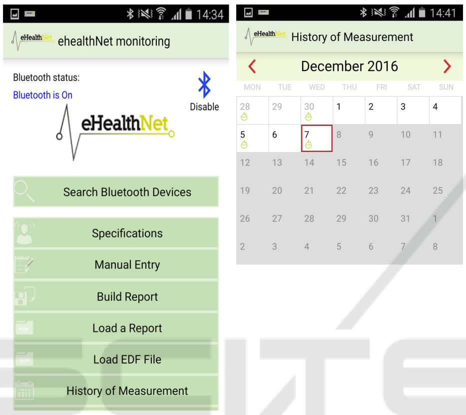

Figure 5: Screenshots of the Homepage and History of Measurement.

In detail, the user can perform the following functionalities:

- Search Bluethooth Devices: the system searches for Bluethooth devices and shows them to the user. The user can choose to collect his/her preferred wearable devices able to execute different the measurements and analyses. If the user connects to the Zephyr Bioharness BH3, for example, he/she can monitor in real-time physiological data such as the heart and breath rate or the ECG signal, as shown in the figure 6.

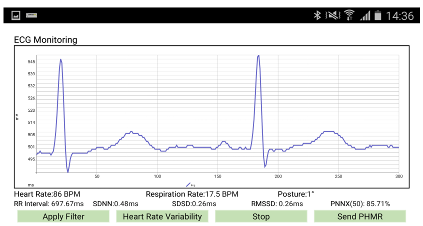

Figure 6: Screenshot of the ECG monitoring.

  During the signal capture, noise can add to the useful signal distorting its interpretation and the resulting diagnosis. To avoid this problem the user can filter the captured signal choosing a filter offered by our system, described in section 3.1. In addition, it is possible to extract the characteristic parameters of the Heart Variability Index (HRV). The HRV describes the variations of both the instantaneous heart rate and RR intervals, useful to evaluate the heart state and any possible anomalies due to the presence of arrhythmias (Townsend et al., 2016);

- Specifications: information about cardiac diseases and healthy lifestyles is provided, useful for the prevention of these disorders;

- Manual Data Entry: the user can directly insert measurement data such as blood pressure, blood oxygen saturation, pulse rate and weight, indicating the date and time when he/she made this measurement;

- Loading Report and EDF file: any report with the recorded measurements can be saved and exported in pdf and European Data Format (EDF) format. EDF is the most used standard to exchange and store biological and physical signals (Kemp and Olivan, 2003). The user can choose this functionality to upload these reports and files, thanks to which the specialist can monitor the user's progress;

- History of Measurements: a calendar with a history of all the measurements performed is displayed.

4.3 Evaluation of Performance

The performance of the proposed system has been evaluated in terms of the allocation of memory and CPU used by the mobile application during the real-time monitoring. The first test consisted of tracking memory and CPU usage during a monitoring period of 15 minutes so as to assess over time the trend of these quantities. The real-time monitoring feature was tested on two different devices with two different Android versions: a Samsung GT-i9505 (S4) with the Android 5.0.1 version and a HUAWEI GRA-L09 (P8) with the Android 6.1 version. The performance of these analyses showed good results, as reported in the figures 7 and 8.

The obtained results indicate that the application is efficient in the use of system resources, which is very important considering that it is designed to run on a mobile device. The memory used by the application in the real-time monitoring feature is constantly less than 32 MB, increasing slightly applying when the filters are applied, and the use of the CPU is low.

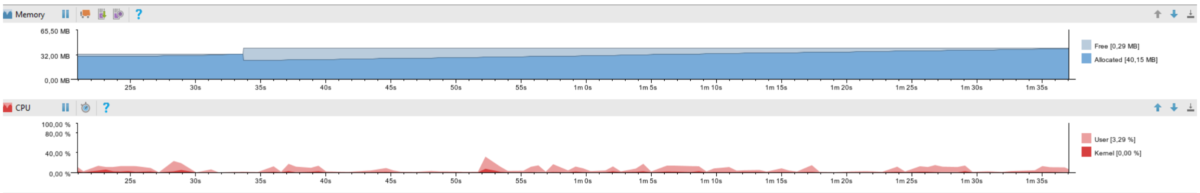

Figure 7: Performance on Samsung GT-i9505

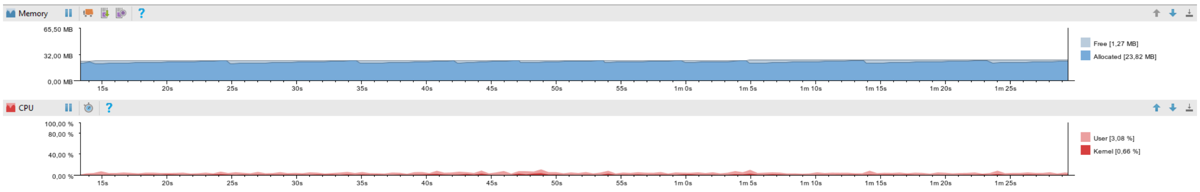

Figure 8: Performance on HUAWEI GRA-L09

To evaluate the CPU use, we compared the performance of our system with that of the SenseView App (http://www.senseview.mobi/), which is one of the most used apps on the market to connect with the Zephyr Bioharness BH3. The results show that our proposed system occupies, during the instantaneous monitoring, about 0,4 % of CPU, while the CPU used by the SenseView App is about 0,2 %. The RAM used, instead, is less for our proposed app (21 MB) than that used by the SenseView App (52 MB). This means that the realized system can be run on mid-range mobile devices without degrading the device performance.

5 CONCLUSIONS

In recent years the prevalence of chronic diseases has increased due to the rise in life expectancy and changes in lifestyle, and thus people suffering from these pathologies often need a continuos monitoring of their vital signs. The mobile health field can provide new access opportunities for treatment and medical services, constituting a valuable support instrument for both patients and doctors.

In this paper we have presented a physiological monitoring application designed for Android mobile devices. The user can visualize his/her own vital signs information, collected by means of an instrument, easy and fast to use, such as a smartphone or tablet and appropriate wearable devices. The system does not only monitor these parameters but also analyzes them, allowing the medical specialist to make a more accurate analysis. The system provides a good performance in terms of memory and CPU used, in comparison with other systems on the market.

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REFERENCES

Al-Taee, M. A., Al-Nuaimy, W., Al-Ataby, A., Muhsin, Z. J., and Abood, S. N. (2015). Mobile health platform for diabetes management based on the internet-of-things. In *Applied Electrical Engineering and Computing Technologies (AEECT), 2015 IEEE Jordan Conference on*, pages 1–5. IEEE.

Anliker, U., Ward, J. A., Lukowicz, P., Troster, G., Dolveck, F., Baer, M., Keita, F., Schenker, E. B., Catarsi, F., Coluccini, L., et al. (2004). Amon: a wearable multiparameter medical monitoring and alert system. *IEEE Transactions on information technology in Biomedicine*, 8(4):415–427.

Banos, O., Villalonga, C., Damas, M., Gloesekoetter, P., Pomares, H., and Rojas, I. (2014). Physiodroid: Combining wearable health sensors and mobile devices for a ubiquitous, continuous, and personal monitoring. *The Scientific World Journal*, 2014.

Bender, D. and Sartipi, K. (2013). Hl7 fhir: An agile and restful approach to healthcare information exchange. In *Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems*, pages 326–331. IEEE.

Bisio, I., Lavagetto, F., Marchese, M., and Sciarrone, A. (2015). A smartphone-centric platform for remote health monitoring of heart failure. *International Journal of Communication Systems*, 28(11):1753–1771.

Carroll, R., Cnossen, R., Schnell, M., and Simons, D. (2007). Continua: An interoperable personal healthcare ecosystem. *IEEE Pervasive Computing*, 6(4):90–94.

Centro nazionale di epidemiologia, sorveglianza e promozione della salute dell'Istituto superiore di sanità (2016). Il portale dell'epidemiologia per la sanità pubblica. http://www.epicentro.iss.it/focus/cardiovascolare/cardiovascolari.asp/.

Chan, M., Estève, D., Fourniols, J.-Y., Escriba, C., and Campo, E. (2012). Smart wearable systems: Current status and future challenges. *Artificial intelligence in medicine*, 56(3):137–156.

Chen, H. and Chen, S. (2003). A moving average based filtering system with its application to real-time qrs detection. In *Computers in Cardiology, 2003*, pages 585–588. IEEE.

Cuomo, S., De Pietro, G., Farina, R., Galletti, A., and Sannino, G. (2016). A revised scheme for real time ecg signal denoising based on recursive filtering. *Biomedical Signal Processing and Control*, 27:134–144.

Forastiere, M., De Pietro, G., and Sannino, G. (2016). An mhealth application for a personalized monitoring of ones own wellness: Design and development. In *Innovation in Medicine and Healthcare 2016*, pages 269–278. Springer.

Gay, V. and Leijdekkers, P. (2007). A health monitoring system using smart phones and wearable sensors. *International journal of ARM*, 8(2):29–35.

Guo, X., Duan, X., Gao, H., Huang, A., and Jiao, B. (2013). An ecg monitoring and alarming system based on android smart phone. *Communications and Network*, 5(03):584.

Kakria, P., Tripathi, N., and Kitipawang, P. (2015). A real-time health monitoring system for remote cardiac patients using smartphone and wearable sensors. *International journal of telemedicine and applications*, 2015.

Kemp, B. and Olivan, J. (2003). European data format plus(edf+), an edf alike standard format for the exchange of physiological data. *Clinical Neurophysiology*, 114(9):1755–1761.

Konstantas, D. (2007). An overview of wearable and implantable medical sensors. *Yearbook of medical informatics*, 7(1):66–69.

Lee, J. M., Hirschfeld, E., and Wedding, J. (2016). A patient-designed do-it-yourself mobile technology system for diabetes: Promise and challenges for a new era in medicine. *JAMA*, 315(14):1447–1448.

Lmberis, A. and Dittmar, A. (2007). Advanced wearable health systems and applications-research and development efforts in the european union. *IEEE Engineering in Medicine and Biology Magazine*, 26(3):29–33.

Lv, Z., Xia, F., Wu, G., Yao, L., and Chen, Z. (2010). icare: a mobile health monitoring system for the elderly. In *Proceedings of the 2010 IEEE/ACM Int'l Conference on Green Computing and Communications & Int'l Conference on Cyber, Physical and Social Computing*, pages 699–705. IEEE Computer Society.

Park, H. S., Cho, H., and Kim, H. S. (2016). Development of a multi-agent m-health application based on various protocols for chronic disease self-management. *Journal of medical systems*, 40(1):1–14.

Rodrigues, D. F., Horta, E. T., Silva, B. M., Guedes, F. D., and Rodrigues, J. J. (2014). A mobile healthcare solution for ambient assisted living environments. In *e-Health Networking, Applications and Services (Healthcom), 2014 IEEE 16th International Conference on*, pages 170–175. IEEE.

Rubel, P., Fayn, J., Nollo, G., Assanelli, D., Li, B., Restier, L., Adami, S., Arod, S., Atoui, H., Ohlsson, M., et al. (2005). Toward personal ehealth in cardiology. results from the epi-medics telemedicine project. *Journal of electrocardiology*, 38(4):100–106.

Sanchis-Gomar, F., Perez-Quilis, C., Leischik, R., and Lucia, A. (2016). Epidemiology of coronary heart disease and acute coronary syndrome. *Annals of Translational Medicine*, 4(13).

Szydło, T. and Konieczny, M. (2016). Mobile and wearable devices in an open and universal system for remote patient monitoring. *Microprocessors and Microsystems*, 46:44–54.

Tang, P. C., Ash, J. S., Bates, D. W., Overhage, J. M., and Sands, D. Z. (2006). Personal health records: definitions, benefits, and strategies for overcoming barriers to adoption. *Journal of the American Medical Informatics Association*, 13(2):121–126.

Townsend, N., Wilson, L., Bhatnagar, P., Wickramasinghe, K., Rayner, M., and Nichols, M. (2016). Cardiovascular disease in europe: epidemiological update 2016. *European heart journal*, page ehw334.

Verde, L., De Pietro, G., Veltri, P., and Sannino, G. (2015). A noise-aware methodology for a mobile voice screening application. In *Advances in Sensors and Interfaces (IWASI), 2015 6th IEEE International Workshop on*, pages 193–198. IEEE.

Wolf, K.-H., Schirmer, S., Marschollek, M., and Haux, R. (2009). Representing sensor data using the hl7 cda personal healthcare monitoring report draft. In *MIE*, pages 480–484. Citeseer.

World Health Organization (2016). Chronic diseases and health promotion. http://www.who.int/chp/en/.