Medical Data Analytics and Wearable Devices

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Abstract

Clinical decision-making may be directly impacted by wearable application. Some people think that wearable technologies, such as patient rehabilitation outside of hospitals, could boost patient care quality while lowering costs. The big data produced by wearable technology presents researchers with both a challenge and an opportunity to expand the use of artificial intelligence (AI) techniques on these data. By establishing new healthcare service systems, it is possible to organise diverse information and communications technologies into service linkages. This includes emerging smart systems, cloud computing, social networks, and enhanced sensing and data analysis techniques. The characteristics and features of big data, the significance of big data analytics in the healthcare industry, and a discussion of the effectiveness of several machine learning algorithms employed in big data analytics served as our conclusion.

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1. Introduction

With the introduction of new instruments for biomedical research and healthcare digitalization, data in current biomedical practise and research have been rising substantially. Recent advances in wearable and big data technology have made it possible to collect and transform biomedical data in real time. By reducing the risk of damage, boosting doctor-patient communication, and exposing previously unseen scanning and sensory aspects, this has the potential to greatly improve healthcare services [1]. Analyzing raw datasets for trends, conclusions, and improvement opportunities is the process of data analytics. Healthcare analytics employs both recent and old data to produce macro and micro insights to help business and patient decision-making. Improved patient care, quicker and more accurate diagnoses,

preventive measures, more individualized treatment, and better decision-making are all made possible by the application of health data analytics. It can reduce expenses; streamline internal processes, and other things at the corporate level. Health information is any information pertaining to a patient's or population's health. The many health information systems (HIS) and other technical tools utilised by government organisations, insurance companies, and healthcare practitioners are where this data is obtained. To obtain, store, communicate, and analyse health data, a number of technologies and systems are employed. Every second, more and more health care data are available for analysis due to digital data collecting. There is a substantial amount of data being collected in real time due to the growth of electronic record keeping, applications, and other electronic ways of data collecting and storage. Because of the complexity of these data sets, conventional

processing tools and storage techniques cannot be utilized. Dealing with "Big Data" necessitates the use of cloud storage. Cloud storage is designed to be secure, which is essential when working with private patient data. Additionally, it is incredibly economical and has contributed to bringing down the rising cost of healthcare. Wearable biosensors, often known as "wearables," have been used as part of a larger, interdisciplinary health care initiative to leverage mHealth to improve data collection, diagnosis, treatment monitoring, and health insights [5, 6].

Among the key elements of smart cities is smart healthcare. The area of intelligent healthcare was created in order to better manage the healthcare industry, make better use of its resources, cut costs, and maintains or even raises quality levels. Consumable and non-consumable resources can be broadly categorised in the healthcare industry. Consumable resources are those that degrade and run out over time, such as all tools and medical equipment. On the other side, non-consumable resources are those that do not deplete over time. Human resources like doctors, nurses, registered nurses, and all other human capital involved in the healthcare process are included in the non-consumable resources. Data is growing quickly by several orders of magnitude because of the promise of a smart city. As a result, the IoT services are built around these enormous volumes of data, often known as "big data." A Bluetooth-enabled in-home patient monitoring system is suggested by Cheng and Zhuang in [28], making it simpler to identify Alzheimer's disease in its early stages. A medical professional can tell whether a target patient is getting Alzheimer's disease based on the way they move. They have created a study that demonstrates the viability and practicability of the suggested in-home patient monitoring system.

2. Why data analysis in medicine?

Anyone and everyone can see the effect COVID-19 has had on the healthcare sector. The influence COVID-19 has had on health care data analytics, however, is something that most people fail to see. According to Health IT Analytics, "big data tools are now used more frequently in healthcare decision-making". Big data analytics and predictive models are being used by politicians, academics, and healthcare practitioners to assist manage resources, forecast demand, enhance patient care and results, and implement preventive measures. The fight against COVID-19 has benefited greatly from big data and health data analytics. The rate of data entry is almost constant. A greater understanding of how to react and treat patients has been made possible by the analysis of such health data. In recent years, the process of gathering data in healthcare settings has been streamlined. In addition to assisting in bettering daily operations and patient care, the data may now be used more effectively in predictive modeling. We can utilize both datasets to track trends and make forecasts rather than just focusing on historical or present data. We can now take preventative action and monitor the results.

In medicine and healthcare, big data analytics can be used to examine huge datasets from hundreds of patients, and data mining techniques can be applied to build predictive models and discover correlations and clusters between datasets [2, 3]. A wide range of reasonably priced technologies has made it possible to continually or frequently monitor physiological parameters and follow changes in a patient's health state or across patient populations. Numerous consumer wearables collect information on physiological characteristics like heart rate (HR), skin temperature, and peripheral capillary oxygen saturation in addition to location, physical activity, and other ambient environmental elements [7].

3. Data Management in the Healthcare

An extensible big data architecture was created with the ability to handle a variety of situations, including the early diagnosis of diseases and the identification of emergencies [13]. HER for electronic health records. It is made up of a variety of medical data that describes the patient's health state, including the patient's characteristics, prescriptions, diagnoses, lab results, doctor's notes, radiological records, clinical data, and payment notes. It also contains a complete patient medical history that has been digitally stored. For the aim of healthcare analytics, the EHR is a rich source of data. EHR also enables data exchange within the community of healthcare professionals [14]. The healthcare cloud is in charge of storing and retrieving this data. Security manager and the health data store are two overlapping components of the healthcare cloud [15]. Large-scale health data is typically challenging to manage and store using conventional tools and approaches. As a result, we require a system that can manage the volume and variety of such data. The proposed method accomplishes this by utilising a health data management system that has been deployed using a distinctive cloud database management system architecture [16]. EdgeCare is a safe and effective data management system for mobile healthcare systems. Local authorities are set up to schedule edge servers for processing healthcare data and enabling data trading. A collaborative, multilevel structure is created for the practical implementation of EdgeCare. Following that, a system-wide investigation into safe data exchange and streaming was conducted. In order to try and come up with the optimum incentive system for a consumers and information gathered in the ethical decentralised data trade, the Stackelberg game-based optimization technique was also used. In order to show that EdgeCare provides effective solutions to safeguard healthcare data and facilitate effective data exchange, numerical results accompanied by security analysis are presented. In various circumstances, edge servers can carry out local network administration operations.

For instance, they are employed to boost decentralised electric car charging and discharging management and to achieve distributed reputation management in vehicular networks [17], [18]. In order to create personal health records, wearable sensors and medical IoT devices have lately started to collect personal life-long data (PHR) [19]. Real-time healthcare analytics enabled by patients, physicians, pharmaceutical researchers, and payers will all receive artificial intelligence (AI) in return. Blockchain technology is an additional practical option for managing individual EHRs. For providing their health information to doctors and their research partners, patients can receive tokens as payment through the use of so-called "smart contracts." For instance, Health Wizz is testing a mobile EHR aggregator app with blockchain and FHIR support, which tokenizes data using blockchains, allowing individuals to safely collect, organise, exchange, give, and/or sell their individual health information. In order to improve fostering interaction between healthcare organisations and caregivers and laying the groundwork for improved care, the goal is to give people the same simple control over personal health information as much control over your online financial accounts [20]. With the help of this platform, patients regain control over their personal information. In order to achieve security, accountability, and integrity, the main objective of this study is to retain patient's personal data on the Blockchain. Patients will have complete control over the blocks that will house their data. The lack of pseudonymity in current healthcare systems is addressed by our platform. "MediBchain" will revive people' interest in healthcare while preserving the responsibility, authenticity, anonymization, privacy, and confidentiality that EHR systems are losing. In a smart city, big data applications can assist various industries by enhancing consumer experiences and providing services that make firms run more efficiently (e.g., higher profits or increased market shares). Healthcare can be enhanced by enhancing patient care, diagnosis and treatment techniques, medical record management, and preventative care services. Big data may assist transportation networks in becoming more environmentally friendly, adjusting to changing demand, and streamlining schedules and routes.

4. Data Analytics Techniques

1. Cluster analysis - The term "cluster" refers to the activity of grouping a set of data components so that they are more comparable (in a certain sense) to one another than to those in other groupings. Clustering is frequently used to discover hidden patterns in the data because there is no goal variable involved. The method is also applied to offer more context to a trend or statistic.

2. Cohort analysis - This kind of data analysis technique employs historical data to study and contrast the behaviour of a chosen subset of users, which can then be compared to that of other users who have similar traits. With the use of this methodology, it's possible to obtain a thorough understanding of a larger target market or a wealth of insight into customer wants. Cohort analysis may be particularly helpful for marketing analysis because it can let you know how your efforts are affecting particular client demographics. Consider sending an email campaign inviting users to register on your website as an example. You construct two copies of the campaign for this purpose, each with unique designs, CTAs, and ad copy. Later, you may follow the effectiveness of the campaign over a longer period of time using cohort analysis to learn which kinds of content are encouraging your customers to sign up, make repeat purchases, or take other actions.

3. Regression analysis - Regression makes use of historical data to analyse how changing or remaining constant values of one or more independent variables affect the value of a dependent variable (linear regression or multiple regression). You may predict potential outcomes and make better judgments in the future by understanding the relationship between each variable and how they evolved in the past.

4. Neural networks - The neural network serves as the foundation for machine learning's clever algorithms. It is a type of analytics that makes an effort, with little assistance, to comprehend how the human brain would produce insights and forecast values. Neural networks change and improve over time because they gain knowledge from each and every data exchange.

5. Factor analysis - The factor analysis, often known as "dimension reduction," is a method of data analysis that is used to express variation among seen, correlated variables in terms of a possibly smaller number of unobserved variables termed factors. Here, the goal is to find independent latent variables, which is a great way to streamline particular parts. A customer review of a product is a useful example for comprehending this data analysis technique. The initial evaluation is based on a variety of factors, including colour, shape, wearability, modern trends, materials, comfort, location of purchase, and frequency of use. Based on what you wish to track, the list could go on forever.

6. Data mining - a technique for analysing data that serves as a catch-all for engineering metrics and insights to provide value, focus, and context. Data mining uses exploratory statistical analysis to find relationships, relations, patterns, and trends in order to produce advanced knowledge. Adopting a data mining attitude is crucial to success when thinking about how to analyse data; as such, it is a topic worth exploring in more detail.

7. Text analysis - Large collections of textual data are organised in a way that makes them manageable for text analysis, commonly known as text mining in the industry. You will be able to extract the data that is actually pertinent to your organisation and use it to create

actionable insights that will advance you if you carefully follow this purification process.

8. Time series analysis - A group of data points gathered over a predetermined time period is analysed using the time series method. The time series analysis is not the only technique used by analysts to gather data over time, even though it allows for more frequent monitoring of the data points than just intermittent monitoring. Instead, it enables researchers to comprehend if variables changed over the course of the investigation, how the many variables are dependent, and how the study arrived at its conclusion.

9. Decision Trees - Making wise and strategic decisions can be supported by using the decision tree analysis. Researchers and business users may quickly assess all the relevant aspects and determine the best course of action by visualising probable outcomes, effects, and costs in a tree-like model. Decision trees can be used to examine quantitative data and improve decision-making by allowing you to identify chances for improvement, save costs, and increase operational effectiveness and production.

10. Conjoint analysis - The conjoint analysis is the last but certainly not least. This strategy is one of the most efficient ways to identify consumer preferences and is frequently used in surveys to discover how people value various characteristics of a good or service. Conjoint analysis can be used to identify your customers' preferences, regardless of whether they are more concerned with pricing, features, or sustainability when making purchases. In this way, businesses can specify pricing plans, packaging choices, subscription plans, and more.

5. Data Analysis in IoT

IoT sensor systems are constrained by their network bandwidth and processing speed. Smart apps, on the other hand, a significant amount of information and processor speed are needed for DL-based research. To overcome these limitations, modern smart applications use deep learning (DL) research at the gateway or cloud [10]. Applications demand input from users or other smart devices capable of bidirectional communication. The processing time needed by a computational intelligence (CI) algorithm that processes input is also greater than is available on constrained hardware [8]. The aged at home are susceptible to falling due to a variety of issues, including heart attacks, physical impairments, low blood pressure, etc. As a result, the rate of elderly falls also rises with age. In the modern world, elderly people utilize smart phones to call or text someone in an emergency. It is preferable to have an automatic fall detection system that can detect falls with accuracy and transmit an emergency message. In order to detect falls accurately,

the system is built with accelerometer and gyroscope sensors. K-Nearest Neighbors (K-NN) and decision trees, two well-known machine learning algorithms, are used to categorize old people's daily behaviors into sleeping, sitting, walking, and falling [9].

A smart house is one that provides a variety of automated services based on Internet of Things (IoT) gadgets equipped with sensors, cameras, and lighting. These devices can be remotely handled via remote controllers like those available on smartphones and smart speakers. In a smart home, IoT devices collect and analyse data on motion, temperature, lighting control, and other variables. They also store more intricate and varied user data. Although different smart home devices employ different methods for storing data, this information might be useful in forensic investigations, but it might be challenging to recover valuable information. As a result, it is crucial to gather data from different smart home devices as well as to recognise and examine data that might be used in digital forensics [11]. Fog computing is a specialised software enhancement that isolates a few key operations and sends them to the consumer's edge. Because of the unique circumstances surrounding the bulk of IoT installations, many of these concerns brought by cloud computing are further addressed [12].

The Sensor HUB framework, which combines a number of technologies, is designed as a tool chain to support the creation of IoT-related projects. Sensor data is gathered, sent, processed, analysed, and supported for use in a variety of ways. The server side development, including data administration and processing, reporting, push notification, and data monetization, are available via a web browser because the framework is designed to be accessed through the Platform as a Service (PaaS) model. The solution's core strength and distinctiveness are found here. Integrated Development Environments (IDEs) frequently only cover a small piece of the total data management process that the Sensor HUB handles, and they still need to be installed and maintained.

6. Wearable Devices

The Smart Healthcare System (SHS) uses wearables and implantable medical devices to continually monitor a patient's various vital signs and automatically identify and treat life-threatening medical disorders [24]. However, these expanding SHS capabilities raise a number of security issues, and attackers can take advantage of the SHS in a number of ways, including by interfering with its regular operation, injecting false data to alter vital signs, and tampering with a medical device to alter the course of a medical emergency [27]. The Wireless Body Area Network (WBAN), made up of wearable electronics, has as its primary objective the collection of physiological data from the human body. Variable standards for various system components cause a significant problem at this stage in the communication process between a Wireless Sensor Network (WSN) and wearable technology. One

the one hand, Zigbee or IEEE 802.15.4 technology is used by sensor nodes to communicate. On the other hand, wearable technology typically utilises the Bluetooth interface. This stage has been crucial because it is establishing a truly complete connection of diverse IoT-related specificities is essential. The development of a smart, comprehensive medical monitoring system with semi devices that can assess oxygen saturation and acceleration (SpO2), and EKG was described by Wan-Young et al. in [29]. Figure 1 shows the data acquisition and transmission from the people to the physician and server storage.
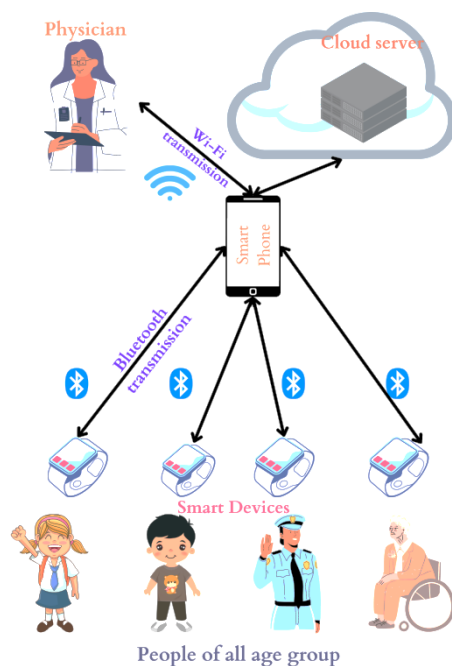

Figure 1. Data Transmission

A wearable device with minimum Electrocardiogram, a motion sensor, and a Blood oxygen saturation sensors board was integrated for user health monitoring. The technology sends physiological data to a base station connected to a computer to make it possible for access to the data across third party apps [30]. Smart Interactive Watch together physical and learning data from school students. Physical data includes heart rate, exercise intensity (number of steps taken while walking), frequency of activity, and learning data includes the number of times students raise their hands and respond to questions as well as the corresponding response time in personal or group competitions. It is also accountable for reporting such data to the cloud-based system and teacher-side application for additional analysis. The study is designed to determine the effect of the pupils' participatory outcomes from the proposed methodology on their academic performances. The interactive results are based on the data that the suggested system has gathered from the students' touch responses, team contests, incredibly quick answers, etc.

7. Smart Healthcare

By establishing new healthcare service systems, it is possible to organise diverse information and communications technologies into service linkages. This includes emerging smart systems, cloud computing, social networks, and enhanced sensing and data analysis techniques. By incorporating individuals, procedures, cultures, norms, standards, metrics, and predictions, such systems may generate added features. Electronic health records (big data), new mobile solutions, and cloud-enabled smart healthcare systems all hold out unprecedented promise for providing efficient, smart, and affordable health care (such as innovative biosensors, wearable tech, and intelligent software agents) [21]. Numerous stakeholders must be accommodated by healthcare services. In addition to assisting physicians, caregivers, and patients, services must also assist clinics, pharmacy, specialized suppliers, research universities, insurance, and service users. Along with advocacy groups, research facilities, government agencies, state and local governments, and device makers, pharmaceutical, biotech, and IT businesses are also present. Consequently, collaboration between interdisciplinary teams is necessary for the greatest healthcare services. Compared to the conventional software product development cycle, the product development cycle in healthcare is substantially longer, more regulated, and more expensive. To keep prices down, adhere to laws, and maintain timeliness, healthcare product companies must be cautious about their innovation strategy and product offers.

Information systems are positioned to produce, capture, store, process, and send timely information to all value partners for better healthcare coordination in addition to the inherent function of IT in clinical and diagnostics equipment. The two primary areas of intelligent healthcare research are those that relate to patients and those that relate to processes. The research that focuses on wearable technology for patient data collection to be reported to medical institutions is included in the patient related category, although it is not restricted to it. The improvement of policies to guarantee many elements of the healthcare industry is a focus of process-related research. Among these are a variety of process definition and management-related factors, such as resource scheduling, quality of service, and resource usage [22].

Integration of all smart systems, including smart healthcare, is crucial for the delivery of a smart city. The use of cloud and edge computing is essential for the effective implementation of smart healthcare services. The suggested smart healthcare system's workflow and resource pools are established on the cloud, where the process is carried out and resources are allocated. Each resource has a unique edge node that reports when a task

has been finished. The cloud scheduling algorithm will then redistribute the resource [25]. The suggested approach distinguishes between three emotional states: satisfied, dissatisfied, and indifferent. They used the one versus the rest strategy in the SVM. There were several experiments performed. They tested the system utilising the speech signal alone, the picture signal alone, and the combined signals in several sets of experiments. During system training, the optimization and kernel parameters of the SVM were fixed. They looked into the RBF and polynomial kernels of two SVMs.

8. Conclusion

Big data analytics are widely used in the healthcare industry. Data formats and big data aspects are described. Big data includes a number of properties that require analysis using improved algorithms, something that regular algorithms cannot do. These types of more effective algorithms are discussed. The characteristics and features of big data, the significance of big data analytics in the healthcare industry, and a discussion of the effectiveness of several machine learning algorithms employed in big data analytics served as our conclusion.

References

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

[2] Ristevski, B., & Chen, M. (2018). Big data analytics in medicine and healthcare. Journal of integrative bioinformatics, 15(3).

[3] Viceconti, M., Hunter, P., & Hose, R. (2015). Big data, big knowledge: big data for personalized healthcare. IEEE journal of biomedical and health informatics, 19(4), 1209-1215.

[4] Witt, D. R., Kellogg, R. A., Snyder, M. P., & Dunn, J. (2019). Windows into human health through wearables data analytics. Current opinion in biomedical engineering, 9, 28-46.

[5] Eapen, Z. J., Turakhia, M. P., McConnell, M. V., Graham, G., Dunn, P., Tiner, C., ... & Wayte, P. (2016). Defining a mobile health roadmap for cardiovascular health and disease. Journal of the American Heart Association, 5(7), e003119.

[6] Neubeck, L., Lowres, N., Benjamin, E. J., Freedman, S. B., Coorey, G., & Redfern, J. (2015). The mobile revolution—using smartphone apps to prevent cardiovascular disease. Nature Reviews Cardiology, 12(6), 350-360.

[7] Li, X., Dunn, J., Salins, D., Zhou, G., Zhou, W., Schüssler-Fiorenza Rose, S. M., ... & Snyder, M. P. (2017). Digital health: tracking physiomes and activity using wearable biosensors reveals useful health-related information. PLoS biology, 15(1), e2001402.

[8] Bhoi, S. K., Panda, S. K., Patra, B., Pradhan, B., Priyadarshinee, P., Tripathy, S., ... & Khilar, P. M. (2018, December). FallDS-IoT: a fall detection system for elderly healthcare based on IoT data analytics. In 2018 International Conference on Information Technology (ICIT) (pp. 155-160). IEEE.

[9] Kim, S., Park, M., Lee, S., & Kim, J. (2020). Smart home forensics—data analysis of IoT devices. Electronics, 9(8), 1215.

[10] Rajawat, A. S., Bedi, P., Goyal, S. B., Alharbi, A. R., Aljaedi, A., Jamal, S. S., & Shukla, P. K. (2021). Fog big data analysis for IoT sensor application using fusion deep learning. Mathematical Problems in Engineering, 2021.

[11] Aazam, M., & Huh, E. N. (2014, August). Fog computing and smart gateway based communication for cloud of things. In 2014 International conference on future internet of things and cloud (pp. 464-470). IEEE.

[12] Lengyel, L., Ekler, P., Ujj, T., Balogh, T., & Charaf, H. (2015). SensorHUB: An IoT driver framework for supporting sensor networks and data analysis. International Journal of Distributed Sensor Networks, 11(7), 454379.

[13] Benhlima, L. (2018). Big data management for healthcare systems: architecture, requirements, and implementation. Advances in bioinformatics, 2018.

[14] Shakil, K. A., Zareen, F. J., Alam, M., & Jabin, S. (2020). BAMHealthCloud: A biometric authentication and data management system for healthcare data in cloud. Journal of King Saud University-Computer and Information Sciences, 32(1), 57-64.

[15] Alam, B., Doja, M. N., Alam, M., & Mongia, S. (2013). 5-layered architecture of cloud database management system. AASRI Procedia, 5, 194-199.

[16] Li, X., Huang, X., Li, C., Yu, R., & Shu, L. (2019). EdgeCare: Leveraging edge computing for collaborative data management in mobile healthcare systems. IEEE Access, 7, 22011-22025.

[17] Abbas, N., Zhang, Y., Taherkordi, A., & Skeie, T. (2017). Mobile edge computing: A survey. IEEE Internet of Things Journal, 5(1), 450-465.

[18] Huang, X., Yu, R., Kang, J., & Zhang, Y. (2017). Distributed reputation management for secure and efficient vehicular edge computing and networks. IEEE Access, 5, 25408-25420.

[19] Dimitrov, D. V. (2019). Blockchain applications for healthcare data management. Healthcare informatics research, 25(1), 51-56.

[20] Al Omar, A., Rahman, M. S., Basu, A., & Kiyomoto, S. (2017, December). Medibchain: A blockchain based privacy preserving platform for healthcare data. In International conference on security, privacy and anonymity in computation, communication and storage (pp. 534-543). Springer, Cham.

[21] Demirkan, H. (2013). A smart healthcare systems framework. It Professional, 15(5), 38-45.

[22] Yin, H., Akmandor, A. O., Mosenia, A., & Jha, N. K. (2018). Smart healthcare. Foundations and Trends® in Electronic Design Automation, 12(4), 401-466.

[23] Oueida, S., Kotb, Y., Aloqaily, M., Jararweh, Y., & Baker, T. (2018). An edge computing based smart healthcare framework for resource management. Sensors, 18(12), 4307.

[24] Newaz, A. I., Sikder, A. K., Rahman, M. A., & Uluagac, A. S. (2019, October). Health guard: A machine learning-based security framework for smart healthcare systems. In 2019 Sixth International Conference on Social Networks Analysis, Management and Security (SNAMS) (pp. 389-396). IEEE.

[25] Alamri, A. (2018). Monitoring system for patients using multimedia for smart healthcare. IEEE Access, 6, 23271-23276.

[26] Haghi, M., Thurow, K., & Stoll, R. (2017). Wearable devices in medical internet of things: scientific research and commercially available devices. Healthcare informatics research, 23(1), 4-15.

[27] Son, D., Lee, J., Qiao, S., Ghaffari, R., Kim, J., Lee, J. E., ... & Kim, D. H. (2014). Multifunctional wearable devices for diagnosis and therapy of movement disorders. Nature nanotechnology, 9(5), 397-404.

[28] Castillejo, P., Martinez, J. F., Rodriguez-Molina, J., & Cuerva, A. (2013). Integration of wearable devices in a wireless sensor network for an E-health application. IEEE Wireless Communications, 20(4), 38-49.

[29] Cheng, H. T., & Zhuang, W. (2010). Bluetooth-enabled in-home patient monitoring system: Early detection of Alzheimer's disease. IEEE Wireless Communications, 17(1), 74-79.

[30] Chung, W. Y., Lee, Y. D., & Jung, S. J. (2008, August). A wireless sensor network compatible wearable u-healthcare monitoring system using integrated ECG, accelerometer and SpO2. In 2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (pp. 1529-1532). IEEE.

[31] Ravi, D., Wong, C., Lo, B., & Yang, G. Z. (2016). A deep learning approach to on-node sensor data analytics for mobile or wearable devices. IEEE journal of biomedical and health informatics, 21(1), 56-64.