A review of internet of medical things (IoMT) – based remote health monitoring through wearable sensors: a case study for diabetic patients

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ABSTRACT

The latest advances and trends in information technology and communication have a vital role in healthcare industries. Theses advancements led to the Internet of Medical Things (IoMT) which provides a continuous, remote and real-time monitoring of patients. The IoMT architectures still face many challenges related to the bandwidth, communication protocols, big data and data volume, flexibility, reliability, data management, data acquisition, data processing and analytics availability, cost effectiveness, data security and privacy, and energy efficiency. The goal of this paper is to find feasible solutions to enhance the healthcare living facilities using remote health monitoring (RHM) and IoMT. In addition, the enhancement of the prevention, prognosis, diagnosis and treatment abilities using IoMT and RHM is also discussed. A case study of monitoring the vital signs of diabetic patients using real-time data processing and IoMT is also presented.

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1. INTRODUCTION

Nowadays, healthcare and modern technology industries [1, 2] have gained crucial intentions in everyday's life including healthcare systems [3]. The main goal in integrating technology with the healthcare systems is to provide a better interfacing capability between patients and caregivers to improve the efficiency and accessibility of medical devices and services [4-8].

Recently, Internet of Medical Things (IoMT) [9-11] played a vital role in remote healthcare monitoring (RHM) [12, 13]. The IoMT is mainly used to collect the remote data for patient through wearable sensors/devices [14] and store them in the cloud databases. These data are made avaialble for real-time analysis and application by caregivers [15]. The IoMT has three main stages: device layer (body sensor network (BSN)) Fog layer and cloud service [16-23] as shown in Figure 1.

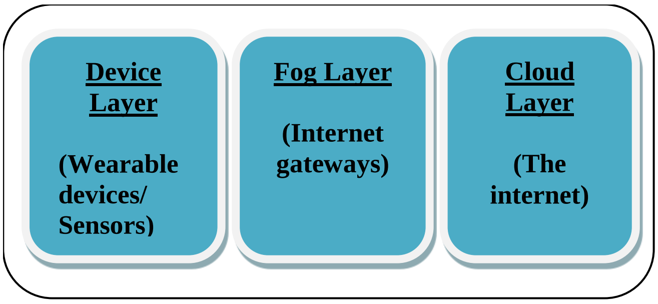

Figure 1. The architecture of IoMT

The main purpose of the device layer (sensing layer) is to establish an effective and accurate sensing technology to collect various types of health-based data. Table 1 shows wearable sensing technologies [24-29]. Communication technologies support network solutions and infrastructures of IoMT system [30, 31]. However, communication techniques include Bluetooth, RFID (NFC), WI-FI, IrDA, UWB, and ZIGBEE [32]. In the cloud layer (data layer) [33], the data is processed and stored [34]. Moreover, cloud get patient's data to perform analysis, processing and storing [35]. Thus, data become available for caregivers [36].

Table 1. Wearable sensing technologies

Sensor type	Example
Inertial sensor	Magnetic field sensors, Accelerometer, and Gyroscopes
Location sensor	GIS and GPS
Physiological sensor	Electrocardiogram (ECG), Electrooculography (EOG), Galvanic skin, and Spirometer
Brain activity sensor	Electroencephalogram (EEG)
Image sensor	Camera

RHM [37-42] is a continuous monitoring process of the health data. This includes: physiological monitoring such as heart rate, temperature and blood pressure, physical activity monitoring, diet monitoring, medication tracking and behavior monitoring). The health-related data are wirelessly communicated to both the patient and caregivers through the cloud [43, 44]. Thus, IoMT supports real-time, fast, remote and reliable diagnosis of several types of disease and enhances the decision-making process. Through this process, large amount of data are received, analyzed and monitored [45].

With nowadays busy life, majority of people don't have thier routine medical checkup. In addition, the cost of the healthcare is rising and governments spend a large amount of money yealry for healthcare services. It is also nkted that people in Europe and United States prefer home healthcare over going to hospitals. Therefore, there is a critical need for remote real-time healthcare monitoring to address all these challenges. Continuous monitoring for patients and elderly people through wearable devices and sensors have gained a a great attention [46-48]. The goal is to provide vital signs monitoring such as blood pressure, temperature and heart rate which has significant importance of today's healthcare world. According to the World health organization (WHO), the number of type 2 diabetes (T2D) patients is 422 million in 2014. That means 8.5 % of adults suffer from diabetes. However, WHO expects that the number will reach to 500 million in 2030 [49]. Therefore, using RHM may reduce the risk for those who are more vulnerable by capturing the medical data and send them to the caregivers [50], as shown in Figure 2. RHM uses inlcude the following [51-53]:

1) Diagnosing diseases
2) Diseases management
3) Diseases prediction
4) Diseases prognosis
5) Diseases prevention
6) Giving the suitable medications and treatments
7) Rehabilitation

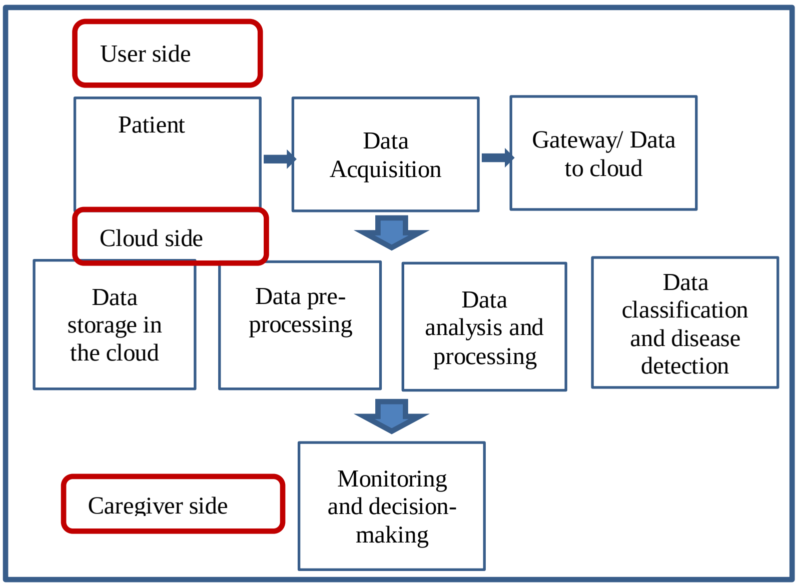

Figure 2. Proposed healthcare monitoring system

Diabetes is a chronic disorder, which needs a continous monitoring [54]. Fortunately, with the help of IoMT, monitoring diabetic patients remotly is becoming more doable[55]. However, the management of diabetes using continous glucose monitoring techniques is still a challenging process [56]. Figure 3 shows the IoMT based contionus glucose monitoring.

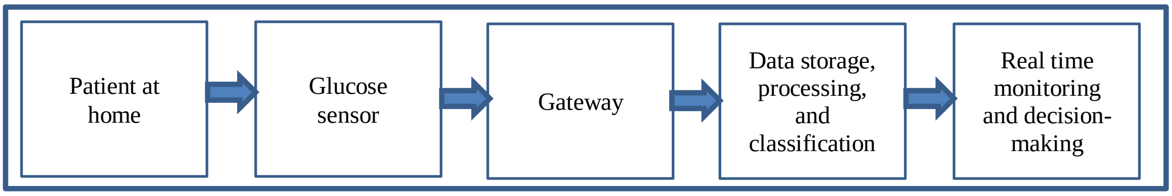

Figure 3. IoMT based contionus glucose monitoring

The main contribution of the proposed study is to enhance the healthcare living facilities using IoMT for RHM of diabetic patients. Patients with diabetes need 24/7 monitoring [57, 58] which can be achived by measuring the blood glucose (BG) level using wearable sensors [59-62].

2. RELATED WORKS

In order to address IoMT related challenges, several studies have been conducted in IoMT – based remote health monitoring for diabetic patients. Table 2 lists the main studies related to IoMT – based remote health monitoring for diabetic patients.

Table 2. IoMT based remote health monitoring for diabetic patients related literatures

Literat-ure	Contribution	Sensing data	Highlights
[63]	Blood glucose monitoring system	Glucose sensor	• Monitor the diabetes using IoT and artificial neural network
[64]	Non-invasive glucose monitoring device	Urine testing	• Self-monitoring, non-invasive, accurate, reliable, and effective system
[65]	IoT-based glucose monitoring algorithm to prevent diabetes complications	Glucose sensor	• Architecture and prognosis algorithm used for elderly diabetic persons • Prognosis of possible critical condition in the patient
[66]	IoT-cloud to monitor the diabetic patients	Alaris-8100 infusion pump	• IoT-based embedded scheme for a diabetic insulin pump is proposed • Insulin pump implementation for control and monitor the diabetic patients • Share health data on the cloud
[67]	Development of wearable physiologic monitoring devices for use in diabetes management	Fitness trackers and smart watches	• Enhance continuous glucose monitoring. • Measure glucose levels in tears • Improve patient safety
[68]	Designing an Internet-of-Things (IoT) and sensor-based in-home monitoring system for assisting diabetes patients	Wireless persuasive sensing	• IoMT and wireless sensor based system to capture daily activity at home • predictive blood glucose levels analytic models are developed
[69]	Continuous movement monitoring of daily living activities	Continuous movement monitoring sensor	• Manage diabetes • Prevention of diabetic foot ulcer by monitoring daily activities and blood glucose
[70]	Glucose monitoring in individuals with diabetes	Glucose clamps and spontaneous glucose excursions	• Long-term implanted for sensor/telemety system for glucose monitoring • glucose control and management
[71]	Sensor-based method for glucose monitoring	FreeStyle Libre Flash glucose monitoring system	• Accuracy, safety and acceptability of the glucose monitoring system in the paediatric population is proposed • Accuracy, safety and user acceptability are discussed
[72]	Continuous glucose monitoring sensors	Continuous glucose monitoring sensor	• Past and present algorithmic challenges of Continuous glucose monitoring sensors are introduced • Automatic basal insulin attenuation methods
[73]	Continuous glucose monitoring to characterize glycemic variability	Continuous glucose monitoring sensor	• Use of CGM for adjustment of insulin dosing, and automated interpretation • Instantaneous real-time display of glucose level and rate of change of glucose, alerts and alarms • Small, comfortable, user-friendly devices based on IoMT
[74]	Continuous glucose monitoring	Self-monitoring blood glucose sensor	• Control and manage diabetes • Reduce the risk of hypoglycemia
[75]	Type 2 diabetes (T2D) management	Home monitoring data (Genomics data repositories)	• Big data technologies and IoMT to manage and control diabetes
[76]	T2D management	Continuous glucose monitoring sensor	• Predictive T2D models using big data analytics and machine learning algorithms
[77]	Remote patients with diabetes fog assisted system	Continuous glucose monitoring and ECG sensors	• Fog-assisted personalized healthcare support system • Monitor glucose level with physical activity and ECG
[78]	Quality life improvement for diabetic patients by using IoMT	Continuous glucose monitoring sensor	• Continuous glucose monitoring, activity, and diet tracking using IoT
[79]	Continuous glucose monitoring system for diabetes based on internet of mobile crowdsourcing health things	Continuous glucose monitoring sensor	• Mobile fog computing, blockchain and IoT are used to control and manage diabetes remotely and continuously
[80]	Detection of diabetic foot ulcer	Flexi-force sensor	• Design and implementation of IoT-based model for diagnosing of diabetic ulcer
[81]	IoT–based blood glucose monitoring system	Blood glucose sensor	• Prototype of an IoT-based glucose testing meter • low-cost and energy-efficient
[82]	Glycemic control using IoT	Photo-acoustic signal	• Non-invasive intelligent blood glucose level monitoring system • Alert signals using IoT is provided
[83]	Continuous glucose monitoring system	Blood glucose sensor	• Fog computing, blockchain and iot-based monitoring system • Rapid, flexible, scalable, and low-cost mHealth system
[84]	IoT based detection of hypoglycemia	Blood glucose, activities, and dietary	• IoT and big data analytics platform
[85]	IoT based intelligent diabetes management system	Activity trackers, continuous glucose monitoring, and implantable defibrillators.	• Machine learning diabetes management application • Smart, fast, and cost-effective
[86]	IoT cloud based automatic diabetes risk assessment system	Feet pressure sensor, blood pressure sensor, and ECG	• Machine learning diabetes management application

3. THE SIGNIFICANCE OF IoMT BASED RHM

RHM based on IoT can make a healthcare easier and more efficient in terms of cost, accessibility, visibility, reliability, accuracy, affordability, continuity, and real time monitoring. For example, hospitalized patients cost a huge money on the patients, healthcare centers, and insurance companies. Moreover, patients living in remote areas do not have an easy access to the hospitals and caregiver centers. Thus, they need to travel for long distances to seek health care. IoT in RHM has the ability of interoperability, communication and information exchange, and data transfer that improve healthcare services. In addition, RHM provides a continues monitoring for chronic diseases (i.e. diabetes) [87]. Table 3 shows the advantages and benefits of RHM based IoMT for patients, caregivers and insurance companies [88-90].

Table 3. Advantages of using IoMT for RHM for diabetic patients

Patients side	Caregivers side	Countries and insurance companies side
Sufficient monitoring	Better reliability and accuracy	Better accessibility
Reduce the duration of stay	Less cost	Less cost
Centralized data	Better accuracy	Better visibility
Prevent emergencies and reduce emergency wait time	Better reliability and accuracy	Better accessibility and less cost
Real time monitoring and on-time alert	Continuous monitoring	Better accessibility
Better quality of treatments	Real time monitoring	Better visibility
Improve the convenience	Better reliability and accuracy	Better visibility
Improve the efficiency	Better reliability, accuracy, less cost, and real time monitoring	Better visibility, accessibility, and less cost
Reduce medication errors	Better reliability and accuracy as well as less cost	Better visibility and accessibility
Solve the long distance problem	Better reliability and accuracy as well as less cost	Better visibility and accessibility
Mobile health (mHealth) capability	Real time monitoring	Better visibility and accessibility
Fast data processing	Better reliability and accuracy	Better affordability
Fast collecting data	Better reliability and accuracy	Better visibility and less cost
Efficient reporting capability	Better reliability and accuracy	Better visibility

4. CHALLENGES AND FUTURE TRENDS

This section summarizes the challenges of the remote health monitoring of the diabetic patients through wearable sensors [91-96]. This include:

1) Cost effective and non- obstructive sensing devices [97]: design and evaluate a non- obstructive sensing devices with low cost is a challenging issue.
2) Data processing [98] and big data problem [99, 100]: big data originate from sensing devises in a short time is hard to store and manage if the access to cloud is unavailable.
3) Security and privacy [101, 102]: medical sensor data and electronic patient records are very critical and sensitive. However, it is crucial to protect these data from potential internet threats.
4) Uncontrolled environment [103] and Noise intrfere [104]: various noise levels may occure.
5) Wireless technology [105-107]: No connectivity and wireless technology standards for IoT.
6) Reliability and availability [108, 109]: several connected devices, software, services, and users are connected which leads to increase the failure rate.
7) Energy efficiency [110]: real time continuous sensing consumes the power.
8) Intelligent algorithms used for data processing require sufficient and big training data. However, available datasets are laboratory datasets [111].
9) New intelligent feature extraction and classification algorithms need more computational time [112].
10) Performance and accuracy [113]: develop medical accurate devices, algorithms, methods, services is highly required.
11) Wearable sensors placement and user safety [114]: location of sensor and placement safety issues are critical factor in design.
12) Single sensor modalities: data fusion body sensor techniques have to discussed more [115].
13) Size of the wearbale sensor must be comfortable [116].
14) Wearable devices must be comfortable [117].
15) Wearable devices must be protected from water and sweat [118].
16) Integration of multiple protocols and devices [119, 120].

5. CONCLUSION

In the IoMT era, remote healthcare monitoring (RHM) represents the future of the healthcare industry. Importantly, in order to improve the people's quality of life, vital signs of humans' body such as glucose level can be monitored. Globally, the number of diabetic patients is continuously increasing which leads to more challenges in the healthcare society. Thus, benefitting from the latest advances and trends in information technology and communication (i.e. IoT) is vital. The proposed review study has covered the IoMT – based remote health monitoring for diabetic patients. In addition, the associated challenges and future trends are discussed and highlighted.

REFERENCES

[1] E. T. Chen, "Examining the influence of information technology on modern health care," in *Data Analytics in Medicine: Concepts, Methodologies, Tools, and Applications*, pp. 1943-1962, 2020.
[2] S. Gupta, et al., "Technologies in Health Care Domain: A Systematic Review," *International Journal of e-Collaboration (IJeC),* vol. 16, no. 1, pp. 33-44, 2020.
[3] J. J. P. C. Rodrigues, et al., "Enabling technologies for the internet of health things," *IEEE Access,* vol. 6, pp. 13129-13141, 2018.
[4] F. Firouzi, et al., "Internet-of-Things and big data for smarter healthcare: from device to architecture, applications and analytics," *Future Generation Computer Systems*, vol. 78, no. 2, pp. 583-586, 2018.
[5] V. Jagadeeswari, et al., "A study on medical Internet of Things and Big Data in personalized healthcare system," *Health information science and systems*, vol. 6, no. 1, p. 14, 2018.
[6] S. L. Ondra, "Macro Trends in Healthcare Delivery," in *Value-Based Approaches to Spine Care,* pp. 1-22, 2020.
[7] S. Tuli, et al., "Healthfog: An ensemble deep learning based smart healthcare system for automatic diagnosis of heart diseases in integrated iot and fog computing environments," *Future Generation Computer Systems,* vol. 104, pp. 187-200, 2020.
[8] A. Gatouillat, et al., "Internet of medical things: A review of recent contributions dealing with cyber-physical systems in medicine," *IEEE Internet of Things Journal,* vol. 5, no. 5, pp. 3810-3822, 2018.
[9] G. J. Joyia, et al., "Internet of Medical Things (IOMT): applications, benefits and future challenges in healthcare domain," *Journal of Communications,* vol. 12, no. 4, pp. 240-247, 2017.
[10] S. Rani, et al., "IoMT: A reliable cross layer protocol for internet of multimedia things," *IEEE Internet of Things Journal,* vol. 4, no. 3, pp. 832-839, 2017.
[11] L. Haoyu, et al., "An IoMT cloud-based real time sleep apnea detection scheme by using the SpO2 estimation supported by heart rate variability," *Future Generation Computer Systems,* vol. 98, pp. 69-77, 2019.
[12] Y. Jin, et al., "Predictive analysis in outpatients assisted by the Internet of Medical Things," *Future Generation Computer Systems,* vol. 98, pp. 219-226, 2019.
[13] C. R. Srinivasan, et al., "An IoT based SMART patient health monitoring system," *Indonesian Journal of Electrical Engineering and Computer Science,* vol. 18, no. 3, pp. 1657-1664, 2020.
[14] S. Sudevan and M. Joseph, "Internet of Things: Incorporation into Healthcare Monitoring," in *2019 4th MEC International Conference on Big Data and Smart City (ICBDSC)*, pp. 1-4, 2019.
[15] M. Cornacchia, et al., "A survey on activity detection and classification using wearable sensors," *IEEE Sensors Journal,* vol. 17, no. 2, pp. 386-403, 2017.
[16] A. Mihovska and M. Sarkar, "Smart connectivity for internet of things (iot) applications," in *New Advances in the Internet of Things*, pp. 105-118, 2018.
[17] A. Yassine, et al., "IoT big data analytics for smart homes with fog and cloud computing," *Future Generation Computer Systems,* vol. 91, pp. 563-573, 2019.
[18] J. Mahapatro, et al., "Selection of Priority in Wireless Body Area Network Sensors using IoT Technology," *5th International Conference for Convergence in Technology (I2CT 2019),* 2019.
[19] Y. Miao, et al., "Green cognitive body sensor network: architecture, energy harvesting and smart clothing based applications," *IEEE Sensors Journal,* vol. 19, no. 19, pp. 8371-8378, 2018.
[20] N. Abbas, et al., "A Mechanism for Securing IoT-enabled Applications at the Fog Layer," *Journal of Sensor and Actuator Networks,* vol. 8, no. 1, p. 16, 2019.
[21] H. Tao, et al., "Secured data collection with hardware-based ciphers for iot-based healthcare," *IEEE Internet of Things Journal,* vol. 6, no. 1, pp. 410-420, 2019.
[22] S. Sharma, et al., "Cloud and IoT-based emerging services systems," *Cluster Computing,* vol. 22, no. 1, pp. 71-91, 2019.
[23] B. Mallikarjuna and D. A. K. Reddy, "Healthcare Application Development in Mobile and Cloud Environments," in *Internet of Things and Personalized Healthcare Systems*, pp. 93-103, 2019.
[24] J. Qi, et al., "Advanced internet of things for personalised healthcare systems: A survey," *Pervasive and Mobile Computing,* vol. 41, pp. 132-149, 2017.
[25] A. Nag, et al., "Wearable Flexible Sensors: A Review," *IEEE Sensors Journal,* vol. 17, no. 13, pp. 3949-3960, 2017.
[26] M. M. Rodgers, et al., "Recent Advances in Wearable Sensors for Health Monitoring," *IEEE Sensors Journal,* vol. 15, no. 6, pp. 3119-3126, 2015.
[27] V. G. Motti, "Introduction to Wearable Computers," in *Wearable Interaction,* pp. 1-39, 2020.

[28] O. AlShorman, et al., "EEG Analysis for Pre-learning Stress in the Brain," in *Asian Simulation Conference*, pp. 447-455, 2017.

[29] O. M. AlShorman and A. M. Alshorman, "Frontal lobe and long-term memory retrieval analysis during pre-learning stress using EEG signals," *Bulletin of Electrical Engineering and Informatics,* vol. 9, no. 1, pp. 141-145, 2020.

[30] C. A. Silva, et al., "A Fog Computing-Based Architecture for Medical Records Management," *Wireless Communications and Mobile Computing,* vol. 2019, pp. 1-16, 2019.

[31] A. A. Mutlag, et al., "Enabling technologies for fog computing in healthcare IoT systems," *Future Generation Computer Systems,* vol. 90, pp. 62-78, 2019.

[32] Y. Yin, et al., "The internet of things in healthcare: An overview," *Journal of Industrial Information Integration,* vol. 1, pp. 3-13, 2016.

[33] Y. Karaca, et al., "Mobile cloud computing based stroke healthcare system," *International Journal of Information Management,* vol. 45, pp. 250-261, 2019.

[34] B. Farahani, et al., "Towards collaborative intelligent IoT eHealth: From device to fog, and cloud," *Microprocessors and Microsystems,* vol. 72, p. 102938, 2020.

[35] S. Dash, et al., "Edge and Fog Computing in Healthcare–A Review," *Scalable Computing: Practice and Experience,* vol. 20, no. 2, pp. 191-206, 2019.

[36] G. Karthick and P. Pankajavalli, "Architecting IoT based Healthcare Systems Using Machine Learning Algorithms: Cloud-Oriented Healthcare Model, Streaming Data Analytics Architecture, and Case Study," in *Incorporating the Internet of Things in Healthcare Applications and Wearable Devices*, pp. 40-66, 2020.

[37] M. Al-khafajiy, et al., "Remote health monitoring of elderly through wearable sensors," *Multimedia Tools and Applications,* vol. 78, pp. 24681-24706, 2019.

[38] L. P. Malasinghe, et al., "Remote patient monitoring: a comprehensive study," *Journal of Ambient Intelligence and Humanized Computing,* vol. 10, no. 1, pp. 57-76, 2019.

[39] N. Bashi, et al., "Remote monitoring of patients with heart failure: an overview of systematic reviews," *Journal of Medical Internet Research,* vol. 19, no. 1, p. e18, 2017.

[40] I. Azimi, et al., "Internet of things for remote elderly monitoring: a study from user-centered perspective," *Journal of Ambient Intelligence and Humanized Computing,* vol. 8, no. 2, pp. 273-289, 2017.

[41] J. T. Giger, et al., "Remote patient monitoring acceptance trends among older adults residing in a frontier state," *Computers in Human Behavior,* vol. 44, pp. 174-182, 2015.

[42] B. Noah, et al., "Impact of remote patient monitoring on clinical outcomes: an updated meta-analysis of randomized controlled trials," *NPJ Digital Medicine,* vol. 1, no. 1, p. 20172, 2018.

[43] A. Benjemmaa, et al., "Design of Remote Heart Monitoring System for Cardiac Patients," in *International Conference on Advanced Information Networking and Applications,* pp. 963-976, 2019.

[44] J. Pagán, et al., "Toward ultra-low-power remote health monitoring: An optimal and adaptive compressed sensing framework for activity recognition," *IEEE Transactions on Mobile Computing,* vol. 18, no. 3, pp. 658-673, 2019.

[45] A. Depari, et al., "An IoT Based Architecture for Enhancing the Effectiveness of Prototype Medical Instruments Applied to Neurodegenerative Disease Diagnosis," *Sensors,* vol. 19, no. 7, pp. 1564-1582, 2019.

[46] B. Farahani, et al., "Healthcare IoT," in F. Firouzi, et al. (eds), Intelligent Internet of Things, Springer, pp. 515-545, 2020.

[47] M. Pham, et al., "Cloud-based smart home environment (CoSHE) for home healthcare," in *2016 IEEE International Conference on Automation Science and Engineering (CASE)*, pp. 483-488, 2016.

[48] A. E. Hassanien, et al., "Medical Big Data and Internet of Medical Things: Advances, Challenges and Applications," CRC Press, 2018.

[49] G. Cappon, et al., "Wearable continuous glucose monitoring sensors: a revolution in diabetes treatment," *Electronics,* vol. 6, no. 3, pp. 65-80, 2017.

[50] A. A. Ghaffar, et al., "Internet of things based multiple disease monitoring and health improvement system," *Journal of Ambient Intelligence and Humanized Computing,* vol. 11, no. 3, pp. 1021-1029, 2020.

[51] G. Alfian, et al., "A Personalized Healthcare Monitoring System for Diabetic Patients by Utilizing BLE-Based Sensors and Real-Time Data Processing," *Sensors,* vol. 18, no. 7, p. 2183, 2018.

[52] C. S. Krishna and T. Sasikala, "Home Based Healthcare Monitoring System for Diabetes Patients Using IoT," *International Conference on Intelligent Data Communication Technologies and Internet of Things*, pp. 676-686, 2018.

[53] D. Gupta, et al., "Integrated healthcare monitoring device for obese adults using internet of things (IoT)," *International Journal of Electrical & Computer Engineering,* vol. 10, no. 2, pp. 1239-1247, 2020.

[54] L. Syafaah, et al., "Study on diabetes prediction based on discrete and continuous mean amplitude of glycemic excursions using machine learning methods," *Bulletin of Electrical Engineering and Informatics,* vol. 9, no. 6, 2020.

[55] A. U. Haq, et al., "A New Intelligent Approach for Effective Recognition of Diabetes in the IoT E-HealthCare Environment," *Preprints*, 2020.

[56] M. A. Al-Dhaheri, et al., "Noninvasive blood glucose monitoring system based on near-infrared method," *International Journal of Electrical & Computer Engineering,* vol. 10, no. 2, pp. 1736-1746, 2020.

[57] S. H. Ley, et al., "Prevention and management of type 2 diabetes: dietary components and nutritional strategies," *The Lancet,* vol. 383, no. 9933, pp. 1999-2007, 2014.

[58] T. L. Michaud, et al., "Remote patient monitoring and clinical outcomes for postdischarge patients with type 2 diabetes," *Population health management,* vol. 21, no. 5, pp. 387-394, 2018.

[59] R. Geetha and R. Anitha, “IoT enabled Life Style Assistance and Glucose Monitoring System for Diabetic Patients,” *Taga Journal*, vol. 14, pp. 1400-1418, 2018.
[60] H. Zhao, et al., “Microchip based electrochemical-piezoelectric integrated multi-mode sensing system for continuous glucose monitoring,” *Sensors and Actuators B: Chemical,* vol. 223, pp. 83-88, 2016.
[61] J. Feng, et al., “Multi-model sensor fault detection and data reconciliation: A case study with glucose concentration sensors for diabetes,” *AIChE Journal*, vol. 65, no. 2, pp. 629-639, 2019.
[62] F. Usman, et al., “A Review of Biosensors for Non-Invasive Diabetes Monitoring and Screening in Human Exhaled Breath,” *IEEE Access,* vol. 7, pp. 5963-5974, 2019.
[63] I. N. Khan, et al., “Blood Glucose level approximation using IOT and ANN’s,” in *2019 3rd International Conference on Computing Methodologies and Communication (ICCMC)*, pp. 525-530, 2019.
[64] S. Geetha, et al., “Non Invasive Technique for Measuring Blood Glucose based on IOT,” *Indian Journal of Public Health Research & Development*, vol. 10, no. 5, pp. 1456-1458, 2019.
[65] F. Valenzuela, et al., “An IoT-Based Glucose Monitoring Algorithm to Prevent Diabetes Complications,” *Applied Sciences,* vol. 10, no. 3, p. 921, 2020.
[66] Z. A. Al-Odat, et al., “A Reliable IoT-Based Embedded Health Care System for Diabetic Patients,” *International Journal on Advances in Internet Technology*, 2019.
[67] F. L. Schwartz, et al., “The promise and perils of wearable physiological sensors for diabetes management,” *Journal of diabetes science and technology,* vol. 12, no. 3, pp. 587-591, 2018.
[68] S. Chatterjee, et al., “Designing an Internet-of-Things (IoT) and sensor-based in-home monitoring system for assisting diabetes patients: iterative learning from two case studies,” *European Journal of Information Systems,* vol. 27, no. 6, pp. 670-685, 2018.
[69] P. Francia, et al., “Continuous movement monitoring of daily living activities for prevention of diabetic foot ulcer: A review of literature,” *International journal of preventive medicine*, vol. 10, p. 22, 2019.
[70] J. Y. Lucisano, et al., “Glucose monitoring in individuals with diabetes using a long-term implanted sensor/telemetry system and model,” *IEEE Transactions on Biomedical Engineering,* vol. 64, no. 9, pp. 1982-1993, 2017.
[71] J. Edge, et al., “An alternative sensor-based method for glucose monitoring in children and young people with diabetes,” *Archives of disease in childhood,* vol. 102, no. 6, pp. 543-549, 2017.
[72] A. Facchinetti, “Continuous glucose monitoring sensors: past, present and future algorithmic challenges,” *Sensors,* vol. 16, no. 12, p. 2093, 2016.
[73] D. Rodbard, “Continuous glucose monitoring: a review of successes, challenges, and opportunities,” *Diabetes technology & therapeutics,* vol. 18, no. S2, pp. 3-13, 2016.
[74] E. Toschi and H. Wolpert, “Utility of continuous glucose monitoring in type 1 and type 2 diabetes,” *Endocrinology and Metabolism Clinics of North America,* vol. 45, no. 4, pp. 895-904, 2016.
[75] R. Bellazzi, et al., “Big data technologies: new opportunities for diabetes management,” *Journal of diabetes science and technology,* vol. 9, no. 5, pp. 1119-1125, 2015.
[76] S. L. Cichosz, et al., “Toward big data analytics: review of predictive models in management of diabetes and its complications,” *Journal of diabetes science and technology,* vol. 10, no. 1, pp. 27-34, 2015.
[77] M. Devarajan, et al., “Fog-assisted personalized healthcare-support system for remote patients with diabetes,” *Journal of Ambient Intelligence and Humanized Computing,* vol. 10, pp. 3747-3760, 2019.
[78] A. M. Longva and M. Haddara, “How Can IoT Improve the Life-quality of Diabetes Patients?” in *MATEC Web of Conferences,* vol. 292, p. 03016, 2019.
[79] T. M. Fernández-Caramés, et al., “Enabling the internet of mobile crowdsourcing health things: A mobile fog computing, blockchain and IoT based continuous glucose monitoring system for diabetes mellitus research and care,” *Sensors,* vol. 19, no. 15, p. 3319, 2019.
[80] P. Gupta, et al., “IoT Based Healthcare Kit for Diabetic Foot Ulcer,” in *Proceedings of ICRIC 2019,* pp. 15-22, 2020.
[81] V. Puri, et al., “BioSenHealth 2.0—a low-cost, energy-efficient Internet of Things–based blood glucose monitoring system,” in *Emergence of Pharmaceutical Industry Growth with Industrial IoT Approach*, pp. 305-324, 2020.
[82] R. K. J. Charles, et al., “VLSI design of intelligent, Self-monitored and managed, Strip-free, Non-invasive device for Diabetes mellitus patients to improve Glycemic control using IoT,” *Procedia Computer Science,* vol. 163, pp. 117-124, 2019.
[83] T. M. Fernández-Caramés and P. Fraga-Lamas, “Design of a fog computing, blockchain and IoT-based continuous glucose monitoring system for crowdsourcing mHealth,” in *5th International Electronic Conference on Sensors and Applications*, vol. 4, no. 1, p. 37, 2018.
[84] A. Kharbouch, et al., “Towards an IoT and big data analytics platform for the definition of diabetes telecare services,” *Smart Application and Data Analysis for Smart Cities (SADASC'18),* 2018.
[85] A. Ara and A. Ara, “Case study: Integrating IoT, streaming analytics and machine learning to improve intelligent diabetes management system,” in *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS),* pp. 3179-3182, 2017.
[86] M. Sujaritha, et al., “An Automatic Diabetes Risk Assessment System Using IoT Cloud Platform,” in *EAI International Conference on Big Data Innovation for Sustainable Cognitive Computing*, pp. 323-327, 2020.
[87] P. A. Lee, et al., “The impact of telehealth remote patient monitoring on glycemic control in type 2 diabetes: a systematic review and meta-analysis of systematic reviews of randomised controlled trials,” *BMC health services research,* vol. 18, no. 1, p. 495, 2018.
[88] S. R. Guntur, et al., “Internet of Medical Things: Remote Healthcare and Health Monitoring Perspective,” in A. E. Hassanien, et al. (eds), Medical Big Data and Internet of Medical Things, pp. 271-297, 2018.

[89] I. Jayatilleka and M. N. Halgamuge, "Internet of Things in healthcare: Smart devices, sensors, and systems related to diseases and health conditions," in *Real-Time Data Analytics for Large Scale Sensor Data*, pp. 1-35, 2020.
[90] J. Jagannathan and U. Udaykumar, "Predictive Modeling for Improving Healthcare Using IoT: Role of Predictive Models in Healthcare Using IoT," in *Incorporating the Internet of Things in Healthcare Applications and Wearable Devices*, pp. 243-254, 2020.
[91] G. Schreier, "The internet of things for personalized health," *Studies in Health Technology and Informatics,* vol. 200, pp. 22-31, 2014.
[92] I. de la T. Diez, et al., "IoT-Based Services and Applications for Mental Health in the Literature," *Journal of Medical Systems,* vol. 43, no. 1, p. 11, 2018.
[93] M. W. Woo, et al., "A reliable IoT system for personal healthcare devices," *Future Generation Computer Systems,* vol. 78, no. 2, pp. 626-640, 2018.
[94] D. V. Dimitrov, "Medical internet of things and big data in healthcare," *Healthcare informatics research,* vol. 22, no. 3, pp. 156-163, 2016.
[95] S. Selvaraj and S. Sundaravaradhan, "Challenges and opportunities in IoT healthcare systems: a systematic review," *SN Applied Sciences,* vol. 2, no. 1, p. 139, 2020.
[96] M. Rath, "Big Data and IoT-allied challenges associated with healthcare applications in smart and automated systems," in *Data Analytics in Medicine: Concepts, Methodologies, Tools, and Applications*, pp. 1401-1414, 2020.
[97] F. Barata, et al., "Towards Device-Agnostic Mobile Cough Detection with Convolutional Neural Networks," in *7th IEEE International Conference on Healthcare Informatics (ICHI 2019),* pp. 1-11, 2019.
[98] M. Al-Osta, et al., "Event driven and semantic based approach for data processing on IoT gateway devices," *Journal of Ambient Intelligence and Humanized Computing,* vol. 10, no. 12, pp. 4663-4678, 2019.
[99] A. Rghioui, et al., "Big Data Classification and Internet of Things in Healthcare," *International Journal of E-Health and Medical Communications (IJEHMC),* vol. 11, no. 2, pp. 20-37, 2020.
[100] M. Al-khassaweneh and O. AlShorman, "Frei-Chen Bases Based Lossy Digital Image Compression Technique," *Applied Computing and Informatics,* 2020.
[101] S. N. Mohanty, et al., "An efficient Lightweight integrated Blockchain (ELIB) model for IoT security and privacy," *Future Generation Computer Systems,* vol. 102, pp. 1027-1037, 2020.
[102] S. Garg, et al., "A multi-stage anomaly detection scheme for augmenting the security in IoT-enabled applications," *Future Generation Computer Systems,* vol. 104, pp. 105-118, 2020.
[103] H. F. Atlam and G. B. Wills, "IoT Security, privacy, safety and ethics," in *Digital Twin Technologies and Smart Cities,* pp. 123-149, 2020.
[104] N. R. De Sarkar, et al., "Agent Based Noise Detection Using Real Time Data Analysis Towards Green Environment," *International Journal of Green Computing (IJGC)*, vol. 8, no. 2, pp. 539-560, 2020.
[105] V. Manjula and R. T. Rajasekaran, "Security Vulnerabilities in Traditional Wireless Sensor Networks by an Intern in IoT, Blockchain Technology for Data Sharing in IoT," in *Principles of Internet of Things (IoT) Ecosystem: Insight Paradigm*, pp. 579-597, 2020.
[106] D. Dasig and J. Mendez, "An IoT and Wireless Sensor Network-Based Technology for a Low-Cost Precision Apiculture," in *Internet of Things and Analytics for Agriculture*, vol. 2, pp. 67-92, 2020.
[107] A. Pratap, et al., "On Maximizing Task Throughput in IoT-enabled 5G Networks under Latency and Bandwidth Constraints," *2019 IEEE International Conference on Smart Computing (SMARTCOMP),* pp. 217-224, 2019.
[108] B. Appasani and D. K. Mohanta, "Monte-Carlo Simulation models for reliability analysis of low-cost IoT communication networks in smart grid," *Real-Time Data Analytics for Large Scale Sensor Data*, pp. 73-96, 2020.
[109] D. Domingos, et al., "Reliability of IoT-aware BPMN healthcare processes," in *Internet of Things and Advanced Application in Healthcare*, pp. 214-248, 2017.
[110] K. K. Bhardwaj, et al., "Designing Energy-Efficient IoT-Based Intelligent Transport System: Need, Architecture, Characteristics, Challenges, and Applications," in *Energy Conservation for IoT Devices*, pp. 209-233, 2019.
[111] M. Schueler, et al., "From Observatory to Laboratory: A Pathway to Data Evolution," *Living in the Internet of Things (IoT 2019),* pp. 1-8, 2019.
[112] G. L. Stavrinides and H. D. Karatza, "A hybrid approach to scheduling real-time IoT workflows in fog and cloud environments," *Multimedia Tools and Applications,* vol. 78, no. 17, pp. 24639-24655, 2019.
[113] V. A. Siris, et al., "Smart application-aware IoT data collection," *Journal of Reliable Intelligent Environments,* vol. 5, no. 1, pp. 17-28, 2019.
[114] O. Gaggi, et al., "Safety First? Users' Perception of Wearable Sensor Networks for Aging," *Mobile Networks and Applications,* vol. 25, pp. 986-994, 2020.
[115] M. Muzammal, et al., "A multi-sensor data fusion enabled ensemble approach for medical data from body sensor networks," *Information Fusion,* vol. 53, pp. 155-164, 2020.
[116] D. Antolín, et al., "A wearable wireless sensor network for indoor smart environment monitoring in safety applications," *Sensors,* vol. 17, no. 2, p. 365, 2017.
[117] M. Haghi, et al., "Wearable devices in medical internet of things: scientific research and commercially available devices," *Healthcare informatics research,* vol. 23, no. 1, pp. 4-15, 2017.
[118] Y. Z. Yip, et al., "Reliability of wearable electronics—Case of water proof tests on smartwatch," in *2017 IEEE 19th Electronics Packaging Technology Conference (EPTC),* pp. 1-5, 2017.
[119] A. Panarello, et al., "Blockchain and IoT integration: A systematic survey," *Sensors,* vol. 18, no. 8, p. 2575, 2018.
[120] J. L. Shah and H. F. Bhat, "Towards Integration of Cloud Computing with Internet of Things," in *Principles of Internet of Things (IoT) Ecosystem: Insight Paradigm,* pp. 229-260, 2020.