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Research paper

Enhancing Healthcare through the Convergence of Medical Robotics and the Internet of Things: Challenges, Opportunities, and Future Trends

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Abstract

This article examines the intersection of medical robotics and the Internet of Things (IoT) in the field of health and examines the role of combining these two technologies in improving health services. This confluence has created new innovations in providing healthcare solutions that have crossed traditional boundaries and increased the accuracy and efficiency of healthcare services. Medical robotics improves health practices with greater precision in interventions and access to more distant locations, as well as the possibility of real-time data collection and analysis by the Internet of Things. This article evaluates the impact of this intersection in improving health services through greater accuracy and efficiency in robotic interventions and the possibility of real-time data collection and analysis by the Internet of Things. Also, the challenges and solutions related to this integration are examined and the future of the intersection of medical robotics and the Internet of Things in the field of health is predicted. This confluence of dynamics creates opportunities to improve the transformative power of the healthcare landscape.

Introduction

In the last 2 decades, robotics has been considered an innovative and challenging field for researchers who are constantly trying to improve it. Robots are machines that, in addition to being able to act, act significantly more autonomously than other machines [1]. More than 40 years ago, robots were introduced to the production line, and now there are accepted standards for the safety of industrial robots, but in contrast, the use of robots in surgery began about 20 years ago and was widely used in this field until the last decade. context is used [2]. Since the 1990s, various articles have been written on medical robots, mostly focusing on specific topics such as surgical robots or urological robots [3]. The development of medical robots in order to improve the accuracy and quality of remote or precision surgeries is needed by human society [4-6]. The ability of robots to combine information with physical actions in complex ways has had an important impact on our societies, especially in medicine and healthcare [7]. The integration of medical robotics and the Internet of Things improves healthcare through smart devices and remote monitoring of patients. In this paper, the impact of the intersection of medical robotics and IoT on the delivery of health services is evaluated by examining the increase in accuracy and efficiency in medical robotic interventions and the ability to collect and analyze

real-time data by IoT. Also, the challenges and solutions related to this interaction are examined and the future of the intersection of medical robotics and the Internet of Things in the field of health is examined and predicted. By examining this dynamic intersection, we can pursue opportunities that improve the power to transform the healthcare landscape.

The emergence of medical robotics in healthcare

Introducing computers and robotics in medicine will lead to revolutionary changes, but consideration of human-centered factors is necessary due to the patient focus and safety concerns inherent in medical robotics research and development [8]. Recently, the fundamental role of robotics in the field of medicine has become evident and significantly contributes to the advancement of human care; In this context, robotics is facing healthcare and its diverse challenges [9,10]. Recent advances in the emerging field of robotics point to a promising future in which robots will be used in various healthcare applications [11]. Robotics in the field of medicine, through advanced technologies, provides the possibility of more accurate health care by doctors or patients themselves, as well as performing more precise and remote surgeries [1,9,10]. The integration of robotics in medicine is a response to the limitations and complexities of current healthcare systems, with the goal of improving patient care and overall quality [8]. The use of robots in the medical field has led to the emergence of new methods that have created a wide array of robots for various applications in the health field, including robotic surgery, assistance to caregivers and patients, reconstruction, and other applications [12-20]. In the field of healthcare, robotics is used to perform mechatronic activities such as assisting disabled people, medical interventions, patient care, and rehabilitation, as well as disease prevention and health promotion [21,22]. In line with the better management of aging and the health of the elderly, as their population increases, it is important to develop and use health technologies such as health robotics, in order to provide physical, cognitive, and social support, up to the individual and community levels [23-36]. Despite the challenges in managing the health care system, the necessity of medical robots should be understood in terms of technology and social background [8].

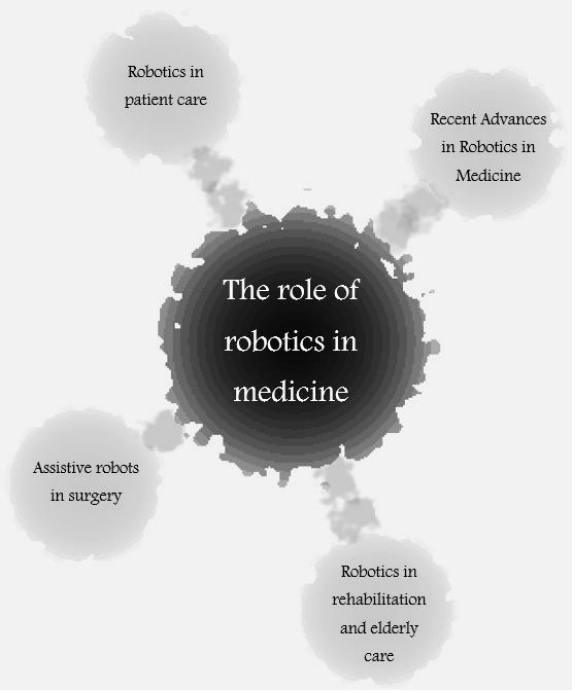

Fig. 1: Roles of robotics in medicine

The Internet of Things: A Revolution in Healthcare Communication

In recent years, technological advances have pushed healthcare toward systems that improve disease diagnosis and health monitoring using smaller devices and advanced communications [27-29] Recent advances in artificial intelligence and robotics improve the possibility of reducing the treatment workload of health service providers through health assistant robots and improve the possibility of providing services to more patients [30]. The Internet of Things (IoT) in the field of health covers from individual programs to health centers and care for different types of patients, including children, young people, and the elderly [31]. The use of the Internet of Things in public health and remote health management is important [32]. The use of IoT devices and robotics in medicine provides improved remote patient care and diverse applications such as rehabilitation, geriatric care, and remote surgery [33]. Rapid progress in artificial intelligence, robotics, and the Internet of Things has led to new challenges for the medical community based on the treatment of incurable diseases by humans [9]. The use of robotics and artificial intelligence in medicine has facilitated the treatment of complex problems such as spine and joint surgeries, and artificial intelligence technologies have improved diagnosis and treatment [1,9,10]. Although artificial intelligence is effective in the field of health, there are also limitations; Such as dependence on computerized information, complex data processing, and the inability to make complex decisions that normally belong to humans [22]. Recent developments in the Internet of Things and related technologies have made healthcare a patient-centered system, improving clinical analytics and transferring clinical data from remote areas to health centers [27,34].

Integration of medical robotics with the Internet of Things

The Internet of Things (IoT) reveals new technology that offers more effective and affordable healthcare services, including robotics for more accurate diagnosis, assisting doctors remotely during surgery, and reducing the duties of medical staff. An Internet of Things-assisted robotic system refers to a wireless network that links multiple robots with a smart environment, aiming to enhance the quality of robotic services [35]. In order to supply inexpensive, affordable, and quick medical services to patients in need [36]. In their work, A.J. Jara and colleagues introduce a personal device for managing diabetes therapy within an ambient assisted living framework, utilizing the Internet of Things (IoT) [37]. These innovative solutions underwent testing conducted by a diverse team comprising patients, physicians, and nurses. [38]. The IoT, wireless communication, and automation technologies with several kinds of cameras are merged into a real-time monitoring wheelchair that could observe its surroundings [39]. Merging robots and IoT-based healthcare systems help paralyzed aged people fulfill their physical tasks [40]. It is feasible to establish a virtual sense of physician presence using IoT-driven robotics, enabling doctors to interact with patients remotely through a robotic body [41,42]. Robots and the health cloud can be integrated to enhance emotional care applications by developing interactive feedback terminals that copy human acts [43]. An IoT-based eHealth platform is designed that combines humanoid robot assistants to control diabetes in children. This is accomplished through a redesignable process in which patients create their health profiles and treatment programs [44]. Today, H-IoT is being used to track fitness by utilizing smart wearables [45].

Fig. 2: Examples of IoT applications in robots

Medical devices equipped with Internet of Things to improve remote monitoring and patient care

IoT-based medical devices revolutionized medical services remarkably. Patient safety improvement, treatment adherence, and healthcare expense reduction, which all result in patient fulfillment, are a few impacts of these tools [27,46,47]. Not long ago, diseases were only diagnosed with a physical and in-person examination. Nowadays, with the help of this medical equipment, diagnosis has become possible from remote areas for doctors [27]. Patient vital parameters and medical data are collected and processed using data analytics such as predictive analysis via biosensors equipped with IoT. This information is transferred to a secure IoT cloud-based network, which is accessible to doctors and they can come up with proper treatment and work toward it afterward [46,51,52]. Patient-physician interaction has transformed significantly. By using IoT-based medical devices, doctors can get feedback on symptoms and discuss adjustments to new treatments for further future with their patients digitally [53]. Many devices and new medical systems are integrated with IoT including connected inhalers, coagulation testing systems, ingestible sensors, connected contact lenses, and continuous glucose monitoring systems using sensors embedded in the skin [50]. Some medical sensors are combined with wearable accessories like watches, necklaces, shoes, etc [27]. These wearable devices can also be attached to the skin, placed in clothing, and implanted in the body [49]. They are non-invasive and can be used for continuous and real-time monitoring [27]. Being lightweight and portable are the qualifications that make IoT wearable medical devices one of the best alternatives for the elderly's health care over distance [48].

The role of the Internet of Things in medical robotics and their use: Challenges and solutions in implementation

The Internet of Things (IoT) is a broad concept encompassing various networks comprising sensors, computers, actuators, and virtually any device connected to the Internet. These interconnected devices can engage with the Internet through a range of sensors, actuators, and gateways, facilitating communication. They are equipped with specific protocol stacks that enable seamless interactions among themselves and communication with end users, forming an integral component of the Internet. [54-56]. IoT's significance in healthcare lies in its ability to collect crucial physiological data and monitor patient health through wearable devices and ingestible sensors, offering substantial potential for

enhancing well-being and enabling diverse applications, encompassing implantable medical devices, wireless body networks, and cloud-based analytics platforms. [57] The passage explains how IoT benefits healthcare professionals by enhancing patient care through data-driven insights and remote monitoring, and hospitals by enabling real-time patient tracking, medical device management, and hygiene surveillance, ultimately improving patient outcomes and hospital operations. Additionally, IoT's real-time monitoring of medical data during emergencies has the potential to save lives by transmitting health data to authorized parties regardless of location or device. [58,59] The passage discusses how IoT-based solutions are addressing challenges in healthcare, including preventing adverse drug reactions through knowledge-based systems and smart pill bottles and improving rehabilitation services for the elderly and disabled population. It also highlights the significance of smartphone healthcare apps in providing flexible solutions for healthcare professionals, aiding tasks such as data collection, patient management, decision-making, and medical education. [60-63]

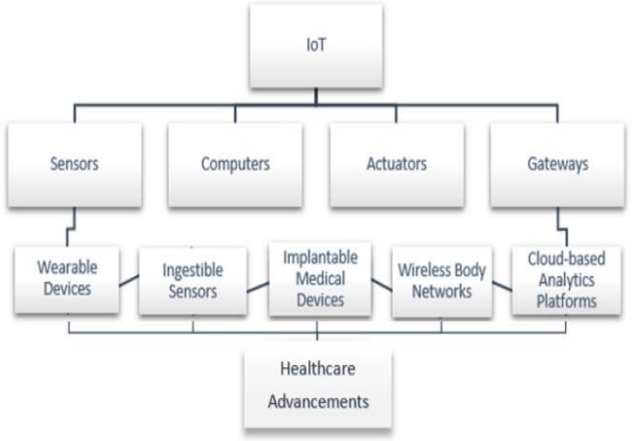

Fig. 3: The productivity path from the Internet of Things to reach advanced healthcare

Future trends in medical robotics and the Internet of Things

The use of IoT in health services helps medical professionals to improve their daily routine activities [36]. Integrating artificial intelligence (AI) and Internet of Things (IoT) technology is extremely helpful in order to reduce human contraction at all stages using AI abilities [64]. It can also reduce the spread of illnesses by using touchless technologies combined with additional inputs [65]. A couple of such examples are Tele-robots and medical drones. Tele-robots are used for remote operations and remote diagnosis without involving humans [66]. Medical drones have reduced hospital visits by delivering healthcare services to patients, it also boosted access to healthcare [64]. Another well-known use of IoT in healthcare is digital medication (pills) which are tablets that have sensors to analyze patient's medicine dosage and can be used for mental treatment. These pills will be more offered in the future [67,68]. It's also significant in the medical field to achieve WBAN-based H-IoT's essential features, which include sensors with small form factors, data security, tolerance for failure, quality of service (QoS), and interoperability [69]. The total operation of H-IoT is improving with the new technologies developed to improve various features [70]. The future holds promising applications, including telehealth with robot-assisted diagnosis, rehabilitation using virtual reality and robotics, and the emergence of microrobots for targeted drug delivery, which will revolutionize the landscape of medical care [71].

CONCLUSION

The use of robots in the medical field, including robotic surgery and other health applications, aims to improve the quality of patient care and healthcare services. With technological advances, today we can provide more accurate medical care by doctors or even patients themselves. The integration of artificial intelligence (AI) and Internet of Things (IoT) technology also reduces the treatment workload of health service providers and increases the possibility of providing services to more patients. Internet of Things technology, combined with robotics, offers more effective and affordable healthcare services, from more accurate diagnosis by assisting doctors to recent remote surgeries done with robots. This merger enables the use of Internet of Things (IoT)-based medical devices that improve patient safety, and treatment adherence, and reduce healthcare costs. The Internet of Things, a set of networks of sensors, computers, actuators, and devices connected to the Internet, interacts with users and offers the best possible health services using these technologies. The incorporation of artificial intelligence and the Internet of Things improves the daily activities of doctors and increases health facilities at all stages. In general, the use of these technologies not only leads to an elevation in the quality of health services but also takes surgeries, diagnoses, and monitoring to another level and is considered part of the most revolutionary changes in the field of health care.

References

[1] Patel, Ankit R., et al. "Vitality of robotics in healthcare industry: an Internet of Things (IoT) perspective." Internet of things and big data technologies for next generation healthcare (2017): 91-109.

[2] Kazanzides, Peter. "Safety design for medical robots." 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE, 2009.

[3] Beasley, Ryan A. "Medical robots: current systems and research directions." Journal of Robotics 2012 (2012).

[4] Howe, Robert D., and Yoky Matsuoka. "Robotics for surgery." Annual review of biomedical engineering 1.1 (1999): 211-240.

[5] Satava, Richard M. "Surgical robotics: the early chronicles: a personal historical perspective." Surgical Laparoscopy Endoscopy & Percutaneous Techniques 12.1 (2002): 6-16.

[6] Simaan, Nabil, Rashid M. Yasin, and Long Wang. "Medical technologies and challenges of robot-assisted minimally invasive intervention and diagnostics." Annual Review of Control, Robotics, and Autonomous Systems 1 (2018): 465-490.

[7] Taylor, Russell H. "A perspective on medical robotics." Proceedings of the IEEE 94.9 (2006): 1652-1664.

[8] Ide, Takatoshi, Najam A. Siddiqi, and Noriya Akamatsu. "Expectations for medical and healthcare robotics." Advanced robotics 7.2 (1992): 189-200.

[9] Ardalani, Ramin. "Biomedical engineering and its aspects through IOT." Future Generation of Communication and Internet of Things 2.2 (2023): 1-5.

[10] Verma, Varnita, et al. "IoT and robotics in healthcare." Medical Big Data and Internet of Medical Things. CRC Press, 2018. 245-269.

[11] Riek, Laurel D. "Healthcare robotics." Communications of the ACM 60.11 (2017): 68-78.

[12] Joseph, Azeta, et al. "A review on humanoid robotics in healthcare." MATEC Web of Conferences. Vol. 153. EDP Sciences, 2018.

[13] Arent, Krzysztof, et al. "Selected topics in design and application of a robot for remote medical examination with the use of ultrasonography and ascultation from the perspective of the remedi project." Journal of Automation Mobile Robotics and Intelligent Systems 11.2 (2017): 82-94.

[14] Nawrat, Z. "Polski robot kardiochirurgiczny." Postępy robotyki/Przemysłowe i medyczne systemy robotyczne/Praca zbiorowa pod redakcją Krzysztofa Tchonia/Warszawa 2005r. str 117 (2005): 129.

[15] Balasubramanian, Sivakumar, Julius Klein, and Etienne Burdet. "Robot-assisted rehabilitation of hand function." Current opinion in neurology 23.6 (2010): 661-670.

[16] Nef, Tobias, Matjaz Mihelj, and Robert Riener. "ARMin: a robot for patient-cooperative arm therapy." Medical & biological engineering & computing 45 (2007): 887-900.

[17] Kaczmarski, Marcin, and Grzegorz Granosik. "Rehabilitation robot rrh1." Archive of Mechanical Engineering 58.1 (2011): 103-113.

[18] Mariappan, Muralindran, et al. "Safety system and navigation for orthopaedic robot (OTOROB)." Intelligent Robotics and Applications: 4th International Conference, ICIRA 2011, Aachen, Germany, December 6-8, 2011, Proceedings, Part II 4. Springer Berlin Heidelberg, 2011.

[19] Mukai, Toshiharu, et al. "Development of a nursing-care assistant robot RIBA that can lift a human in its arms." 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems. IEEE, 2010.

[20] Urdiales, C., et al. "A collaborative control scheme for haptics-based blind wheelchair driving." Prace Naukowe Politechniki Warszawskiej. Elektronika 175, t. 1 (2010): 3-22.

[21] Guntur, Sitaramanjaneya Reddy, Rajani Reddy Gorrepati, and Vijaya R. Dirisala. "Robotics in healthcare: an internet of medical robotic things (IoMRT) perspective." Machine learning in bio-signal analysis and diagnostic imaging. Academic Press, 2019. 293-318.

[22] Dixit, Pooja, et al. "Robotics, AI and IoT in medical and healthcare applications." AI and IoT-Based Intelligent Automation in Robotics (2021): 53-73.

[23] Mois, George, and Jenay M. Beer. "The role of healthcare robotics in providing support to older adults: a socio-ecological perspective." Current Geriatrics Reports 9 (2020): 82-89.

[24] Broadbent, Elizabeth, Rebecca Stafford, and Bruce MacDonald. "Acceptance of healthcare robots for the older population: Review and future directions." International journal of social robotics 1 (2009): 319-330.

[25] Moerman, Clara J., Loek Van Der HEIDE, and Marcel Heerink. "Social robots to support children's well-being under medical treatment: A systematic state-of-the-art review." Journal of Child Health Care 23.4 (2019): 596-612.

[26] Zhao, Jing-Xin, et al. "Evolution and current applications of robot-assisted fracture reduction: a comprehensive review." Annals of biomedical engineering 48 (2020): 203-224.

[27] Pradhan, Bikash, Saugat Bhattacharyya, and Kunal Pal. "IoT-based applications in healthcare devices." Journal of healthcare engineering 2021 (2021): 1-18.

[28] Yang, Geng, et al. "A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box." IEEE transactions on industrial informatics 10.4 (2014): 2180-2191.

[29] Yan, Yan, et al. "A home-based health information acquisition system." Health Information Science and Systems 1 (2013): 1-10.

[30] Brannan, Laura. "Inference over Knowledge Representations Automatically Generated from Medical Texts with Applications in Healthcare Robotics." (2021).

[31] Tekeste Habte, Temesghen, et al. "IoT for healthcare." Ultra Low Power ECG Processing System for IoT Devices (2019): 7-12.

[32] Kashani, Mostafa Haghi, et al. "A systematic review of IoT in healthcare: Applications, techniques, and trends." Journal of Network and Computer Applications 192 (2021): 103164.

[33] Kavidha, V., N. Gayathri, and S. Rakesh Kumar. "AI, IoT and robotics in the medical and healthcare field." AI and IoT-Based Intelligent Automation in Robotics (2021): 165-187.

[34] Gatouillat, Arthur, et al. "Internet of medical things: A review of recent contributions dealing with cyber-physical systems in medicine." IEEE internet of things journal 5.5 (2018): 3810-3822.

[35] Pradhan, Bikash, et al. "Internet of things and robotics in transforming current-day healthcare services." Journal of Healthcare Engineering2021 (2021): 1-15.

[36] Zeadally, Sherali, and Oladayo Bello. "Harnessing the power of Internet of Things based connectivity to improve healthcare." Internet of Things 14 (2021): 100074.

[37] Antonio J. Jara, Miguel A. Zamora, and Antonio F. Skarmeta (2011), An Internet of Things--based personal device for diabetes therapy management in ambient assisted living (AAL). Personal Ubiquitous Comput. 15, 4 (April 2011), 431-440. DOI=10.1007/s00779-010-0353-1

[38] Turcu, Cristina Elena, and Cornel Octavian Turcu. "Internet of things as key enabler for sustainable healthcare delivery." Procedia-Social and Behavioral Sciences 73 (2013): 251-256.

[39] T. N. Nguyen and H. T. Nguyen, "Real-time video streaming with multi-camera for a telepresence wheelchair," in Proceedings of the 2016 14th International Conference on Control, Automation, Robotics and Vision (ICARCV), pp. 1–5, IEEE, Phuket, Thailand, November 2016.

[40] Sahu, Deblu, et al. "The internet of things in geriatric healthcare." Journal of healthcare engineering 2021 (2021).

[41] S. Koceski and N. Koceska, "Evaluation of an assistive telepresence robot for elderly healthcare," Journal of Medical Systems, vol. 40, no. 5, p. 121, 2016.

[42] A. Orlandini, A. Kristoffersson, L. Almquist et al., "Excite project: a review of forty-two months of robotic telepresence technology evolution," Presence: Teleoperators and Virtual Environments, vol. 25, no. 3, pp. 204–221, 2016.

[43] Ma, Yujun, et al. "Big health application system based on health internet of things and big data." IEEE Access 5 (2016): 7885-7897.

[44] Al-Taee, Majid A., et al. "Robot assistant in management of diabetes in children based on the internet of things." IEEE Internet of Things Journal 4.2 (2016): 437-445.

[45] 45 H. Qiu, X. Wang and F. Xie, "A Survey on Smart Wearables in the Application of Fitness," in IEEE 15th Intl Conf on Dependable, Autonomic and Secure Computing, 15th Intl Conf on Pervasive Intelligence and Computing, 3rd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress (DASC/ Pi Com/ Data Com/ Cyber Sci Te, Orlando, FL, USA, 2018

[46] Shamsul Arefin, A. S. M., KM Talha Nahiyan, and Mamun Rabbani. "The basics of healthcare IoT: Data acquisition, medical devices, instrumentations and measurements." A Handbook of Internet of Things in Biomedical and Cyber Physical System (2020): 1-37

[47] Kang, Minhee, et al. "Recent patient health monitoring platforms incorporating internet of things-enabled smart devices." International neurourology journal 22.Suppl 2 (2018): S76

[48] Xing, Fei, et al. "Challenges for deploying iot wearable medical devices among the ageing population." Distributed, Ambient and Pervasive Interactions: Understanding Humans: 6th International Conference, DAPI 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15–20, 2018, Proceedings, Part I 6. Springer International Publishing, 2018

[49] Verma, Damini, et al. "Internet of things (IoT) in nano-integrated wearable biosensor devices for healthcare applications." Biosensors and Bioelectronics: X 11 (2022): 100153

[50] PremaLatha, V., E. Sreedevi, and S. Sivakumar. "Contemplate on internet of things transforming as medical devices-The internet of medical things (IOMT)." 2019 International Conference on Intelligent Sustainable Systems (ICISS). IEEE, 2019

[51] Singh, Kamalpreet, et al. "Role and impact of wearables in IoT healthcare." Proceedings of the Third International Conference on Computational Intelligence and Informatics: ICCII 2018. Springer Singapore, 2020

[52] Amira, Abbes, et al. "Empowering eHealth with smart internet of things (IoT) medical devices." Journal of sensor and actuator networks 8.2 (2019): 33

[53] Bhatt, Yesha, and Chintan Bhatt. "Internet of things in healthcare." Internet of things and big data technologies for next generation HealthCare (2017): 13-33

[54] R K Kodali, G Swamy, & B Lakshmi. (2015). An implementation of IoT for healthcare. In: IEEE Recent Advances in Intelligent Computational Systems (RAICS).

[55] N N Thilakarathne. (2020). Security and privacy issues in iot environment. International Journal of Engineering and Management Research, 10(1), 26–29.

[56] C Li, X Hu, & L Zhang. (2017). The IoT-based heart disease monitoring system for pervasive healthcare service. Procedia Computer Science, 112, 2328–2334.

[57] W Sun, Z Cai, Y Li, F Liu, S Fang, & G Wang. (2018). Security and privacy in the medical internet of things: A review.

[58] Aniket. (2020). The role of IoT in healthcare: Applications implementation.

[59] Farooq, M Umar, M Waseem, S Mazhar, A Khairi, & T Kamal. (2015). A review on internet of things (IoT). International Journal of Comp. Applications 113(1), 1-7.

[60] A Kumari, S Tanwar, S Tyagi, & N Kumar. (1018). Fog computing for Healthcare 4.0 environment: Opportunities and challenges. Computers; Electrical Engineering 72.

[61] R Jayswal, R Gupta, & K K Gupta. (2017). Patient health monitoring system based on Internet of Things. Fourth International Conference on Image Information Processing (ICIIP).

[62] A S Mohammad Mosa, I Yoo, & L Sheets. (2012). A systematic review of healthcare applications for smartphones. BMC Medical Informatics and Decision Making, 12(1).

[63] G J Joyia, R M Liaqat, A Farooq, & S Rehman. (2017). Internet of Medical Things (IOMT): Applications, benefits and future challenges in healthcare domain. Journal of Communications.

[64] Nasajpour, Mohammad, et al. "Internet of Things for current COVID-19 and future pandemics: An exploratory study." Journal of healthcare informatics research 4 (2020): 325-364.

[65] Agarwal S, Punn NS, Sonbhadra SK, Nagabhushan P, Pandian K, Saxena P (2020) Unleashing the power of disruptive and emerging technologies amid COVID 2019

[66] Avgousti S, Christoforou EG, Panayides AS, Voskarides S, Novales C, Nouaille L, Pattichis CS, Vieyres P (2016) Medical telerobotic systems: current status and future trends.

[67] R. Chambers, M. Schmid, and J. Birch-Jones, Digital Healthcare: Tthe Essential Guide.

[68] A.S. Yeole, D.R. Kalbande, Use of Internet of Things (IoT) in healthcare: a survey, in: Proceedings of the ACM Symposium on Women in Research (WIR), 2016, pp. 71–76, doi:10.1145/2909067.2909079.

[69] L. Filipe, F. Fdez-Riverola, N. Costa and . A. Pereira, "Wireless Body Area Networks for Healthcare Applications: Protocol Stack Review," International Journal of Distributed Sensor Networks, vol. 2015, pp. 1-23, 2015.

[70] Qadri, Yazdan Ahmad, et al. "The future of healthcare internet of things: a survey of emerging technologies." IEEE Communications Surveys & Tutorials 22.2 (2020): 1121-1167.

[71] Dixit, Pooja, et al. "Robotics, AI and IoT in medical and healthcare applications." AI and IoT-Based Intelligent Automation in Robotics (2021): 53-73.