IT in Industry, Vol. 7, No.3, 2019

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

Smart Healthcare Systems: The Impact of IoT on Medical Diagnostics and Treatment

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Abstract
The rapid advancement of technology has led to the development of the Internet of Things (IoT), which is revolutionizing various sectors, including healthcare. Smart healthcare systems, powered by IoT, have the potential to significantly improve medical diagnostics and treatment, thus enhancing patient outcomes and reducing healthcare costs. This paper aims to analyze the impact of IoT on medical diagnostics and treatment, focusing on three key areas: remote patient monitoring, telemedicine, and artificial intelligence (AI) in diagnostics. Remote patient monitoring allows for real-time data collection and analysis of patient health, enabling healthcare professionals to make informed decisions and provide prompt interventions. IoT devices, such as wearable sensors and smart medical equipment, facilitate the continuous monitoring of vital signs and symptoms, leading to timely detection of abnormalities and improved disease management. Telemedicine, enabled by IoT, allows healthcare providers to virtually consult with patients, reducing the need for in-person visits and expanding access to medical care, especially for individuals in remote or underserved areas. This technology enhances patient-provider communication, fosters a more personalized approach to medicine, and increases the efficiency of healthcare services. Finally, AI-powered diagnostic tools, integrated with IoT devices, can process and analyze large volumes of data to identify patterns and correlations, leading to more accurate and efficient diagnoses. These systems can also aid in treatment planning and decision-making, resulting in improved patient care and outcomes.

1. Introduction

The global healthcare landscape is undergoing a significant transformation as a result of advancements in technology, particularly with the advent of the Internet of Things (IoT). IoT refers to the network of interconnected physical devices, embedded with sensors and software, that communicate and exchange data with each other, providing real-time insights and enabling improved decision-making. In the healthcare sector, the integration of IoT has led to the emergence of smart healthcare systems, which hold the promise of revolutionizing medical diagnostics and treatment. Smart healthcare systems leverage IoT technology to collect, analyze, and transmit patient data, facilitating remote patient monitoring, telemedicine, and artificial intelligence (AI) in diagnostics. These systems have the potential to address some of the most pressing challenges faced by the healthcare industry, such as rising costs, limited access to medical care, and the need for improved disease management and prevention strategies. Figure 1 show the use of IOT devices in healthcare field. The healthcare systems framework consists of following important components:

1. Data Collection: This component is responsible for collecting data from various sources, including electronic health records (EHRs), medical devices, sensors, and social media platforms. The data collection process should ensure data integrity, privacy, and security while complying with relevant regulations and standards.

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

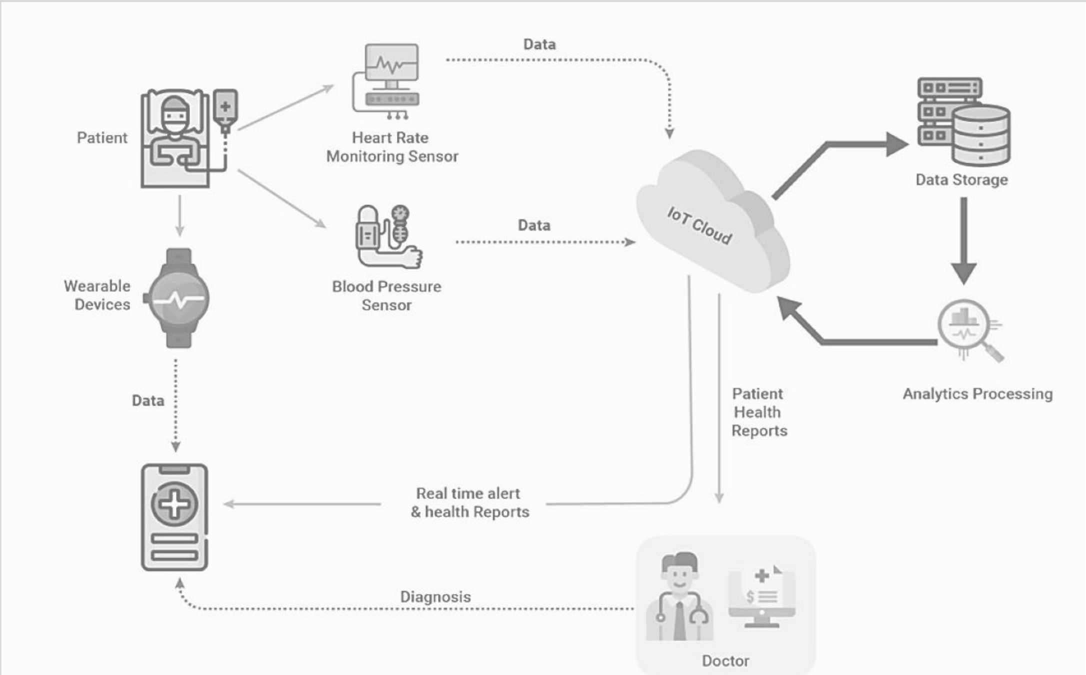

Figure 1. Application of IOT in Healthcare

2. Data Storage and Management: This component deals with the storage, management, and retrieval of healthcare data. It should ensure data availability, accessibility, and scalability while maintaining privacy and security. The author highlights the importance of data standardization, data exchange protocols, and data governance in this context.
3. Data Analytics and Decision Support: This component focuses on the analysis of healthcare data to extract valuable insights and support decision-making processes. The author emphasizes the role of advanced analytics techniques, such as machine learning, data mining, and predictive modeling, in improving the accuracy and efficiency of healthcare decision-making.
4. Service Delivery and Integration: This component involves the delivery of healthcare services and the integration of various healthcare processes and systems. The author discusses the importance of service-oriented architecture (SOA), interoperability, and collaboration among different healthcare stakeholders to enable seamless and efficient service delivery.

This paper also explores the impact of IoT on medical diagnostics and treatment by delving into three key aspects of smart healthcare systems: (1) remote patient monitoring, which enables the real-time collection and analysis of patient health data; (2) telemedicine, which allows healthcare providers to virtually consult with patients, expanding access to medical care and enhancing patient-provider communication; and (3) AI-driven diagnostics, which can process vast amounts of data to identify patterns and correlations, resulting in more accurate and efficient diagnoses. By examining the role of IoT in these areas, this paper aims to provide a comprehensive understanding of the potential benefits and challenges associated with the adoption of smart healthcare systems, and to highlight the ways in which IoT technology is transforming the future of medical diagnostics and treatment.

2. Literature Review

Chernyshev et al. [1] have presented a comprehensive overview of research simulators and testbeds for IoT in their paper. They provide valuable insights into the design, implementation, and evaluation of IoT systems by discussing various simulation tools,

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

testbeds, and research projects. This study is instrumental in understanding the current state of IoT research and identifying potential areas for future advancements.

The Industrial Internet of Things (IIoT) has made significant strides in recent years, leading to a wide range of applications across various sectors, including healthcare. The integration of IoT technology in healthcare systems has the potential to revolutionize patient care, remote monitoring, and early detection of diseases. In this context, the study by Al-Turjman and Alturjman [2] propose a context-sensitive access mechanism for IIoT healthcare applications, which aims to address the challenges of security, privacy, and data management. This mechanism takes into account contextual information, such as location, time, and user behavior, to make intelligent decisions regarding data access and sharing. By incorporating contextual awareness into the system, the proposed approach enhances the security and efficiency of data management in IIoT healthcare applications.

Muhammed et al. [3] proposed a personalized healthcare system that leverages cloud and edge computing technologies to provide efficient services in smart cities. The system incorporates Electronic Health Records (EHRs) and various IoT devices such as wearables and medical sensors, allowing continuous patient monitoring and real-time data processing. The UbeHealth system uses data analytics and machine learning techniques to offer personalized healthcare services, while also ensuring privacy and security. The advantages of the UbeHealth system include seamless integration with smart city infrastructure, improved efficiency, and enhanced personalization. However, the system relies heavily on cloud and edge infrastructure, which could present challenges in terms of implementation, scalability, and security.

Rashmi and Sangve [4] aimed to address the security concerns related to data integrity and protection in cloud storage. The proposed protocol enhances the existing remote data possession checking schemes by introducing a bilinear pairing technique and a random masking process, ensuring that the data owner and auditor can efficiently verify the data's integrity. The advantages of this protocol include enhanced security, confidentiality, and data integrity in cloud storage systems. However, the study's focus is limited to public auditing systems and may not be applicable to all cloud storage scenarios.

Catarinucci et al. [5] developed a flexible, scalable, and interoperable architecture for healthcare systems that leverages IoT devices and technologies. This architecture aims to address the challenges of implementing IoT in healthcare, such as device heterogeneity, communication protocols, and data management. The proposed architecture includes modules for device abstraction, communication, data storage, and analytics, allowing seamless integration of various IoT devices and systems. The advantages of this IoT-aware architecture include its potential for improving healthcare services, reducing costs, and facilitating real-time monitoring and decision-making. However, the architecture also presents challenges in terms of technological complexity, implementation, and security, which must be addressed for successful deployment.

Patil Rashmi et al. [6] focused on the early detection and accurate classification of melanoma, a type of skin cancer, using dermoscopic images. The study highlighted the significance of thickness in melanoma diagnosis and described various methods for melanoma detection, such as image pre-processing, segmentation, feature extraction, and classification techniques. The advantages of this approach include early detection of melanoma, accurate classification based on thickness, and improved treatment planning. However, the study is limited to dermoscopic images and may not detect all melanoma cases or be applicable to other imaging modalities.

Cui et al. [7] proposed a secure search scheme that allows users to perform keyword searches on encrypted data stored in cloud systems without compromising privacy. The scheme

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

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DOI: https://doi.org/10.17762/itii.v7i3.814

employs a searchable symmetric encryption (SSE) method, which combines advanced encryption techniques with efficient search algorithms to enable expressive keyword searches while preserving data confidentiality. The advantages of this approach include secure and expressive keyword search, privacy preservation, and potential applicability to various cloud storage scenarios. However, there may be performance trade-offs between encryption and search efficiency, which should be considered in practical implementations.

Mišić et al. [8] developed a system that integrates IoT devices and technologies, such as smart orthopedic implants and wearable sensors, to continuously monitor bone fracture recovery in real-time. The system uses machine learning algorithms to analyze collected data and provide personalized recommendations for patients and healthcare professionals. The advantages of this approach include continuous monitoring, faster recovery, data-driven treatment planning, and improved patient outcomes. However, there are potential challenges in device implementation, user compliance, and data privacy that need to be addressed for successful deployment.

Li et al. [9] focused on the integration of IoT technologies in hospital logistics and supply chain management to improve efficiency, reduce errors, and optimize resource allocation. The study discussed the use of IoT devices such as RFID tags, sensors, and wireless communication systems to track and manage medical supplies, equipment, and medication. The advantages of this approach include enhanced hospital logistics efficiency, reduced waste, and improved patient care. However, the implementation of IoT in hospital logistics may face challenges related to cost, technology adoption, and data security.

Catarinucci et al. [10] developed a flexible, scalable, and interoperable architecture for healthcare systems that leverages IoT devices and technologies. This architecture aims to address the challenges of implementing IoT in healthcare, such as device heterogeneity, communication protocols, and data management. The proposed architecture includes modules for device abstraction, communication, data storage, and analytics, allowing seamless integration of various IoT devices and systems. The advantages of this IoT-aware architecture include its potential for improving healthcare services, reducing costs, and facilitating real-time monitoring and decision-making. However, the architecture also presents challenges in terms of technological complexity, implementation, and security, which must be addressed for successful deployment.

Demirkan [10] proposes a smart healthcare systems framework aimed at improving the quality, accessibility, and efficiency of healthcare services. The author identifies the key components and functionalities required to create a smart healthcare system, focusing on the integration of information technology, data analytics, and decision-making capabilities. The paper also discusses various challenges and opportunities related to the development and implementation of smart healthcare systems. The paper also addresses several challenges associated with the development and implementation of smart healthcare systems, such as data privacy and security, data quality, and the need for standardization and interoperability. Demirkan suggests that overcoming these challenges requires a collaborative effort from various stakeholders, including healthcare providers, patients, policymakers, and technology vendors.

Budida and Mangrulkar [11] proposed a smart healthcare system that integrates IoT devices, such as wearable sensors and medical equipment, to monitor patients' health and provide real-time feedback to healthcare professionals. The system uses cloud-based data storage and processing, enabling remote access and continuous monitoring. The advantages of the proposed smart healthcare system include improved patient care, real-time monitoring, and the potential for telemedicine applications. However, the study's implementation may face challenges related to

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

scalability, data security, and the integration of diverse IoT devices and technologies.

Sundaravadivel et al. [12] propose a deep-learning-based automated nutrition monitoring system called Smart-Log, which leverages IoT technology to monitor an individual's food intake and provide personalized nutrition recommendations. The aim of this system is to improve people's health and well-being by promoting healthy eating habits and lifestyle choices. The Smart-Log system comprises three main components: The IoT-based data acquisition module, the deep learning-based image processing module, and the personalized nutrition recommendation module. The data acquisition module captures images of the user's food items using a smartphone or wearable camera, and sends the images to the image processing module. The image processing module employs a deep learning model called the Convolutional Neural Network (CNN) to identify and classify the food items present in the images. Once the food items are identified, the system retrieves nutritional information for these items from a database. The personalized nutrition recommendation module then analyzes the user's food intake based on the nutritional information and provides personalized dietary recommendations, taking into account the user's age, gender, weight, height, and activity level. The system also provides feedback to the user about their daily calorie intake, macronutrient distribution, and adherence to recommended dietary guidelines. The authors conducted experiments to evaluate the performance of the proposed system, focusing on the accuracy of the CNN-based image recognition model and the effectiveness of the personalized nutrition recommendations. The results show that the system achieved a high level of accuracy in food item classification, and the personalized nutrition recommendations were effective in helping users achieve their dietary goals.

Gope and Hwang [13] propose BSN-Care, a secure IoT-based modern healthcare system utilizing body sensor networks (BSNs). BSNs are composed of wearable or implantable sensors that collect and transmit physiological data. The authors focus on the security of such systems and present a lightweight security protocol for secure data communication between the BSNs and the remote server. The proposed security protocol offers confidentiality, integrity, and authentication, utilizing a combination of symmetric and asymmetric cryptographic techniques. The authors also discuss various attacks that the system may face, such as replay attacks, man-in-the-middle attacks, and denial of service (DoS) attacks, and explain how the proposed protocol can mitigate these threats. The performance of the proposed system is evaluated through simulations and experimental results, demonstrating its effectiveness and low overhead compared to existing approaches.

Rahmani et al. [14] present a fog computing-based approach to exploit smart e-health gateways at the edge of the healthcare Internet of Things (IoT). The authors address the challenges of managing and processing the vast amounts of data generated by IoT devices in healthcare settings. They propose a fog computing architecture that leverages smart e-health gateways to enable efficient data processing and management at the edge of the network. The proposed architecture consists of three layers: IoT devices, smart e-health gateways, and cloud servers. The smart e-health gateways perform tasks such as data aggregation, filtering, and analysis, reducing the load on the cloud servers and improving overall system efficiency. The authors also discuss the security and privacy concerns related to the proposed architecture, and propose several countermeasures to address them. The paper includes case studies and simulations to demonstrate the feasibility and effectiveness of the proposed approach.

In this paper, Andreu-Perez et al. [15] review the advancements in wearable sensors and smart implants, and discuss how these technologies can contribute to pervasive and personalized healthcare. The authors provide a

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

comprehensive overview of various wearable and implantable devices, their applications, and their potential impact on healthcare.

They discuss the challenges associated with the implementation of such technologies, including data privacy, security, and the need for standardized communication protocols. Additionally, the authors highlight the importance of data analytics and machine learning techniques for processing the vast amounts of data generated by these devices, which can lead to more accurate diagnoses, personalized treatment plans, and improved patient outcomes.

Rahmani et al. [16] propose a smart e-health gateway designed to bring intelligence to IoT-based ubiquitous healthcare systems. The authors address the challenges of integrating and managing heterogeneous IoT devices and their data in healthcare systems. They present an architecture for the smart e-health gateway, which serves as an intermediary between IoT devices and the cloud, providing features such as data processing, storage, and communication capabilities. The proposed gateway architecture consists of three main layers: The IoT device layer, the smart e-health gateway layer, and the cloud server layer. The gateway layer is responsible for managing and processing data from the IoT devices, as well as handling authentication and security. It also provides decision-making capabilities based on the collected data, enabling real-time monitoring and analysis of patients' conditions. The authors also discuss the security and privacy concerns related to the proposed architecture and provide solutions to address them. They evaluate the performance of the proposed system through simulations and experimental results, demonstrating its feasibility and effectiveness in managing IoT-based healthcare systems.

Polat and Gunes [17] propose a three-step approach for lung cancer diagnosis based on medical data. The primary goal is to improve the accuracy and efficiency of lung cancer diagnosis using artificial intelligence techniques.

1. Principle Component Analysis (PCA): In the first step, PCA is applied to reduce the dimensionality of the data, retaining only the most relevant features. PCA is a widely-used technique for data compression and feature extraction, which simplifies the data by identifying and selecting the most significant components that account for the majority of the variance in the dataset.
2. Fuzzy weighting pre-processing: After applying PCA, the authors introduce a fuzzy weighting pre-processing step to assign weights to the selected features based on their relevance to the diagnosis. This step incorporates domain knowledge to further refine the feature set and enhance the performance of the classification process.
3. Artificial Immune Recognition System (AIRS): The final step involves the use of an Artificial Immune Recognition System, an artificial intelligence technique inspired by the natural immune system. The AIRS algorithm is employed to classify the pre-processed data into different classes, such as healthy individuals and lung cancer patients. The algorithm works by creating a set of artificial memory cells that can recognize and respond to specific patterns in the input data, simulating the immune system's ability to recognize and eliminate foreign substances.

The authors evaluate the performance of the proposed diagnostic system using real-world medical data from lung cancer patients and healthy individuals. They compare the performance of the system to other classification techniques, such as Support Vector Machines (SVM), Decision Trees, and k-Nearest Neighbors (k-NN). The results demonstrate that the proposed system achieves high classification accuracy and outperforms the other techniques, indicating its potential for use in lung cancer diagnosis.

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

3. Result and Discussion

A. Comparative Analysis

Table 1 shows the comparative analysis of various author research, their proposed methodology, advantages and limitations.

Table 1. Comparative Analysis of researcher work

Author(s)	Methodology Used	Advantages	Limitations
Muhammed et al. (2018) [3]	Ubiquitous Cloud and Edge-Enabled Networked Healthcare System	Personalization, improved efficiency, smart city integration	Dependence on cloud and edge infrastructure
Rashmi & Sangve (2015) [4]	Improved Remote Data Possession Checking Protocol	Enhanced security and integrity of data in cloud storage	Limited to public auditing system
Catarinucci et al. (2015) [5]	IoT-Aware Architecture for Smart Healthcare Systems	Scalability, flexibility, and interoperability for healthcare IoT systems	Technological complexity and implementation challenges
Bellary & Patil Rashmi (2017) [6]	Melanoma detection & classification using dermascopic images	Early detection, accurate classification based on thickness	Limited to dermoscopic images, may not detect all melanoma cases
Cui et al. (2018) [7]	Keyword search over encrypted data in cloud	Secure and expressive keyword search, privacy preservation	Performance trade-offs in encryption and search
Mišić et al. (2018) [8]	Real-Time Monitoring of Bone Fracture Recovery using Smart Orthopedic Devices	Continuous monitoring, faster recovery, data-driven treatment	Device implementation and user compliance
Li et al. (2018) [9]	IoT in supplies logistics of intelligent hospital	Improved supply chain management, reduced human error, cost savings	Reliance on IoT infrastructure, possible security risks
Budida & Mangrulkar (2017) [11]	Smart Healthcare System using IoT	Real-time monitoring, remote accessibility, cost-effective	Implementation challenges, security concerns
Sundaravadivel et al. (2018) [12]	Deep-Learning Based Automated Nutrition Monitoring System	Personalized nutrition tracking, improved health outcomes	Reliance on user input, possible inaccuracies
Gope & Hwang (2016) [13]	Secure IoT-based Healthcare System using Body Sensor Network (BSN)	Enhanced security, real-time monitoring, data privacy	BSN implementation challenges, data security concerns

ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

Rahmani et al. (2018) [14]	Smart e-Health Gateways with Fog Computing	Reduced latency, improved scalability, data processing at the edge	Complexity of fog computing, infrastructure requirements
Andreu-Perez et al. (2015) [15]	Pervasive and Personalized Healthcare with Wearable Sensors and Smart Implants	Continuous monitoring, tailored healthcare, improved patient outcomes	Device compatibility, data privacy, user compliance
Rahmani et al. (2015) [16]	Smart e-Health Gateway for IoT-based Ubiquitous Healthcare Systems	Enhanced data processing, real-time monitoring, scalable architecture	Technological complexity, implementation challenges
Polat & Gunes (2008) [17]	Lung Cancer Diagnostic System using PCA, Fuzzy Weighting and Artificial Immune Recognition System	Accurate diagnosis, improved treatment planning	Limited to lung cancer, possible false positives/negatives

B. Challenges

While smart healthcare systems offer significant benefits, they also present various challenges that must be addressed to ensure their successful implementation and adoption. Some of the key challenges include:

1. Data Security and Privacy: As IoT devices collect and transmit sensitive health data, ensuring the security and privacy of this information is crucial. Healthcare systems must implement robust data encryption and secure communication protocols to protect against unauthorized access, data breaches, and cyberattacks.
2. Interoperability: The integration of various IoT devices, platforms, and healthcare systems can be challenging due to differences in communication protocols, data formats, and standards. Ensuring seamless interoperability is essential for the effective functioning of smart healthcare systems, requiring the development of unified standards and protocols.
3. Infrastructure Requirements: The implementation of smart healthcare systems requires reliable internet connectivity, advanced data storage, and processing capabilities. In resource-limited settings or remote areas, inadequate infrastructure can impede the adoption and effectiveness of IoT-based healthcare solutions.
4. Regulatory and Legal Frameworks: Existing regulatory and legal frameworks may not adequately address the unique challenges posed by smart healthcare systems. Policymakers must establish clear guidelines and regulations to ensure the safe and ethical use of IoT technology in healthcare, addressing issues such as data ownership, liability, and patient consent.
5. Digital Divide: The digital divide between urban and rural areas, as well as socioeconomic disparities in access to technology, can limit the availability and effectiveness of smart healthcare systems for certain populations. Efforts must be made to bridge this divide and ensure that IoT-enabled healthcare services are accessible to all individuals, regardless of their location or socioeconomic status.
6. Workforce Training and Adoption: Healthcare professionals need to be trained in the use of IoT devices and smart

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ISSN (Print): 2204-0595
ISSN (Online): 2203-1731

Published Online 30-Dec-2019
DOI: https://doi.org/10.17762/itii.v7i3.814

healthcare systems to fully utilize their potential. Additionally, addressing concerns related to job displacement and promoting the adoption of IoT technology among healthcare providers is crucial for the successful integration of smart healthcare systems.

7. Data Overload and Management: The massive amounts of data generated by IoT devices in healthcare can overwhelm healthcare providers and systems. Effective data management strategies, including the use of AI and machine learning algorithms for data processing and analysis, are necessary to extract meaningful insights from the vast amounts of collected information.

Addressing these challenges is essential for the successful implementation and adoption of smart healthcare systems, ultimately enabling them to deliver on their promise of revolutionizing medical diagnostics and treatment.

4. Conclusion

The integration of the Internet of Things (IoT) into healthcare has given rise to smart healthcare systems, which have the potential to significantly reshape medical diagnostics and treatment. By leveraging IoT technology, these systems facilitate remote patient monitoring, telemedicine, and AI-driven diagnostics, offering numerous benefits to both patients and healthcare providers. Remote patient monitoring allows for continuous data collection and analysis, leading to timely detection of abnormalities and improved disease management. Telemedicine expands access to medical care, particularly for individuals in remote or underserved areas, and fosters more personalized, efficient healthcare services. AI-driven diagnostic tools enable the processing and analysis of large volumes of data, resulting in more accurate and efficient diagnoses and better-informed treatment planning. However, it is crucial to address the challenges associated with the implementation of smart healthcare systems, such as data security and privacy concerns, infrastructure requirements, and the need for robust regulations and standards. Additionally, the potential digital divide between urban and rural areas and the accessibility of IoT-enabled healthcare services for all socioeconomic groups must be considered. The impact of IoT on medical diagnostics and treatment is immense, offering a promising avenue for improving patient outcomes and optimizing healthcare delivery. As smart healthcare systems continue to evolve, it is essential for stakeholders, including healthcare providers, policymakers, and technology developers, to collaborate in order to harness the full potential of IoT and pave the way for a more efficient, accessible, and personalized healthcare system.

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ISSN (Online): 2203-1731