Recent Developments, Opportunities, Challenges and Future Outlook of AI-driven IoT Healthcare Systems for Addressing Covid-19 in Smart Cities

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Abstract

The rapid pace of globalization along with proliferation of the smart devices has augmented the demand for more sophisticated healthcare systems, which can address the unique needs, wants, and demands of modern patients. In this context, the Internet of Things (IoT) sensors provide real-time healthcare solutions that can be customized as per the client's demand. These devices revolutionized the healthcare system. The integration of IoT in healthcare not only improves the patients' outcomes but also makes the healthcare system more responsive and efficient as per the demands of consumers.

These IoT healthcare systems are proficient in the processing of large amounts of data produced by sensor networks due to Artificial Intelligence (AI). The preceding surveys on smart healthcare systems were focused on fog and cloud computing networks only, while others focused on the IoT or AI separately. The purpose of this study is to find the development of AI-driven IoT healthcare systems for addressing the disease of COVID-19 in the smart cities of the world. With the help of this data, the operations of the city get streamlined. This paper also presents a short overview of AI-driven and IoT-based smart healthcare systems in smart cities for addressing the COVID-19 situation.

Keywords: Artificial Intelligence, Internet of things (IoT), Smart Cities and COVID-19

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Introduction

In today's modern world, the healthcare systems are increasingly dependent on technologies for getting information. With this information, these healthcare systems speed up the health diagnostic and treatment processes of the patients (Haleem et al., 2022). These smart healthcare systems provide intelligence services for the medical automation in different environments and contexts like offices and hospitals. Therefore, such IoT healthcare systems allow for a substantial reduction in the visits of physicians along with their costs (Greco et al., 2023). On the other hand, they are producing an enhancement of the quality of patient care in the smart cities of the world.

The diffusion of powerful AI hardware together with the development of smart medical devices and sensors for sophisticated healthcare systems has made the IoT change the way healthcare is approached. The number of healthcare systems using AI and IoT technologies will reach 440 million by the end of 2024 (Imoize et al., 2023). This happens because of the ease, which these smart healthcare systems are providing to their patients.

The IoT smart healthcare systems capture the bulk amount of data by using ingestible and wearable sensors and mobility patterns (Wang et al., 2023). Moreover, there are some devices, which use certain patterns for tracking the habits of the users. These patterns can reveal the critical conditions by using AI. the previous research has shown that traditional cloud-based architectures are good for analyzing a large amount of data and they provide good performance and reliability but when your patients are the end users, who have some time-sensitive needs then a higher degree of accessibility and robustness is required (Velásquez et al., 2018). In case of disconnection from the core network will hurt the performance of the sensors and devices and it could result in fatal consequences in emergencies. This is a big challenge for cloud-based architectures (Khan et al., 2022).

The IoT smart healthcare systems use AI and IT to provide smart systems to hospitals to speed up health diagnosis and provide the right and effective treatment to the patients at the right time without any procedural delay. The IoT healthcare systems provide services to the various environments and workplaces in the smart cities of the world, which include homes, hospitals, workplaces, and transportation (Umair et al., 2021). This reduces the cost of doctor visits and increases the quality of patient care at an effective rate.

These smart healthcare systems have changed the approaches to healthcare by providing certain electronic devices. The data is collected and analyzed by using deep and machine learning techniques. These techniques reveal certain patterns that exist in the data. These techniques

also warn about the warning signals, which are generated by these devices. These embedded and wearable IoT sensors collect real-time data related to the mobility and habits of the users and generate warning signals by using AI (Ali et al., 2021). The combination of AI and IoT is to exploit the maximum benefit for data collection, processing, interpretation and analysis. This smart healthcare provides promising solutions for the customized needs of the clients with high reliability. The whole world is facing the dilemma of COVID-19 at this time. This paper is an attempt to find the solution to this problem by using IoT-based smart healthcare systems. It shows how COVID-19 could be tracked with the help of certain signals generated by electronic sensors and devices (Dong & Yao, 2021).

Chiang and Zhang (2016) have proposed different methods for using the various techniques of DL and ML for the allotment and distribution of interference-based tasks among the fog and edge nodes. This increases the computational capabilities and power of the edge devices. In smart healthcare systems, the AI and IoT have been used, which provide the highest coverage with more reliable data processing speed. The focus of this study is on smart cities as smart cities rely heavily on electronic gadgets and sensors for collecting and transmitting the data at the right place. Similarly, Maris et al. (2023) have evaluated a research framework to facilitate health technologies in sub-Saharan Africa in five phases. This framework was assessed quantitatively through a questionnaire and its regression analysis has shown the varying relationship among the adoption of technologies by users ranging from 0.643 to 0.927.

Smart healthcare systems make extensive use of AI and the IoT. These architectures incur a huge cost for the healthcare systems. The early healthcare systems started with monitoring solutions and now the use of these technologies converts them into smart healthcare systems, which address the specific needs of the patients. This study also presents the recent developments, opportunities, challenges and outlook of these smart healthcare systems in dealing with the coronavirus.

1. Comparison of the state-of-the-art for IoT Healthcare System

The IoT is a new technology that connects different physical objects by using the internet. The IoT uses different applications in the smart cities of the world. It uses a wide range of applications for healthcare systems, and industrial and logistics management. The major application of the IoT is in the field of the healthcare system, where it provides remote monitoring facilities to the healthcare systems. With the help of wearable electronic sensors and devices, greater flexibility is provided to elder people of the population to monitor their health from home without visiting the medical healthcare centre physically. As per the latest research of the World Health Organization (WHO), the majority of the population in the world die due to the chronic cardiovascular diseases (Finegold et al., 2013).

The IoT based smart healthcare systems provide immediate access to hospitals and doctors for monitoring and reporting the important signals of the patients, which are recorded with the help of electronic sensors. These smart healthcare systems help in reducing the mortality rate in the world due to strokes and heart failures. The medical sensors measure the patient's blood pressure, body's heartbeat, pulse, ECG and blood. Different signals are generated from these data, which are sent to the doctors to make the right decision by deciphering the reports of AI (Topol, 2019). The traditional healthcare systems are very expensive. These IoT based smart healthcare systems provide many benefits like lower cost, lower hospital stays, and timely and easy access to healthcare systems. Moreover, these healthcare systems improve the self-management of the health conditions of the patients. The new IoT-based healthcare systems are efficient in the management of chronic diseases of the ageing population of the world in smart cities (Yuehong et al., 2016).

After doing the extensive literature review and surveys of the state-of-the-art architectures, there are certain aspects of the smart healthcare systems, which are identified. The smart healthcare systems require either DL or ML techniques. These techniques are an integral part of these smart systems. The ML and DL models are used in the devices for data collection, processing and transferring to the other systems. By using AI, this data is transformed into a meaningful picture (Blasch et al., 2021). Table one presents a comparison of previous studies and IoT-based healthcare systems. This study focused on using IoT-based healthcare systems to combat the serious disease of Coronavirus in the smart cities of the world.

The IoT-based healthcare systems are very helpful in the monitoring of heart disease patients. The heart patients need to be monitored regularly, therefore a huge amount of data is processed at a given point in time (Santos et al., 2020). For the last many years, the most familiar name in the healthcare systems, which is attracting attention and creating benchmarks in the whole world is the IoT. It can be called the future of communication, which transforms real-time things and information into smart objects. Its main function is to unite the whole world with the help of cone common infrastructure. It has a wide range of applications in almost all areas of the world as shown in Fig. 1.

This research reviews the studies of various authors in the field of IoT. There are several healthcare applications, which are used for monitoring and measuring the physiological health data that includes, voice, movement, posture and skin. The data collected through the IoT-based smart sensors is gathered and processed by using AI, which gives it a meaningful picture. For advanced processing and classification, this data is sent to the ML backend, where different algorithms perform their functions and go for in-depth analysis, which is compulsory for decision-making.

2. Overview of AI-driven Healthcare systems in Smart Cities

With the evolution of payment systems, the patients are now demanding more from the healthcare providers. The data, which is captured by these smart healthcare systems, is increasing at a confounding rate. The AI brings a lot of advantages as compared to traditional healthcare systems. It helps in proper decision-making in the healthcare systems by using different algorithms. Learning these algorithms can be more accurate as it goes into the interaction with the data, captured by using different electronic and digitized sensors.

These smart healthcare systems use many electronic sensors and devices for monitoring the activities of the patients. With the help of these sensors, the data is collected, which is computed by using different methodologies and fog/edge computing devices. By using these techniques, smart healthcare systems are providing different facilities to patients for curing their diseases. The working of the IoT-based smart healthcare system is shown in Figure 2. As shown in the picture, the data is captured by using the different electronic IoT medical sensors and devices; this data is sent to the internet resources by using different internet services for decryption by using different AI techniques. The data

gets stored after the decryption and it is available for further management and processing within the healthcare system. After all these processes, the data is sent to the healthcare system, where doctors generate different reports after analyzing this data. This is the main attraction of these smart healthcare systems. These healthcare systems provide more flexibility and they enable patients even those suffering from chronic diseases like COVID-19 to stay at home and get treatment without coming to the hospital (Kendzerska et al., 2021).

3. IoT based Healthcare Applications

The current research has shown that the IoT based smart healthcare systems will have a large impact overall economy of the world by the end of 2025. These smart healthcare systems use the different applications of the IoT in their health settings. For example, there is a sensor, which checks the glucose level in the blood of the patients. These sensors measure the sugar level of the blood by using non-invasive procedures and techniques. There are some other sensors, which measure the body temperature. These sensors are responsible for measuring and recording the body temperature of the patients and transferring the data to the main server with the help of internet services.

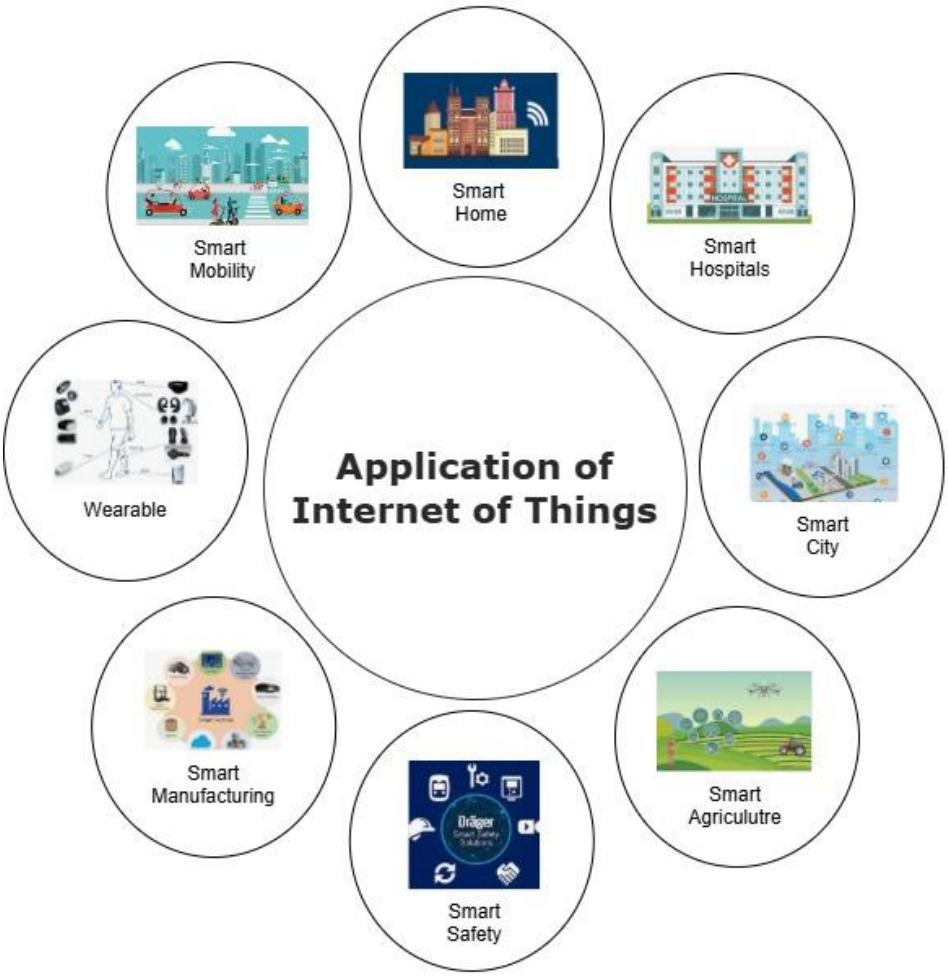

Fig. 1: Application of the Internet of Things (IoT), (Author's Own Work)

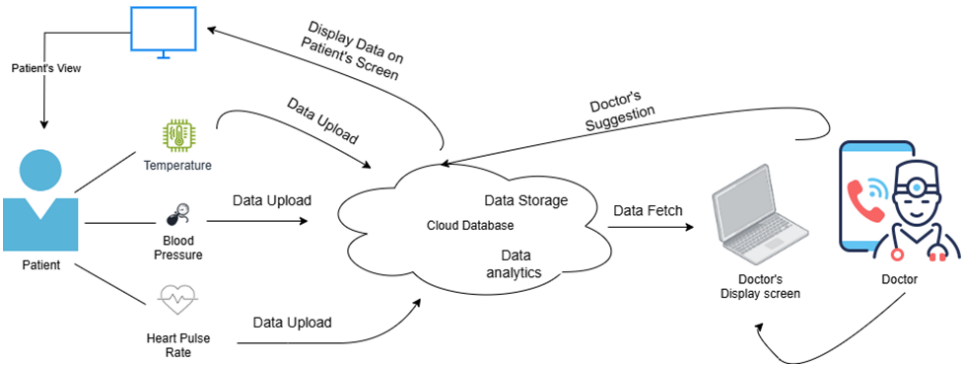

Fig. 2: Working on IoT-based Healthcare Systems, (Authors Own work)

The existing traditional healthcare monitoring cannot provide health facilities to the whole population of the world. They have higher costs and more complexities in understanding the operations of the hospitals. The new advanced IoT based healthcare systems reduce the cost as compared to the traditional healthcare systems. Research has also shown that every year around 17.3 million people die due to cardiovascular diseases and this number will not remain the same. This number will increase by the end of 2030. These IoT-based healthcare systems use different electronic sensors and devices, which display the physiological data of the patients. This data is present in the operating rooms. Then it needs many wires, which makes it much more complicated and hard to understand. Then several protocols are used within the gateways for transferring the data between gateways and the cloud. Such protocols are MQTT, HTTP and XMPP (Tukade and Banakar, 2018).

3.1. Bio-Medical Sensors

The IoT-based smart healthcare systems use the following bio-medical sensors for monitoring the activities of patients at home. The important parameters, which are needed to be recorded, are the pulse, ECG and temperature of the patients. These wearable electronic sensors are easy to wear on the body of the patient without disturbing his daily routine (Chan et al., 2012). The data, which is extracted with the help of these sensors, is transferred to IoT devices wirelessly.

Fig. 3: Biomedical Sensors (Freepik, 2024)

Fig. 4: Pulse Sensors (Freepick, 2024)

3.2. Pulse Sensors

These sensors are used for measuring the oxygenation condition of the patients. A situation can arise, where the patient requires intensive care, recovery, emergency or operation. These sensors measure the need for oxygen supplements by the body of the patients in case of emergencies.

3.3. Temperature Sensors

These sensors are used for measuring the body temperature of the patients. These sensors measure the changes in the body temperature due to the disease and transmit the signals to the healthcare systems for the advice of the doctors.

Fig. 5: Temperature Sensors (Freepik, 2024)

Fig. 6: ECG Sensors (Freepik, 2024)

3.4. ECG Sensors

These sensors are used for measuring the electrical and muscular function of the heart of the patients. By monitoring the wave pattern of the patients, doctors can find the imbalances of the electrolyte, conduction, rhythm and disturbance abnormalities.

4. Big data is IoT-based smart Healthcare Systems

Recent developments in the field of clinics have shown that big data storage technology is mandatory for storing huge amounts of data in IoT-based smart healthcare systems. It records a huge amount of data by using different electronic sensors and devices, which are processed by different AI techniques to give a meaningful picture. The recent developments in the field of smart healthcare systems have shown that a combination of cloud computing and big data is swaying the remote healthcare systems in the smart cities of the world. The EMR (Elastic Map Reduce) provides a different way of handling this big data and it transfers the data onto the clusters. This Amazon EMR has a unique and different function for loading the data into the clusters (Deyhim, 2013). This sensor data from Amazon S3 is sent to the base by using the technology of Apache Pig. It is used for the analysis of data in the healthcare systems. A lightweight model is introduced for the Semantic annotation of the big data of IoT-based smart healthcare systems. This model is produced for predicting and forecasting the quality of the air in the urban areas of the world as shown in Fig 7.

Fig. 7: AirSence (Freepik, 2024)

Fig. 8: IoT-based Smart Healthcare Systems (Freepik, 2024)

5. Security in IoT-based smart Healthcare Systems

One of the biggest challenges for IoT-based smart healthcare systems is the issue of security. It is a major concern in smart healthcare systems because hackers can easily attack the data, which is collected by using different electronic sensors and gadgets. Therefore, to solve this issue, this smart healthcare system has to look for different security methods as well. To solve this issue of privacy on a low budget, the IoT-oriented data placement model was introduced and it is called IDP (Xu et al., 2018). The main purpose of this proposed model is to optimize the access time of the data. It also increases the resource utilization ratio and it reduces energy consumption to a considerable extent at the same time. This is done by satisfying the constraints of data privacy (Dhanushkodi et al., 2024). Privacy preservation is trying to address this by using the algorithm called Non-Dominated Sorting Genetic Algorithm II. The data captured through the sensors is computed and analysed over real-time health data. This data is sent to the healthcare systems for recommendations for the users. Then recommendation process is carried out and the user is informed. Different models have been proposed for addressing this issue of privacy because data needs to be secure otherwise, users will not trust these healthcare systems. This would hinder the growth and development of these smart healthcare systems.

6. Artificial Intelligence-driven IoT Healthcare Systems for Combating COVID-19

The population of the world has increased a lot. This huge population, make it impossible for the elders of the new generation to go for the traditional healthcare systems. The situation becomes worse in the case of epidemics like COVID-19 (Burlacu et al., 2020). The IoT-based healthcare system provides these services to the people of a new generation. These systems provide an accurate diagnosis of the users' body conditions, activities, temperature and heartbeat by using different wearable electronic sensors and gadgets. These sensors detect and prevent the episodes by capturing, transferring, analysing and reporting the health trends of the patients. Then with the use of Intel Edison equips these IoT-based systems, with multitasking ability. These smart healthcare systems can cater the huge amounts of data in the emergencies of the country. Moreover, these smart healthcare systems consume little power. In case of epidemic disease, when the hospitals are facing the problems of surge capacity, then these IoT-based smart healthcare systems help the doctors, who or overwhelmed with the load of patients. These smart healthcare systems are useful for smart cities but at the same time, these systems are beneficial for providing health facilities in the rural areas of the country, which have limited access to healthcare facilities as shown in Fig 8.

The current COVID-19 scenario has changed the whole scene of the world, therefore the need for smart healthcare systems has increased. Researchers are now proposing IoT-based smart healthcare systems for accurate screening, maintaining, processing and analysis of a larger amount of data (Li et al., 2021). It also helps in maintaining the social distance and diagnosis of certain obvious systems like body pain, cough etc. The DL is used for detecting the forehead area for measuring the temperature of the body by using infrared cameras. Other researchers have produced smartphone sensors for finding out the location and for warning people about the risk prone areas (Majumder & Deen, 2019).

With the outbreak of Coronavirus, the AI and IoT-based smart healthcare systems have gained significant attention from the world. These techniques use learning algorithms to provide quality care to patients efficiently and effectively. The convergence of AI and the IoT has many opportunities and it is playing a significant role in the smart cities of the world (Singh et al., 2020). It provides affordable personal care for the patients. It helps in collecting, processing and storing a larger amount of data with accuracy and reliability. This amalgam has a lot of

opportunities and future challenges as well. The IoT smart healthcare systems can revolutionize the typical aspects of the healthcare system and provide people with quality services in an efficient way (Catarinucci et al., 2015).

The IoT framework is used for tackling COVID-19. Users are using different electronic sensors and gadgets for recording the activities of these users. The data recorded by these sensors is sent to the main device by using a wireless communication channel like Wi-Fi or Bluetooth (Ferro & Potorti, 2005). Then with the help of AI, this data is processed further and generates the reports. These reports are sent to the doctors, who decide for the patients after studying these reports.

7. Recent Development, opportunities, challenges and future outlook of IoT based Healthcare

The IoT based healthcare systems have adopted a different type of applications, which assists the healthcare systems in doing a variety of tasks like a smart home system for patients of diabetes and patient monitoring etc. but at the same time, these healthcare systems have certain challenges which are undermining their growth around the globe.

These smart healthcare systems pave the way for more flexibility. For example, patients who require the constant care of doctors, can stay at home, and their conditions could be monitored by using IoT-based technology but wearable devices cause discomfort for the patients and they feel uncomfortable after wearing those devices. The data transmitted from these sensors to the controlling device, from where it is delivereto the monitoring centre, during this entire journey the quality of the data gets affected due to the noise (Hancke & Hancke, 2013).

It is a great challenge for these smart healthcare systems. By using better architecture, healthcare systems can transmit the data without affecting its nature. The removal of the noise from the data will improve the quality of the data as well but this architecture is very expensive. It costs the healthcare system and patients as well. Then most of the current methods for monitoring ECG involve the signals, which should be monitored in an appropriate way (Serhani et al., 2020). Monitoring so many patients in the smart healthcare systems is also a big challenge for these systems because it requires storage and mainframe, which require heavy investment and could be stored with the help of clouds. However, if the healthcare systems start using the clouds for storing the large amount of data it will increase the complexities of the system, which is another challenge for these smart healthcare systems. The biggest challenge for these IoT-based smart healthcare systems is the privacy of the patients (Alshehri & Muhammad, 2020). It is more vulnerable to attack. These electronic sensors are prepared on a low budget so it is difficult to apply encryption techniques to them for securing the data. All these factors are posing a great challenge for these smart healthcare systems.

However, if we talk about the outlook of these smart healthcare systems, then different solutions could be used in future, which would enable these healthcare systems to overcome these challenges. For example, machine learning could be used for analyzing the signals, received through the electronic sensors. This technique will improve the efficiency of the signals and will not increase the budget of the healthcare as well. Different scholars are doing extensive research in this field and they have found that different optimization algorithms can be used in these healthcare systems to reduce the usage of energy, which is currently causing problems for these healthcare systems in managing the larger amount of data (Dash et al., 2019).

In future, when these healthcare systems are in larger numbers, then companies will start producing electronic sensors and devices in larger quantities, which would enable them to get the benefits of economies of scope and economies of scale as well. These benefits would lower the cost of these products and make them cheaper in the markets. Therefore, in future, there will be an increased scope for these smart healthcare systems. If they are supervised properly, then these above-mentioned challenges could be converted into opportunities because these smart healthcare systems are the need in this modern and digitized world for combating serious chronic diseases like Coronavirus.

Conclusion

The Artificial Intelligence-driven IoT healthcare systems are advancing from the simple traditional models, which were used for data collection, processing, transmission and analysis only. These smart systems of today's globalized world are providing the smart, intelligent and sophisticated systems that do extensive data analysis on a larger set of information and help in making smart decisions for the world. These new models require the DL methods to increase the computational ability of the systems while increasing the overhead cost of the company. These models are normally implemented in a cloud layer due to the larger amount of data being processed with the help of real-time sensors. These approaches have some dark sides as well with the quality, availability and processing of a large amount of data in scenarios where timely decisions are very important. In case of any delay, fatal consequences could be there.

Data storage and its security is another major concern for the smart healthcare systems in the world. Confidentiality of the data is important because with the help of IoT, a large amount of data is being stored in the system. Research has been done in the area of distributed DL, which uses the fog nodes, and with its help, it reduces the processing time of the data. The increased importance of AI and IoT-based healthcare systems is there due to their computational ability of the larger amount of data. With the help of these smart healthcare systems, smart cities can combat any serious disease like Coronavirus. The smart electronic sensors would enable the IoT-based smart healthcare systems to address this disease efficiently and effectively.

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