PART IV

Artificial Intelligence of Things: Applications in Healthcare

22

AI- and IoT-Enabled Healthcare Applications: A Review

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Abstract

This chapter discusses how artificial intelligence (AI) and the internet of things (IoT) are being used in various technologies and components of healthcare systems to detect diseases with better accuracy. To tackle the healthcare system in an efficient way, AI and IoT are the preferred technologies. The IoT provides a platform that helps to share information through the communication network. Moreover, it helps collect various data on patients' health and monitors any health conditions accordingly. In this chapter, the key features of IoT in the healthcare profession will be thoroughly discussed, along with the use of AI for diagnosis and rehabilitation services. We are sure that this chapter will attract the attention of those working in healthcare centers where innovation plays a crucial role. This technology will continue to fill the gap between the patient and doctor in critical situations.

Keywords: AI, IoT, healthcare, patient, doctor, technology

22.1 Introduction

The internet has become part of our daily lives. In the early stages of the internet, it was used for communication among people in the form of emails, voice calls, video calls, etc. With the advancements in technology, now most electronic devices have become very smart. A device which works with the internet is commonly known as a smart device. Now the devices which are connected through the internet are operated from anywhere without any boundaries towards the operating location. The basic architecture of IoT is shown in Figure 22.1 [1].

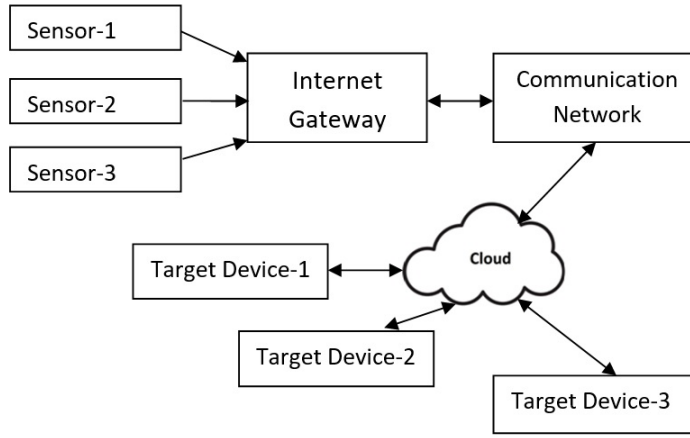

Figure 22.1: Basic architecture of IoT.

As seen in Figure 22.1, sensors are the devices that collect data and send it via an internet gateway to reach the cloud. A gateway is a device that acts as an intermediate node between the communication network and sensor network. Communication network provides real-time information sharing. But, a reliable and secured connection has to be ensured. The cloud is a storage device where the user data is saved in the service provider memory. Then the data can be accessed by the intended people, who have the authorization over the cloud. With the rapid growth in technology, such as manufacturing smart devices and the availability of high data rates on the internet, IoT has changed its perception of real-world applications. Now, most of the global fields are dependent on the internet. The usage of the internet has lifted the boundaries from mail usage to unlimited applications. At the earlier stages of IoT, researchers targeted the operation of a few devices like fans, air-conditioners, and geysers. Now, the IoT covers almost all the areas of research mentioned below.

The key applications for the IoT are in the following areas [2]:

1. Smart home
2. Agriculture
3. Industry
4. Transport
5. Education

6. Retail market
7. Manufacturing
8. Military
9. Environmental monitoring
10. Energy management
11. Healthcare.

The most important field of application of IoT is healthcare [3]. In the next section the main focus is on IoT in healthcare applications.

22.2 Literature Review

One of the most important fields in any country is healthcare. Most of the healthcare systems are traditional, wherein patients visit the hospital. Based on the patient symptoms, the appropriate tests are done for the diagnosis of the disease. Thee basic evaluation parameters of a patient, such as heartbeat, blood glucose level, and blood pressure, are measured with the help of traditional methods such as a stethoscope, one touch glucometer and blood pressure monitor. These tests are done when the patient feels ill and sometimes the patient's health condition becomes critical. Under critical conditions, there is a possibility the patient will die because of not detecting the symptoms earlier.

Huang and Cheng [4] proposed a system which uses 2G network, sensors, Bluetooth and Zigbee to transfer data. Here, the system supplies drugs for the patient.

Xu and his team [5] proposed a method for a patient health monitoring system based on cloud computing, which is cost effective.

Ghose *et al.* [6] proposed a system for monitoring the health condition of elderly people. This system only monitors the patient's condition and decisions are made with this system.

22.3 IoT in Healthcare

One of the most important things in human life is health. Most governments place a priority on healthcare and education. Due to food habits and environmental conditions, people are facing a lot of health issues.

If any person is admitted to a hospital due to severe health issues, then the patient will be physically monitored. Based on the diagnosis results, appropriate treatment is carried out on the patient. With the growth in technology, patient monitoring [7,8] has become an easy task, in which sensors are connected to the patient and the corresponding data is retrieved from the database. The data is processed and if any adverse effects are identified, an immediate alert will be given to nurses and doctors, where a quick response can be expected to save the patient's life.

The major advantages of IoT in healthcare are:

a. Reduction in cost: Since IoT devices are used by the patient, it enables the monitoring of the patient in real time, thereby reducing the patient's stay in the hospital and also reducing frequent visits by the doctor during the stay in the hospital.

b. Faster diagnosis of disease: With real-time data on the health condition of a patient, it is easy to diagnose a disease at the early stage.

c. Better treatment: Because of the early detection, it is easy for doctors to give better treatment.

d. Fewer human errors: With the help of IoT devices, it is possible to get effective data and thereby avoid the possibility of misreading patient data.

e. Continuous observation: With the help of the IoT, it is possible to regularly monitor the patient's condition without a physical appointment.

22.3.1 IoT Applications in Healthcare

The most popular applications of IoT are:

- Blood glucose monitoring
- Blood pressure monitoring
- Heart rate monitoring
- Temperature monitoring
- Depression monitoring
- Asthma inhalers
- Smart contact lenses
- Robotic surgery

22.3.2 Blood Glucose Monitoring

If the blood glucose levels are above normal limits, it causes a diabetes mellitus (DM) metabolic disorder [9]. Lack of enough insulin in the body will induce diabetes. Insulin controls the glucose levels in the blood. As per World Health Organization data, more than 500 million people are suffering from diabetes.

There are two types of diabetes. The first one is Type-1, which usually develops in teenagers and young adults, as well as in children. Type-1 is due to the loss of insulin. Type-2 usually develops in the elderly due to defects in insulin secretion. This diabetes can be monitored with the help of invasive, non-invasive, and minimally invasive monitoring systems. With the advancements in technology, sensors are available that have made it easier to continuously monitor glucose levels. A sensor that is used to measure glucose levels is shown in Figure 22.2.

Figure 22.2: A sensor to measure glucose levels.

The complete setup for getting the patient glucose levels from the sensor to the doctor's phone is shown in Figure 22.3.

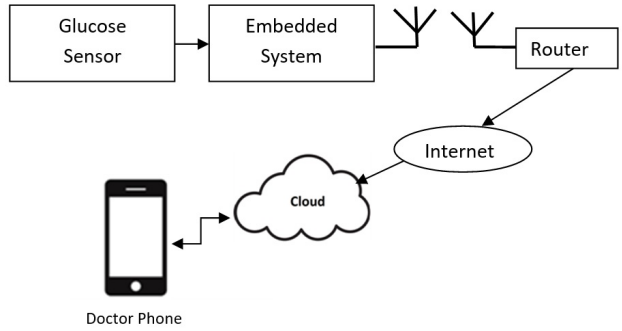

Figure 22.3: Setup for getting patient data from the sensor to the doctor.

22.3.3 Blood Pressure Monitoring

One of the important parameters that is used to indicate the physiological information of a human body is blood pressure [10]. A number of devices are developed to measure blood pressure. The continuous measurement of blood pressure is desirable for home healthcare or easing the workload of clinicians in hospital settings. There are various noninvasive techniques to measure blood pressure. These methods are either continuous, such as plethysmography, arterial tonometry, and pulse transit time methods; or non-continuous, such as oscillometric and auscultatory methods.

Figure 22.4: Wearable blood pressure sensor.

Wireless blood pressure devices are available on the market, and one such device is shown in Figure 22.4 [11]. This is a highly accurate blood pressure sensor that is worn on the arm, as shown in Figure 22.5. It reads the data and sends it to the cloud through a wireless modem. Finally, the data can be seen on the mobile screen.

Figure 22.5: Blood pressure sensor fixed to arm.

22.3.4 Heart Rate Monitoring

These days, cardiac arrest has become a major concern [12-22]. With the advancement in technology, smart wearable devices are connected with the internet of things (IoT) in order to provide a solution for heart patients. In the past, cardiac arrest only occurred in older adults; now, in the present generation, it has been seen in teenagers also. For children below the age of 17, the resting heart rate is between 65 and 115 beats per minute (bpm); in adults between the ages of 17 and 60 the resting heart rate is 60 to 100 bpm; whereas in adults over the age of 60 years, their heartbeat rate is between 65 to 120 bpm.

The wireless heart rate monitoring device is shown in Figure 22.6 [23] and the way it is placed on the body is shown in Figure 22.7.

Figure 22.6: The wireless heart rate monitoring device.

Figure 22.7: Placement of wireless heart rate monitor.

22.3.5 Temperature Monitoring

The normal body temperature varies from person to person based on age. The accepted body temperature is in the range from 97 °F (36.1 °C) to 99 °F (37.2 °C). To measure the temperature and send it wirelessly, a number of sensors are available. One of the most useful sensors which is in the form of a patch is shown in Figure 22.8 [23]. It is capable of sharing real-time data with the server through the internet.

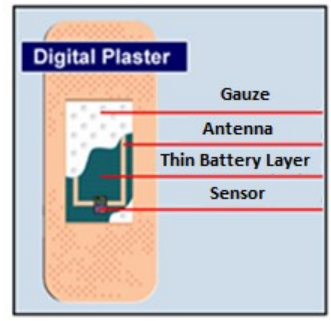

Figure 22.8: A wireless plaster for temperature monitoring.

22.3.6 Depression Monitoring

Around 25% of the world's population is affected by depression [13] annually. Those who are depressed experience psychological difficulties as well as physical symptoms, which may also lead to higher rates of suicide. As a result, depression has become an important public health issue. But identifying the symptoms of depression is not a straightforward process. To find the stage of depression, healthcare professionals go through a series of conducting interviews as well as self-report questionnaires. But regrettably, these methods take a lot of time, are pricey, and professional involvement is also required. These can be eliminated with the help of smart devices and the complete setup for depression monitoring is shown in Figure 22.9.

Figure 22.9: Depression monitoring equipment.

With the help of the above setup, the daily activity of the patient is identified. Based on the reports generated from it, appropriate action will be taken. It also saves lives of patients who are critically depressed and at high risk for suicide.

22.3.7 Asthma Inhalers

Asthma is a respiratory disease [14], which is similar to chronic obstructive pulmonary disease (COPD). It is caused by factors such as air pollution, active or passive smoking, exposure to certain chemicals or fumes, etc. As per the data of the World Health Organization (WHO), COPD will become the third leading cause of death worldwide by 2030. This has driven the market for digital respiratory devices, which include both therapeutic (inhalers, nebulizers) and diagnostic devices (see Figure 22.10) [24].

Figure 22.10: Smart asthma inhaler.

The purpose of a smart inhaler is to help patients and their doctors monitor adherence and other treatment factors.

22.3.8 Smart Contact Lenses

A smart contact lens [15] can be used as an excellent interface between the human body and an electronic device for wearable healthcare applications. Despite wide investigations of smart contact lenses for diagnostic applications, there has been no report on electrically controlled drug delivery in combination with real-time biometric analysis. A smart contact lens is shown in Figure 22.11 [25]. Although it is mainly used to detect the glucose levels, it will also find application in smart vision.

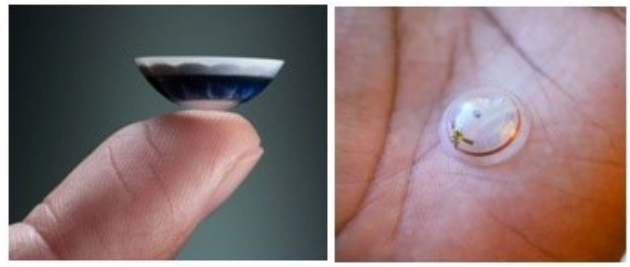

Figure 22.11: Smart contact lens.

22.3.9 Robotic Surgery

Robots have become a focal point in the healthcare and medical industries, where they are performing their duties using electronics and mechanics [16]. These are used for the force or movement measurement or domain, sensor system technology, etc. The duties that are performed by robots are:

- Patient care
- Rehabilitation
- Artificial prosthetics
- Medical interventions
- E-health monitoring

The involvement of robots in surgery is shown in Figure 22.12. Robotics and healthcare automation in the IoT-based healthcare industry allow multiple robots to be interconnected. The IoT platform offers distinctive facilities by interconnecting objects or people and transferring those data between the two robots – without human-to-computer or human interaction. Most advanced surgeries are done by robots with the support of humans.

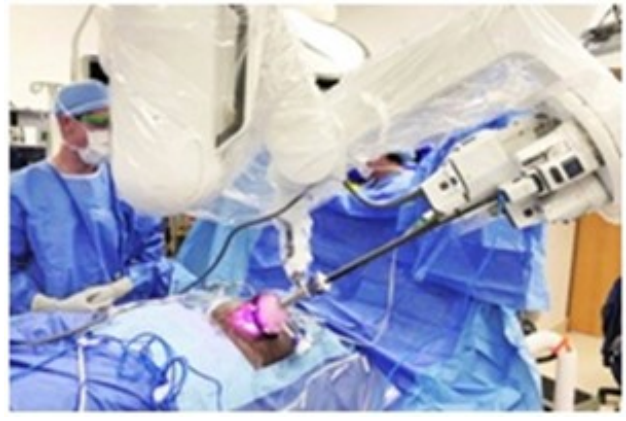

Figure 22.12: Robotic surgery.

Though there are numerous applications available, there are a few challenges [17] related to implementing IoT in healthcare, which involve:

1. Reliability of the internet: Make sure that there is always a connection between the sensor device and the target device (doctors).
2. Device-to-device connectivity: It is very important that the connection from one stage to another stage is properly connected and communicated.
3. Resource management: Involves resources like data storage, processing, and their corresponding devices.
4. Data processing: How the data is transmitted from the sensors and is stored in the cloud and how the data is being processed for further action is very important.
5. Security: It is very important to use encryption and decryption techniques to provide security.

22.4 Role of Artificial Intelligence in Healthcare

The most popular research trend is artificial intelligence (AI). It has made machines think and act like humans. Nowadays, most of the research scholars, scientists, academicians, and those in industry are working together towards a tremendous change in the area of artificial intelligence. This is mainly possible by understanding how humans think, behave, learn, and solve problems. In order to make machines think like humans, it is necessary to develop intelligent software as well as systems. Although the goal of AI is to simulate human intelligence in machines that are programmed to think and act like humans, it's a difficult process to understand and achieve. In order to develop AI, several areas of science need to contribute, which are:

- Computer Science
- Maths
- Neuron science
- Biology
- Sociology
- Psychology
- Philosophy

In AI, along with major areas, it is necessary to understand intelligence. Artificially intelligent systems have the ability to store and retrieve data from memory, speak language, write, see, calculate, react, mimic emotions, solve problems, get ideas, think, and so on. Intelligence mainly consists of

- Learning
- Reasoning
- Problem-solving
- Perception

- Linguistic intelligence

The major difference between human intelligence and machine intelligence is that humans are able to store and recall information with the help of patterns, whereas machines need a set of rules and data.

Applications of AI: The most popular applications of AI are in

- Healthcare
- Data security
- Retail
- E-commerce
- Chatbots
- Robotics
- Education
- Transport
- Agriculture
- Finance
- Gaming
- Astronomy
- Entertainment
- Automotives
- Social Media

Here, the discussion is confined to the application of healthcare. AI will help to diagnose disease faster than humans and with more accuracy. Based on the results, the system will help the patient receive early treatment by giving a warning. This is possible with artificial intelligence. Artificial intelligence has found major applications [18] in the following areas of healthcare:

- Diagnostic imaging
- Genetics
- Electrodiagnosis
- Disability evaluation
- Nervous system disorders
- Cardiovascular disease
- Digestive disorders
- Dermatology

In order to detect the disease, artificial intelligence uses a various machine learning algorithms such as,

- Support vector machines
- Neural networks
- Hidden Markov
- Linear regression
- Logistic regression
- Random forest
- Nearest neighbor
- Decision tree

With the help of the above machine learning algorithms shown in Figure 22.13, AI devices analyze data such as genetics, imaging, and other information. With the help of natural language processing, it extracts information such as clinical notes. The most widely used machine learning algorithm is the support vector machine.

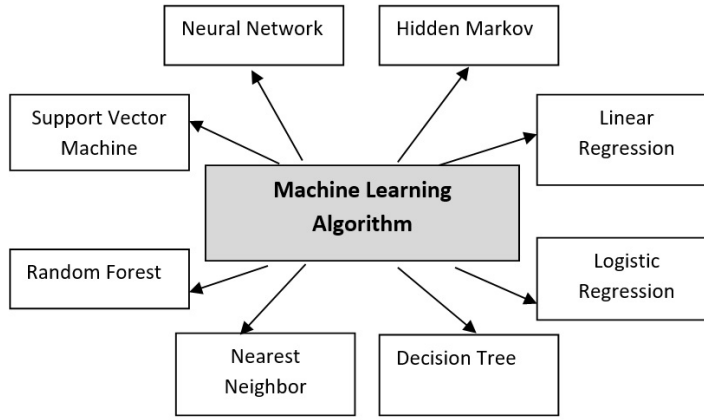

Figure 22.13: The machine learning algorithms used in AI.

The reason to go ahead with artificial intelligence is that administration is very difficult in healthcare and clinical support. In the case of healthcare administration, if a patient comes to the hospital, then the data will be entered into the system. If the patient repeatedly comes to the hospital, then the complete data will be available in the system. With the help of AI, it is very useful for clinicians to access the patient data and track the patient's condition. It is even possible to accurately detect the disease with the help of advanced machine learning algorithms. It also helps to make decisions in clinical reports. Systems with preloaded clinical data and knowledge are able to reduce medical errors and improve the efficiency and consistency of clinical reports for healthcare professionals [19]. This AI system in medical reports has been used since the 1970s. With the advancements in AI systems, it has become much easier and effective to diagnose a disease and to warn the patient at earlier stages, thereby saving the lives of patients. With AI, aspects of a patient's

health will be monitored such as sleeping patterns, blood pressure, heart rate, etc. AI makes use of the machine learning methods for the use of personalized medicine, patient monitoring, drug discovery, and patient record management.

Artificial intelligence is combined with IoT, as shown in Figure 22.14. AI is used for diagnosis and to give accurate results of the disease. Therefore, it becomes much easier for doctors to understand the current position of the patient and to give better treatment. This is possible with the preloaded data about all the diseases.

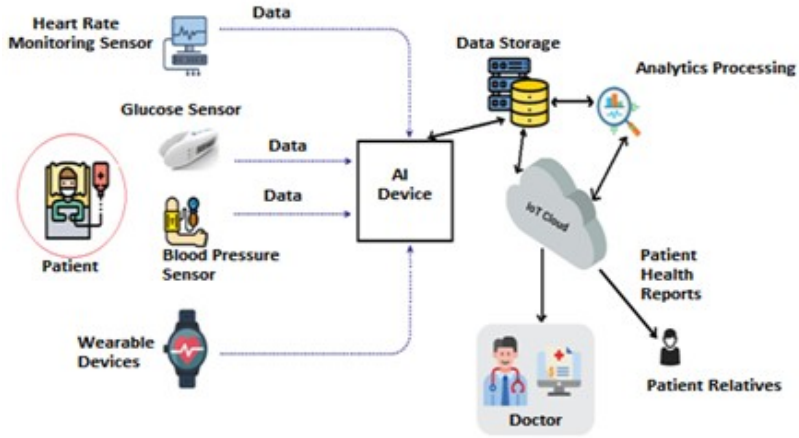

Figure 22.14: AI with IoT.

The role of AI is to collect data from the patient sensors and process it using machine learning and natural language processing. The data is stored in the cloud permanently. Based on the patient data, it will generate information on the disease and the current level of criticality. If IoT gets added to AI, it gives a real-time alert to the doctors, as well as the patient's relatives, about the patient's condition. For example, if a heartbeat sensor gets connected to the patient, if there is any abnormality in the heartbeat it will be detected by AI. Then an alert will be sent to the doctor as well as patient's relatives with the help of IoT. Therefore, it becomes easy for the doctor to give appropriate treatment at the right time.

In addition to technological developments, there are still some challenges associated with the use of AI and the IoT in healthcare, such as

1. Retrospective vs. prospective studies
2. Peer-reviewed randomized control trials as an evidence gold standard
3. Metrics often don't reflect clinical applicability
4. Difficulty in comparing different algorithms
5. Challenges related to machine learning science
6. Dataset shift
7. Accidentally fitting confounders vs. true signal
8. Algorithmic bias

22.5 Challenges of IoT in Healthcare

The major challenges of IoT in the healthcare system are:

1. Prototype development: It is a difficult task to develop a prototype that suits the intended application with the necessary sensors. Based on the structure of interconnection, it will decide the effective communication between the sensor information along with the simulation.

2. Authentication: It is necessary to provide authentication in order to verify the information that has been stored for a patient.

3. Robustness and flexibility: The system has to be robust as it is to provide a steady behavior of the intended system. At the system time, the system has to be flexible for the real-time changes in the architecture and communication among the devices.

4. Data transmission: All the sensors read the information and transmit it to the central control unit. In order to transmit the data to the control unit, it is necessary to ensure it has been received without any sort of noise addition.

5. Cost: Due to the increased number of sensors that require high-speed internet, a good controller along with an efficient algorithm, the implementation cost also increases.

6. Connectivity: Here the entire communication among the sensors and controller is based on reliable connectivity. A lost of connectivity could result in death.

7. Data Storage: In order to store the information received from the sensors, a large storage capacity is required. One option for this is to use cloud services.

8. Privacy: There are more chances for the IoT devices to be attacked in the IoT environment.

9. Energy requirements: If more devices are connected to the environment, devices consume a greater amount of energy.

10. Integrity: It is very important that how the sensors and other equipment are connected for effective communication among them without any disturbances.

22.6 Conclusion

The internet of things (IoT) will continue to be a major support in healthcare in the future. Here, it can be concluded that the IoT in healthcare is trying to fill the gap between patients and doctors. At the same time, effective and efficient monitoring of the patient is possible with the technology, whereas it may not be possible with human involvement. Diagnoses also become more accurate and it is easier to identify the disease. In the future, it is expected that smart devices will continue to take care of patients. In addition to this, AI will play a crucial role in detecting the disease and understanding the critical care level of the patient. Combining both technologies will result in detecting medical problems of patients with more accuracy for better treatment. Therefore, in the next few years, we can expect the use of AI with the IoT in healthcare.

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