AI and IoT Enabled Smart Hospital Management Systems

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Abstract With the rapid increase in the advancement of different methods and technologies, efficient and optimized solutions have been introduced for providing support in the healthcare sector. With the steady increase in the population, smart healthcare system requires optimized data management algorithms for storing various data that is collected from various applications and sensors. For obtaining these objectives, integration of such modern techniques including artificial intelligence, the Internet of Things, machine learning, etc. becomes a mandatory step in developing smart hospital-based services. Artificial intelligence-based robots for surgery and diagnoses of various medical imaging are providing better results over time for smart hospital systems. IoT-based temperature management systems, sensors for checking the health of instruments, and many more applications are available for the smart hospital management system. Researchers are now becoming more penchant toward the smart hospitals, cities, etc. based development domains and have proposed various architectures which contribute to the same. These modern techniques are solving major chunks of problems in a faster way by providing good results and more facilities when compared to aged techniques. In this paper, the main focus is to provide various aspects and factors of AI and IoT-based smart hospital systems and the role of AIoT in the growth of the modern world as a combination of these niche areas is giving outstanding results in the field of healthcare. We also provide various hurdles which are encountered during the development of smart hospital management systems.

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1 Introduction

Artificial Intelligence and the Internet of Things (IoT) are the most popular and enhanced technology in today's society, contributing to almost all domains from medical to home security systems. Nowadays, everyone is in search of convenient methodologies and better service with proper instructions and it is the point where IoT comes into play and acts as a crucial pillar for the enhancement of today's working of smart hospitals and other workstations. The use of IoT, cloud services, AI, and ML-based techniques can be seen in every workstation all over the globe including smart hospitals and other intelligent search-based applications. The Internet of Things [1] refers to the system or objects that are fully functional and operable via the Internet. For instance, we can consider a weather monitoring system where data is generated and collected via various sensors which will be beneficial for managing thermostats of any public infrastructures, cutting emissions, and many more. Artificial intelligence [2] is also a crucial part of modern technologies as it helps in developing a thinking ability of a machine and makes it capable to think, decide and learn. AI is helpful in the sector of healthcare by providing facilities for AI-assisted robotic surgery [3], nursing assistant [4], and decision-making like diagnosis and prediction of diseases [5].

The combination of these niche areas is efficiently solving major chunks in various domains namely the medical sector, financial sector, and other industrial sectors. Interaction between homo-sapiens and machines is enhancing day by day with the help of artificial intelligence of things (AIoT) [6]. Technologies that are getting contributions from these domains are achieving better data management, protection, analysis, data gathering, and the closest step toward efficient human–machine interaction. In the field of healthcare AIoT is providing various smart facilities like improvement in accuracy of diagnosis of disease, remote patient monitoring, reduction in needs for follow-up visits, reduction in wait times in smart hospitals by tracking bed-tracking system, and identification of critical patients who are suffering from some critical diseases and disorder. The development of various advanced machines like CT scans [7], CXR scans, and maintenance of records plays a vital role in the field of healthcare. Diagnoses of various diseases like breast cancer [8], lung cancer [9], and liver disease [10] are getting easier with the help of various AI techniques. Figure 1 shows the combination of AI and IoT which results in AIoT.

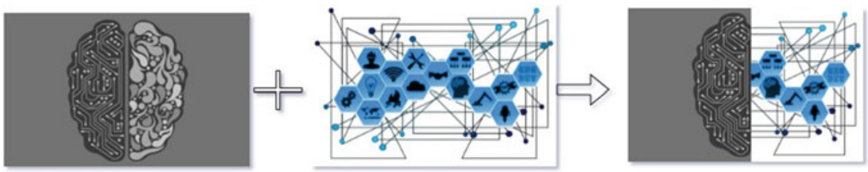

Fig. 1 Combination of AI and IoT

The healthcare system in India needs a major improvement in terms of system and management. Modern techniques like artificial intelligence and the Internet of things play an important role in the field of healthcare by optimally providing modern solutions. Optimized and efficient diagnosis of various diseases like retinal disease [11], breast cancer, diabetic retinopathy [12], lungs cancer, tuberculosis [13], and many more are possible in optimal time with less error by using smart and modern methodologies. Hospital environmental section is getting contributions from the Internet of Things where various sensors are playing an important role in maintaining temperature, humidity, and air regulation. Hospital assets are getting a predictive maintenance system for proper analysis and tracking of all the devices and machines.

The modern medical-related problem is getting solved efficiently with the help of Artificial Intelligence and the Internet of Things. With advanced technologies and introduction of smart hospital management systems, medical cases can be reduced. In the current scenario of the COVID-19 smart hospital management system worked efficiently by handling a large number of cases. The upcoming of the chapter is categorized in the following manner: 2. Literature Review, 3. Contribution, 4. Evolution of Artificial Intelligence with sub-domains and applications 5. Evolution of Internet of Things with its importance and various use cases 6. Combination of Artificial Intelligence and Internet of Things with their practical usage in healthcare 7. The smart hospital management system will discuss how these modern techniques are contributing to the field of health care.

2 Literature Review

With the steady development in the medical fields and advancements in technology, researchers have been presenting their work on the concept of smart cities, hospitals, etc. With the use of AI and IoT technology, tons of information can be analyzed by AI-based algorithms and can provide accurate results saving a lot of time and effort. Researchers have been working in the field of smart medical rooms and have proposed various architectures which help in patient monitoring and other analysis which can be found very helpful for their treatment process.

The study presented by Alharbe et al. [14], used Fuzzy-Delphi analytical hierarchy process for the evaluation purposes of various factors including the basic usable security, considering six different important factors. The combination of Fuzzy-Delphi with the analytical hierarchy process leads to an efficient diagnosis of various factors during the development of smart hospital-based systems. Many researchers have reviewed and analyzed various advanced technologies and algorithms which are found to provide exceptionally accurate and efficient results for maintaining and managing facilities of smart hospital systems. Another study was presented by Lakhoua et al. [15] where authors reviewed and analyzed various advanced techniques which are found to be helpful in the maintenance and management of smart hospitals. The paper was more penchant toward the applications based on IoT like SADT methods, UML, GRAI, GIM, etc. With the steady increase in the use of advanced technologies and integration of these applications in the medical sector, AI and IoT have proved to be the most efficient techniques for making resources automatic and customized depending upon the environment they are used in. The study presented by Lin et al. [16] used AHP (Analytical Hierarchy Process) combined with MCDM (Multiple Criteria Decision Making) was used for providing a better evaluating criterion for smart hospitals during COVID-19 where there were mapped with BIM-related alternatives for information regarding asset information management practices.

A novel model was proposed based on Smart Hospital Management Systems by Kunar et al. [17]. The authors proposed a model focusing on a smart hospital information management system that runs by using hybrid cloud, IoT, ML, and AI-based applications. Apart from the hospital perspective, the model provided benefits to the patients as well. The model will be self-sufficient and will act as an assistant to both patients as well as the administration sector. The model will not require manual support and will be beneficial for the medical sector in long term. Bender et al. [18] provided detailed information about smart pharmaceuticals. The authors discussed various aspects of pharmaceuticals and how they can be used for providing advanced devices which are used for respiratory diseases. The study talks about the potential impacts of smart pharmaceuticals and technology that can help in the improvements. A similar study was presented by Islam et al. [19], where authors present a novel model for healthcare systems in the IoT environment that can effectively monitor patient's movement for better treatment processes. The model will also be able to provide a customized experience for the patients. The model transmitted collected data to the main server for analysis and other authentications. For this various hardware devices were used namely heartbeat, body temperature, room temperature, CO, etc. sensors. The error percentage was limited to less than 5% for every case.

The study presented by Kumar et al. [20] proposed a novel approach for generating waveforms like Non-Orthogonal Multiple Access (NOMA), Universal Filter Multi-Carrier (UFMC), and Filter Bank Multi-Carrier (FBMC) systems. Various parameters were considered in the experiment for analyzing purposes. These parameters included power spectrum density, bit error rate, capacity, Peak to Average Power (PAPR) of advanced waveforms, and Orthogonal Frequency Division Multiplexing (OFDM) methods. All these techniques were based on the development of smart hospital systems over 5G networks. Another work was presented by Amudha et al. [21], where authors proposed a system embedded with optimized and beneficial methods to predict future events based on the observations. A new framework was presented for contributing to the smart hospital management systems with the integration of intelligent decision-making, data fusion, and prediction algorithms using machine learning concepts. The authors explained various IoT-related layers including resource, communication, application, etc. layers. The chapter also explains various protocols that are used in IoT for achieving a smooth communication system. Smart automation of health monitoring frameworks and the use of cloud services for managing databases were also introduced by the authors. Apart from the frameworks, the authors also talk about the challenges faced during the development of smart hospital systems and the use of deep learning models in analyzing the patterns in the disease from the information provided. A similar study was presented by Afferni et al. [22] where authors presented various methodologies for developing smart hospitals. The authors pointed out various key points that affect the patients which included complex organizational workflow, lack of integrated IT infrastructure in the laboratories, and other healthcare structures. The proposed framework was more oriented toward the patients' satisfaction levels. This was achieved by the interconnection of programmable collaborative robots, 3D printers which are connected to the developing servers, AR supporting the production process, etc. In our chapter, we tend to explain various other factors that contribute to the building up of smart hospital management systems and the challenges faced in the process.

3 Contribution

With the rapid growth in the fields of AI and IoT, the concept of smart cities, hospitals, etc. has become the major area for researchers. With our discussion in the chapter on the efficient and beneficial use of combined AI and IoT techniques for the development of *Smart Hospital Management Systems*. Our objective behind the chapter is to deliver various aspects by which Smart Hospitals can provide better healthcare facilities to the patients as well as staff members. Our main goals are described in the following points.

A. Detailed discussion about the evolution of Artificial Intelligence and the Internet of Things. We also present various challenges that are faced in developing such applications and their after-effects for the end-users.
B. We explore various smart management systems which include various architectures of hospitals, cities, etc.
C. Our chapter provides a proper evaluation of the limitations of all the different AIoT-based techniques.
D. Contribution of these integrated technologies in the domain of medical fields for providing advanced and customized healthcare environments to the patients.
E. Our major focus revolves around the concept of developing smart hospital systems with proper analysis and use of various technologies including RFID tags and other hardware devices.
F. Our end goal is to find a concrete path for developing a new concept of the medical systems unlike the traditional style of providing healthcare to its patients.

4 Evolution of Artificial Intelligence

From a normal medical ecosystem to a smart and intelligent medical ecosystem, artificial intelligence played an important role in its evolution. In the eighteenth century, artificial intelligence was a myth and fiction according to people but the evolution and development of technologies helped in the enhancement of machines

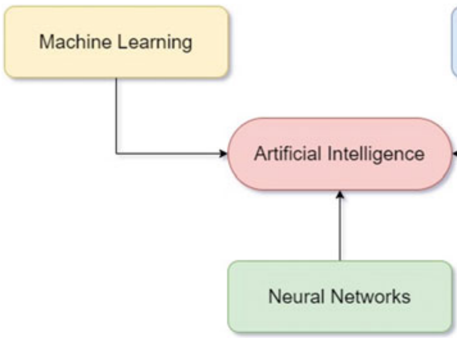

Fig. 2 Components of AI

by providing the ability to reason, making predictions, and analyze. Artificial intelligence is contributed by various sub-domains like machine learning, deep learning, and neural networks. From driverless cars to smart diagnosis of diseases is getting contribution from artificial intelligence. Artificial intelligence is the combination of 3 sub-parts, i.e., machine learning [23, 24], deep learning [25, 26], and neural networks. Figure 2 shows the formation of artificial intelligence with the help of all sub-domains.

I. Neural Networks
Neural networks are the basic component of deep learning which helps in the formation of a large network for understanding and solving large-scale problems in the healthcare system. Neural networks have proved to provide exceptional results in various domains namely fraud detection in the banking sector [27], medical sectors, etc. Artificial neural networks [28] are the basic component of neural network that is highly used for efficiently solving large-scale problems. These neural networks are based on brain-based neurons which are receiving input from one end and the output of the end works as input for other neurons. This full architecture leads to the development of fully connected layers which train them on various datasets like heart disease dataset [29], cholera dataset [30], and many more. With this advanced technique hospital management system is getting an upper edge in the diagnosis of various diseases. More accurate results are accomplished with the help of neural networks and which also results in low computational costs (Fig. 3).

II. Deep learning
Deep learning is a sub-domain of machine learning which contributes a major role in the field of artificial intelligence [31]. Almost every sector in the field of technology is getting contributions from deep learning. The healthcare domain requires high accuracy and precise results for the evaluation of results. So deep learning is essential for modern techniques to achieve high results. Smart hospital management requires an intelligent recognition system for the diagnosis of various diseases like brain tumors [32], ulcer detection

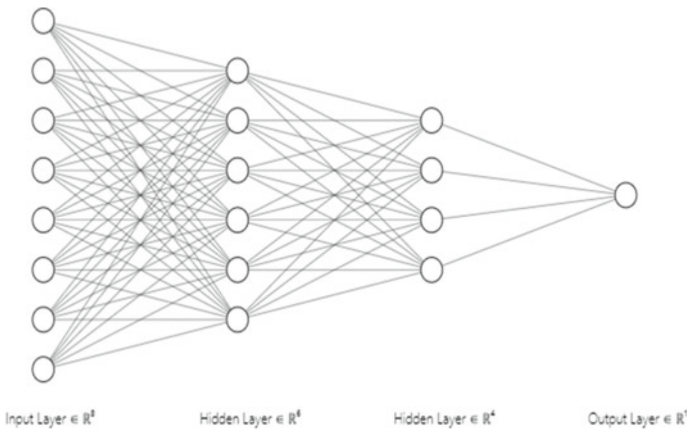

Fig. 3 The basic structure of neural networks

[33], lungs disease detection [34], ECG classifications [35], etc. Convolutional neural networks, recurrent neural networks, and transfer learning [36] are a few applications of deep learning which are helpful in the efficient diagnosis of various chronic diseases. Table 1 enlists various applications which require deep learning methods for the diagnosis.

III. Machine Learning
Machine learning is an important sub-domain of artificial intelligence. This domain enables the ability of the machine to recognize and analyze the various type of use cases. By the usage of various medical imaging techniques, several models can be developed for the proper analysis of diseases. Dangerous diseases like cancer, tumor, COVID-19 [37] can be easily diagnosed and recognized by a machine learning system where the models will be trained on various datasets for distinguishing several cases. Standard machine learning algorithms like Support vector machine, Decision tree, random forest, linear regression, logistic regression is beneficial for the prediction of various critical diseases like cholera, pneumonia disease [38, 39], cervical disease [40], heart disease diagnosis [41, 42] and many more. Figure 4 shows the basic algorithms of machine learning.

With the help of artificial intelligence, growth in the medical sector is increasing rapidly where advanced facilities like the proper diagnosis of disease, AI-assisted surgery robots, advanced machines for scanning like optical coherence tomography system [43], CT scans, and chest X-ray images, they all are advance techniques for diagnosis and detection of critical diseases. The assistance of robots for surgery, medical assistance are major applications of artificial intelligence. So, for more understanding regarding the role of AI in smart healthcare management, we are

Table 1 Deep learning-based applications

Application type	Deep learning method	Application	Input data
Medical image analysis and prognosis	Deep autoencoders Convolutional neural networks Deep belief networks	3D Brain reconstruction Neural Cells classification Classification of brain tissues	MRI scan Fundu image PET scans
	Deep autoencoders Deep neural networks	Tumor detection Cell clustering Organ segmentation	Microscopy CT image X-Ray image scan
Medical informatics	Deep autoencoders Convolutional neural networks Deep belief networks	Disease prediction Human behavior analysis Motion monitoring	HER sensor data Medical datasets Lab test reports/blood group
Public health	Deep autoencoders Convolutional neural networks Deep belief networks Deep neural networks	Predicting demographic information Lifestyle diseases Infection disease epidemics Air pollution prediction	Social Media data collection Metadata generated from mobile phones Geo-tagged images Test messages

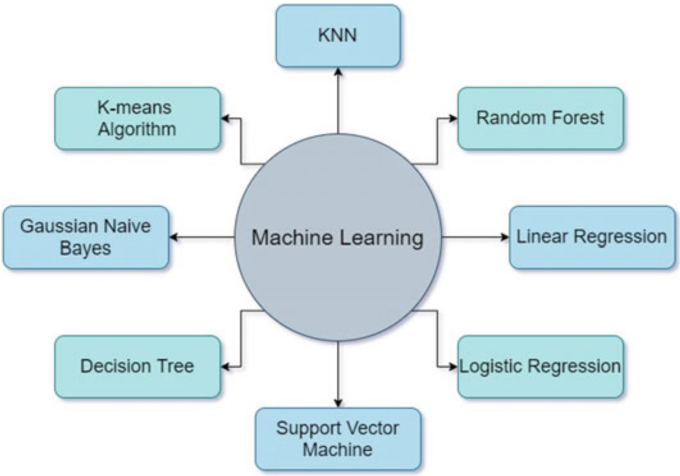

Fig. 4 Basic algorithms of machine learning

going to discuss various applications of AI in the field of health care. So, there are many applications of artificial intelligence in the medical field and a few of them have been discussed below.

A. Better diagnosis system
Healthcare requires high accuracy and precise results for the analysis of diseases. Earlier without these technologies diagnosis was time-consuming but with the help of artificial intelligence, it is a much more convenient and faster way to diagnose various chronic [44] and critical diseases. Using high-end machines for the detection of disease enables us to early diagnose of disease which will help in the reduction of repercussions. From chest X-ray to optical coherence tomography requires advanced machines for analysis of the disability. So, after reports, this medical imaging can be used for the classification and identification of patients with and without the disease [45]. With this early diagnosis, people can have their proper treatment at various medical centers. Artificial Intelligence will diagnose early but will also reduce computational costs and will save time.
B. AI-Based Surgery Robot
With the increase in the number of patients and less availability of doctors, AI-based surgery robots will play a crucial role in the medical field. These robots are highly trained in various surgery techniques like stitching, cutting, and many more. These operations can be easily performed by these AI-based robots who are under usage of reinforcement learning which analyzes and performs the best operation on various use cases according to the condition [46]. These robots are beneficial as normal operations and surgeries can be time-consuming but with the help of these technologies, we can save time with proper and fast surgeries.
C. Nurse Assistance
Artificial intelligence provides us the facility of assistance that is specific to the healthcare system [47]. With the help of this assistant people can easily have their basic treatment at home only. These assistants are trained with the help of components of machine learning, i.e., Natural Language Processing. These assistants can easily inform you about all the details about basic medication and services. So with the help of this assistance time consumption will be reduced and crowd gathering will be less. So with the help of these advanced methods smart hospital management system.

5 Challenges Faced by Artificial Intelligence

Many challenges are faced by artificial intelligence in today's real-world problems and a few of them are listed below:

- High Computing Power—Artificial Intelligence requires a high computer station for carrying out operations. Advance CPU/ GPU is required for high performance. Researchers/ workers need to maintain that computational cost is low for a given task.

- Deficiency of Trust—Major reason behind worry is due to an unknown pattern of working of the AI system. Many researchers find difficulty in finding the working pattern of AI devices.
- Less Knowledge—many peoples don't know the original potential of artificial intelligence.
- Higher accuracy with Human-Level Analysis—Machines can achieve the highest accuracy early at 95–99% but human analysis can be fully correct when compared with machines.
- Data Privacy—Data used are public and they can be used for various harmful purposes.
- Biasing Problem—The dependency of a machine is fully on the trained dataset. Dataset needs to be balanced for proper working and analysis via any workstation.

6 Evolution of Internet of Things

Internet of Things is a major component of modern technologies starting from smartphones to smart toothbrushes. An ecosystem where all devices are interconnected and transportation of data through a wired or wireless network leads to a smart IoT system. Figure 5 shows the basic structure and conversion of data for IoT systems. These generated datasets are further processed and to a cloud environment where various instances and insights are observed and decision-making takes place. From small areas like smart homes [48], smart toilets to large areas like smart hospitals [49], smart malls, and many more are focusing on an IoT-based ecosystem.

These smart devices are an important part of our lives where they help in decision-making by providing various suggestions and recommendations. These recommendations are beneficial as they help in giving an optimal solution for efficiently solving problems. Internet of Things is providing benefits on a large scale as most of the infrastructures and big giant companies are concentrating on the benefits of customers

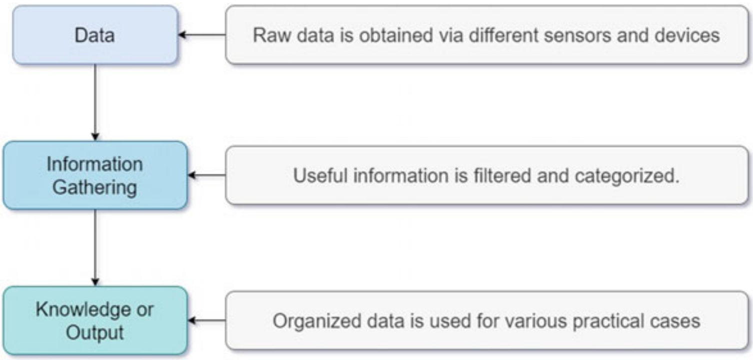

Fig. 5 Basic structural and conversion of data for IoT system

so IoT is a convenient tool for building up a better and healthy connection between servers and clients. Though IoT is not been an early bird since 1982 IoT is a crucial part of homo-sapiens. ARPANET [50] was the first connected network that used IoT and we can also call him the grandfather of the Internet and this led to the initial growth of the Internet of Things.

Internet of things is having a wide range of practical applications like.

(a) In-home—
   a. Smart Lighting [51] for saving energy by adapting conditions and auto function of switching on/off according to need.
   b. Smart Appliances like smart television, refrigerators, music systems, and washers/ dryers, etc. Smart thermostats for controlling the room temperature.
   c. Intrusion Detection [52] is like security cameras and sensors to detect abnormal activities and raise alerts according to situations.
   d. Smoke/Gas Detectors [53] are installed in the home for detection of leakage of gas or detection of fire

(b) In Industry—
   a. Machine diagnosis and Prognosis for analyses of the performance of a machine by the implementation of various operations on data for estimation of various use cases under different conditions.
   b. Indoor air quality monitoring [54] in factories is important for the health and safety of workers.
   c. Indoor temperature monitoring system [55] for maintaining and monitoring the temperature of working areas.

(c) In Energy—
   a. Smart Grids are data communication networks integrated with the electrical grid for collecting and analyzing data related to plants.
   b. Renewable Energy Systems for detection of an imbalance in the ecosystem by maintaining the proper supply.
   c. Prognostics for verification of all the machinery parts whether they are working inappropriate manner or not [56].

(d) In Retail—
   a. Inventory Management [57] for analyses of understocking and risk of expenses and loss according to various conditions
   b. Smart Payments like Paytm, BHIM for contactless payment and transferring sums of money and bounties virtually
   c. Smart Vending Machines [58] is responsible for the management of inventory and providing elastic pricing of products.

(e) In Logistics—

a. Route generation and scheduling system for generation of the dataset and collecting from various sources that will be beneficial for upcoming consumers.
b. Fleet tracking [59] is used for tracking the vehicles which are used as logistic delivery vehicles by the usage of GPS technology.
c. Shipment monitoring allows having a diagnostic look according to the condition of the transportation system
d. Remote vehicle diagnostics [60] is used for the detection of a fault in delivery vehicles

(f) In agriculture—

a. Smart irrigation system [61] for watering the crops by saving water and supplying the required water at a stipulated time.
b. Greenhouse control for monitoring the condition and performance of growth of plants in greenhouses.

(g) In environment—

a. Weather Monitoring [62] system for gathering information regarding climatic change and predicting the weather of upcoming days
b. Air Pollution monitoring system [63] monitors the quality of air present in the atmosphere by comparing the percentage of all the gases present
c. Noise pollution monitoring for checking and diagnosing the frequency and decibel value of sound and categorizing it into various categories.
d. Forest Fire monitoring [64] enables to have an alert on increment and decrement of temperature which can lead to fire forest and sensors for analyzing the fire.

So, from the above points, we can notice that the Internet of Things is widely used and it is one of the flexible technologies which can be easily used and integrated with other niche areas like machine learning, deep learning, and artificial intelligence. Figure 6 shows the characteristics of IoT.

So, from all of the above discussion, we can say that the Internet of Things plays an important role in day-to-day life as it is contributing to almost every domain. Internet of Things (IoT) is helping a lot in the healthcare system by contributing to the smart hospital system. By using various monitoring systems in smart hospitals IoT provides a facility to track all the information regarding the patient's health by using various sensors for checking conditions. IoT enables us to track the health of all instruments used in surgery and are helpful for medical purpose. By usage of IoT on a large-scale healthcare is getting an edge over old techniques. Structural health monitoring of the environment of the hospital is also an application of IoT. Figure 7 shows the evolution of IoT.

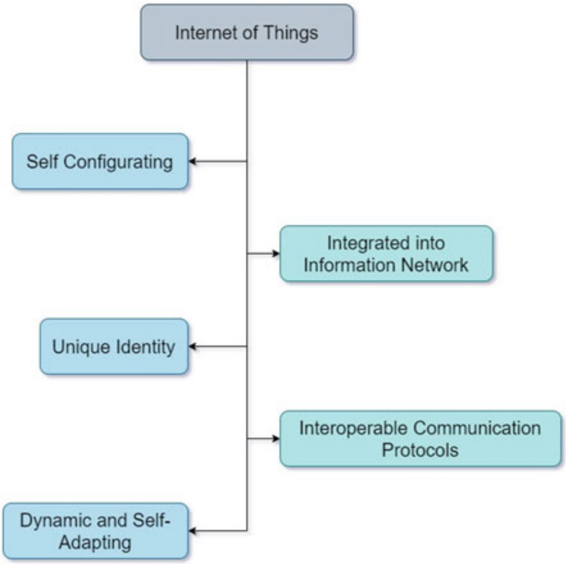

Fig. 6 Characteristics of Internet of Things

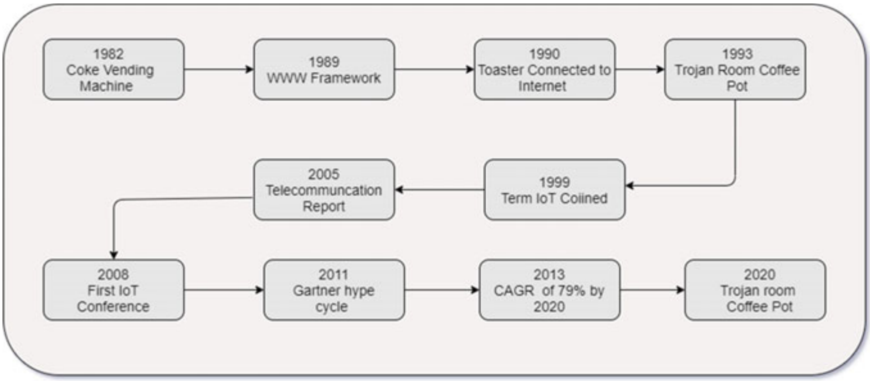

Fig. 7 Evolution of Internet of Things

Internet of Things has rapidly made a change in the lifestyle of human beings. From early 1982 till 2020 Internet of things has contributed and enhanced various domains and especially the healthcare system has received major up-gradation. So the Internet of Things has various interfaces for connecting with other devices where they can be either wired or wireless.

a. Connectivity Interface—USB Host, RJ45/ Ethernet
b. Processor/Graphics—CPU/GPU
c. Audio/Video Interface—HDMI, 3.5 mm audio, RCA

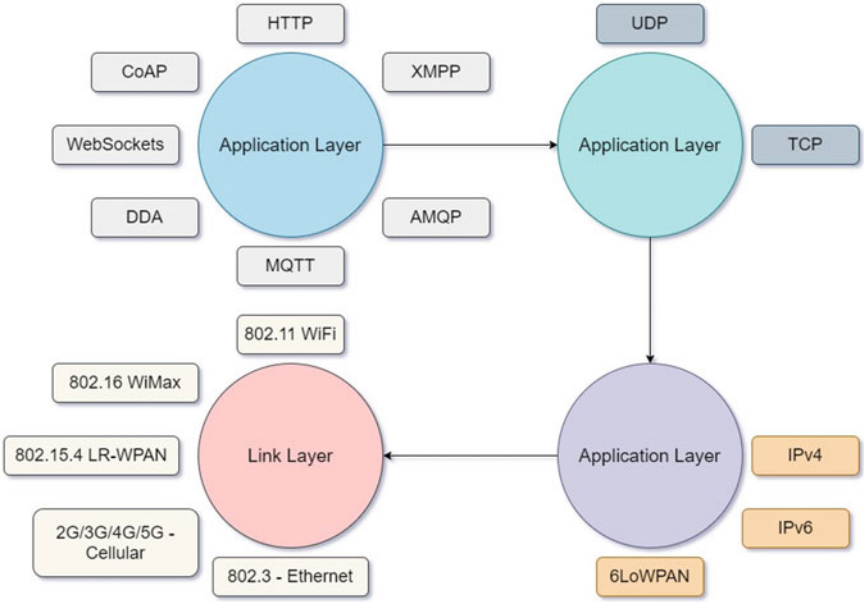

Fig. 8 Protocols of Internet of Things

d. Memory Interface—NAND/NOR, DDR1/DDR2
e. Storage Interface—SSD, MMC, HDD, SD
f. Input/ Output Interface—UART, I2C, CAN

These are the generic part of the interfaces of the Internet of Things. IoT is a vast field which is having a wide range of applications. Smart hospitals are having a smart analysis feature for tracking various instruments, health check-ups on all the instruments.

IoT helps us by keeping the track record of various medicines by having a detailed record from their manufacturing date till their expiry date which helps in marinating a hygienic and smooth operating of smart hospitals. Figure 8 shows the IoT protocols.

7 Challenges Faced by the Internet of Things

Internet of things is a vast field so it also faces some challenges which are quite important for providing better facilities. A few of the challenges are listed below:

1. Security Issue—Generation of large data expands the chance of cyber-attack and data leaks.
2. IoT regulations—Standard and quality data collection at regular intervals is necessary.

3. Compatibility—The compatibility of IoT devices requires regular updates and patch notes.
4. Bandwidth Limit—IoT requires Internet every moment for updating and monitoring data.

8 Smart Hospital Management System

With the rapid development in the medical industry and technology, patient care and satisfaction have reached new limits. The concept of SHMS comes from the optimization of file management and automation of various functionalities required by the authorities. The objective is to improve the traditional methods of storing data, treatment process, and manual analysis of various reports. Now, apart from the proper hygiene and other basic requirements, patients are more penchant toward the easiness and comfort while diagnosis and other prognosis steps. These satisfactory levels are accomplished by integrating various services namely cloud-based, IoT, Machine Learning, and AI into their management system. It is predicted that by the end of 2024, the smart hospitals market will be worth approximately 63 million dollars [65]. The start of the *Industrial Revolution 4.0* [66], brings up various AI and ML-based algorithms that help in accurately diagnosing various diseases [67], analyzing details collected from different sources. With this integration, now hospitals are customized in a more ingenious manner and personalized solutions which provide a soothing effect on the customers and hence provide a better approach toward the medical treatment of the patients. Various applications have been integrated with hospitals for making smart systems. Figure 9 illustrates the pillars of the smart hospital systems.

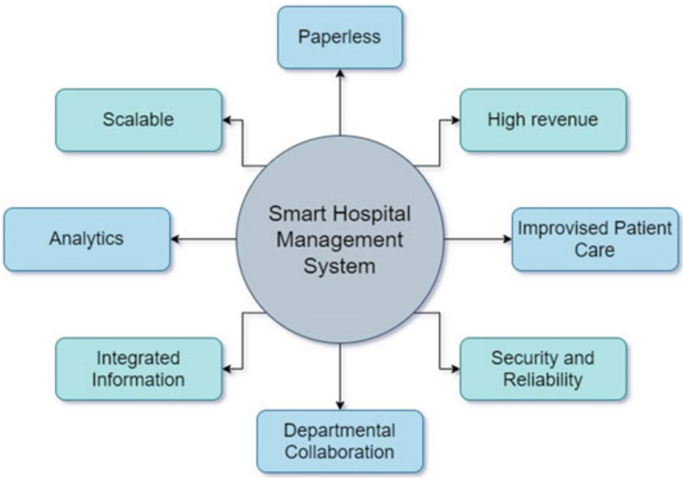

Fig. 9 Pillars of smart hospital systems

In the upcoming chapter, we present various applications involved with the Smart Hospital Management Systems (SHMS). With the integration of IoT in the management system, hospitals are now able to overcome the problem of storing limited data, inflexible networking mode, etc. The upcoming chapter is categorized in the following subsections: IoT Based Technology, Hardware Devices, Architecture model, Applications based upon smart hospital management systems, and limitations of SHMS.

I. IoT Based Technology
   With the recent development, many IoT technologies have contributed to building strong information networks based on the type of integration. Following are some of the widely used techniques.

   A. Internet-based Technology
      With the help of the internet, the next-generation network is established within the premises of the hospital and allows the authorities to share data with other branches or the desired persons without any effort. Internet becomes the first and key technology that is required for the development of SHMS. By such integration, both patients and doctors can have friendly communication with minimum effort requirements.
   B. RFID Technology
      Termed as Radio Frequency Identification is a widely used technology in the healthcare sector for providing better reliability, and secure services [68]. This technology is used for the streamlined flow of heavy modules and provides full automation in the hospitals for providing details in a very optimized manner to the patients, staff, and doctors. These details include patient identification, staff allocation, doctors, medicines in the inventory, treatment details, and other necessary desired details. RFID relies upon wireless sensor-based technology which makes use of radiofrequency in forming the electromagnetic fields for transferring the data among themselves. These tags contain information stored electrically for transferring data on a large-scale basis. However, for short-range tags, magnetic fields are used and also act as a transponder for emitting microwaves. Fig. 10 demonstrates the basic components of the RFID system.

      RFID has furthermore applications which are mainly classified into two categories namely *Inventory Management and Control* and *Workflow and Process Optimization.* Apart from these, RFID comes with its advantages which include patient safety (Diet, dosage monitoring), reduced medical errors (Patient identification, readable documentation), temporal data management (Hospital data on daily basis, Bi-Temporal support), provides real-time data access facility, its time and cost-effective (reduced workload on staff, reduced theft and waste), and improvised medical processes (customized billing process, patient registration process).
   C. Sensor Network Technology
      Various sensors are merged for building a fully functional system. Sensors being the core component of IoT, is integrated with RFID technology for

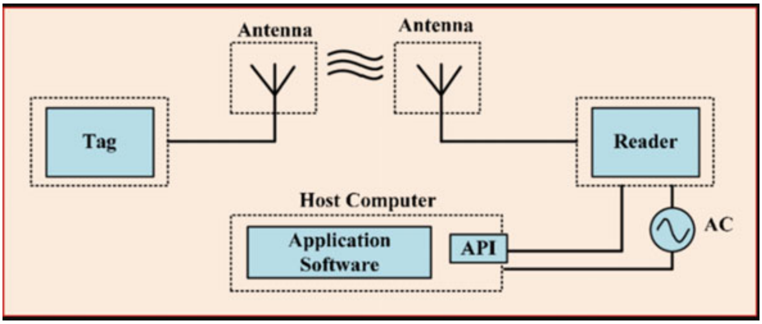

Fig. 10 RFID-based system components

better tracking and data transfer. These sensors help in tracking the various status of a variety of things including location, temperature, movements, etc. With the development of these sensors [69], making them microminiature, improved intellectual power, and collection of information, are now used in various scenarios including environmental monitoring, e-health devices, smart transporting systems, industrial plants, and military.

D. Wireless Communication and Embedded Technology
With the help of wireless connections, communication between various RFID tags can be made possible and effective. Through this network, information can be transmitted to central information systems. These wireless technologies include Bluetooth, WIFI, UWB, IrDA, etc.

II. Hardware Devices
To provide fully functional systems, various hardware units are integrated into the system that provides various information about the surroundings based upon the type of the device. Some of the widely used components are described under this sub-section.

A. ESP32 Processor
Such processors are widely used as learning tools in IoT offering Linux-based systems on scalable platforms at a minimal cost. Such processors connect sensors and actuators using GPIO pins. ESP32 provides an ingenious and customized way of developing healthcare systems. These processors contain inbuilt antenna switches, RF-balun, control amplification, low noise amplifier, various filters, and a power management system. Although these processors are combined with sensors for customized outputs, they can also work independently and ultimately reduce the overhead interaction within the main application processor. Fig. 11 demonstrates the ESP32 processor.

B. Heart Beat Sensor
These sensors are developed based on the plethysmography theory. Sensors measure the blood volume change by organs that allows a certain light

Fig. 11 ESP32 processor

intensity to pass through it. However, pulse timing becomes a critical task in the system in which the heart pulse rate is to be tracked. This tracking of heart rate tracking helps in determining blood volume. Fig. 12 shows the basic hardware used for the heartbeat sensor.

C. Body Temperature Sensor
   LM35 series of the hardware device is used for accurate detection of temperature change with the output voltage. These sensors are required to be placed in the patient's body cavity for measuring the body temperature, and the data is further transmitted or collected via suitable methods. Once

Fig. 12 Heartbeat sensor

the data is collected, the data analysis process starts, and corresponding to the results proper medications are prescribed. With the data collected, some predictions can also be derived using proper AI and LM techniques. Fig. 13 demonstrates the basic LM35 sensor.

D. Room Temperature Sensor
For analysis of the room temperature, DHT11 sensors are integrated with the RFID tags. These sensors also provide information about the humidity level in the surroundings. The sensors have integrated NTC and 8-bit microcontroller chips for temperature measurement. These sensors are manufactured with such a design so that they can interconnect with other microcontrollers as well. Fig. 14 shows the room temperature sensor.

E. CO and CO_2 Sensor
MQ-9 and MQ-135 sensors are used in CO and CO_2 detection, respectively. However, MQ-9 is preferred for the detection of LPG, CO, and methane gas

Fig. 13 LM35 sensor (body temperature sensor)

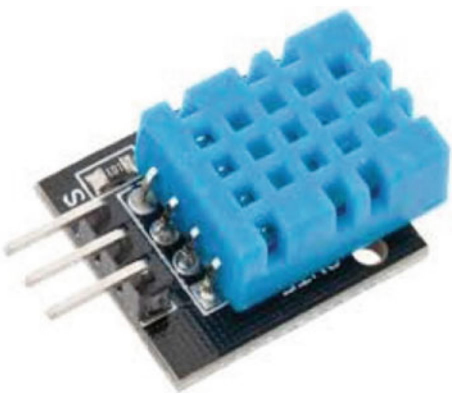

Fig. 14 Room temperature sensor

whereas MQ-135 is used for NH_3, Nicotine, Benzene, smoke, and carbon dioxide gas levels. The amount of gases is calculated in terms of PPM using analog pins and their sensitivity can be changed using the potentiometer. These sensors fit with the modern microcontroller and are widely used in the industrial domain.

III. Architecture

Based on the various proposed architectures and current requirements of the hospital systems, a customized architecture has been introduced for smart hospital systems. Fig. 15 demonstrates the block diagram of the SHMS architecture. The architecture comprises mainly three layers which include the Perception layer, Network layer, ad Application layer. These layers are described in detail in the upcoming chapter.

A. Application Layer

This layer is further bifurcated into two parts namely *Management Decision* and *Information Application.* Hospital information application includes

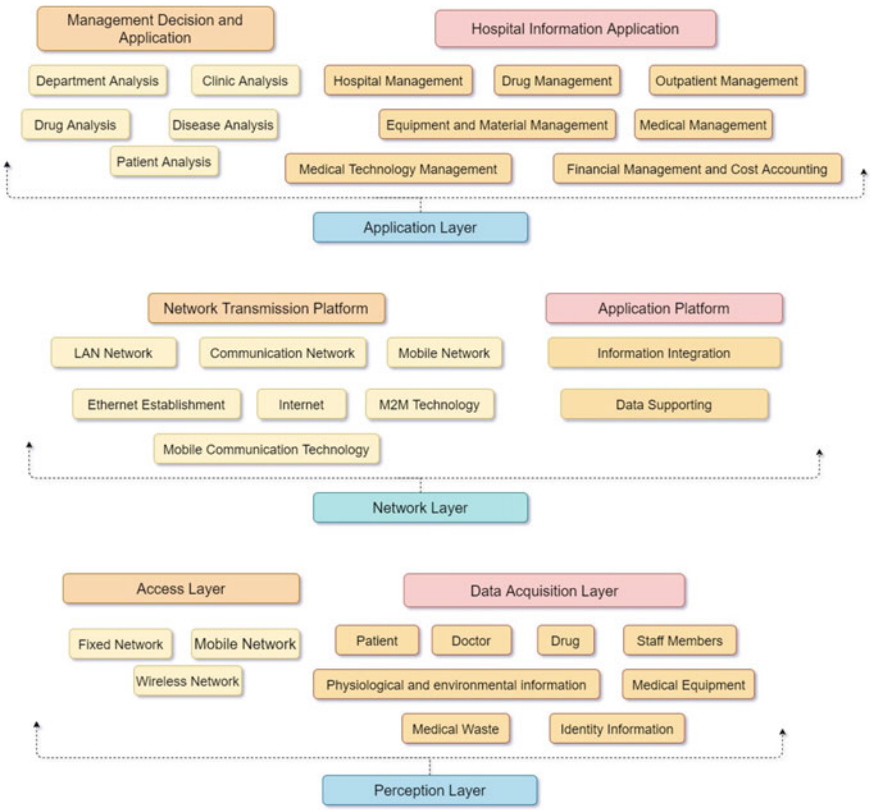

Fig. 15 Basic architectural layers for SHMS

information about the patient, hospital, medical, drug, physical therapy and materials management, medical technology, etc. On the other hand, management decision and information applications come under the senior category which includes various analyses using AI technologies. These analyses include disease (distribution based on location, expected cost of treatment, onset time), patient (age distribution, regional distribution, time of meeting, free medical services), clinic (patients visit, doctors visit), drug (amount, quantity of prescribed consumption, revenue from drugs, after-effects), etc.

B. Network Layer

The network layer has furthermore sub-layers namely *Network Transmission Platform (NTP)* and *Application Platform (AP)*. NTP becomes the backbone for the hospital networks providing real-time reliable transmission of data collected from the perception layer using various technologies (Ethernet, mobile networks, LAN, M2M, etc.). AP layer helps in the integration of various information collected to the third party for the development of the client-side interface. These client-side platforms are generally developed for the staff members of the hospitals.

C. Perception Layer

The perception layer is composed of two sub-layers which are *Data Collection* and *Access Layer*. Data Acquisition Layer is used to get a hold of hospital networking nodes, collection of surrounding data which can include information about the identity of the patient, doctors, nurse, etc., medicinal information, pharmaceutical related information, location details, etc. While Access Layer is required for transmitting the data which is collected from the other layer to the application layer or to the main server where the data can be processed and analyzed. For transmission of data, various ways can be explored including mobile networks, wireless connections, etc. These connections will become the entrance point to smart hospital systems because of their wide coverage, optimized working, cost-effectiveness, user-friendly, convenient deployment, and scalable features. Fig. 16 illustrates the basic working of the *Smart Hospital Management Systems* in a real-life scenario [19].

IV. Applications based on SHMS

In this sub-section, we provide various applications which are provided by SHM systems. These applications are acquired in the hospitals for providing a better experience to the incoming patients, doctors, staff members, and other authorities. One of the major advantages of using AIoT-based systems is the automated data management and collections which efficiently saves an immense amount of time.

A. Patient Experience

Smart hospital management systems come with customized room features for the patients and their guardians. Patient's experience can be improvised

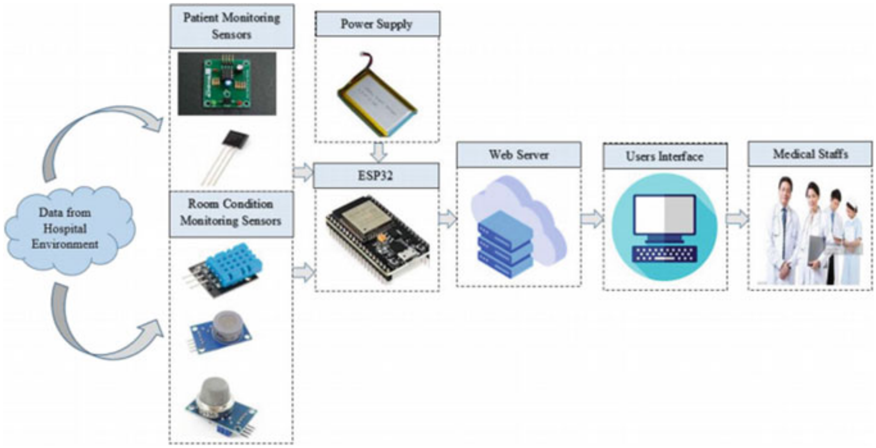

Fig. 16 Real-life smart hospital management system workflow

in various ways including remote health monitoring systems, personalized treatment, patient engagement, notification about the results, etc.

Through a remote health monitoring system, staff members can easily keep a check on the activities and other requirements of the patient from a private environment. For this IoT-based technologies play a key role, furthermore, the help of AI and ML techniques can reduce the work pressure of doctors. For instance, with the camera-based sensors and AI and ML detection algorithm models, patient movements can be viewed and can raise appropriate alarms based on them. Secondly, temperature monitoring sensors with ML techniques can help in automating the room temperature based on the required treatment process. All these sensors can be processed by the proper doctors and can watch their patients without any movement. On the same side, patients will also be able to get a personalized treatment process which will keep them motivated and joyful all way long. With medical data collection and monitoring systems in the patient's EHR, AI algorithms can provide doctors, lab staff members, and other related staff members to get end-to-end visibility of the patient's health details. These details can be found helpful while analyzing the patterns, detecting anomalies, and so on.

With the implementation of proper networks in the premises, guardians can be provided with up-to-date details and notifications about the patient's treatment process on a touch screen, or any monitor device which will improve their experience as well as patient-doctor relations. Guardians now can be involved in the care process and can have a better insight into the treatment schedules.

B. Streamlining Communication

One of the major limitations of the traditional hospital system was the improper communication between the patient and the doctors. This sometimes results in miscommunication and patients found the treatment to have overdosed. These miscommunications arise because doctors are more focused on the treatment process and other body movements which show their current state of health, while on the other hand, patients find this as doctors are ignoring them. This leads to forming a bad impression on both patients and doctors. With the integration of proper IoT technologies, patients can view their treatment details and improves timely communication between the caretakers and the patients enhancing their satisfactory level.

C. Optimized Workflow

IoT and proper network establishment can help in providing a new shape to the traditional hospital systems. Effective tools with proper functionality can provide tracking and identification services which can help in the navigation of staff members, unlike the traditional method where you have to manually go and ask for directions to meet the desired doctor. These navigation systems can also provide the live status of physicians and other staff members that are present in the hospital. Other than navigation purposes, messaging and routing features can be used to provide turn-by-turn directions and arrival time directions to make the incoming visitor less stressed about the navigation in large-scale hospitals.

D. Operational Efficiency

Operational efficiency is dependent upon two major factors namely facility management and predictivity maintenance. Facility management collects various details like temperature, humidity level, air regulation in the surroundings, security needs, etc. These details are analyzed and with the help of AIoT, efficient management systems are developed which provide automation of the actions required for maintaining proper levels of various factors (temperature, humidity, air regulation, etc.). The sensors can also help in the detection of the physical safety of the people around. With the evolution of mankind, various diseases have emerged out and will continue with more variations and effects. For achieving proper automation in the diagnosis of such variants, predictive assets of the hospitals which contribute to the healthcare domain should be updated at all time. With this, proper treatment can be given to the patients achieving better results.

E. Clinical Tasks

With the collection of real-time information from IoT-based healthcare devices, accurate diagnoses can be made by the practitioners in the hospital environment. These details can help in analyzing the illness patterns, reduce human errors, and can provide new insights with proper visualizations.

With the rapid growth in AI robots in the industries, the use of such robots is increasingly acquired by the medical industry for analyzing the hospital environment and maintaining the proper balance of various factors. These robots are also used as a helping hand in surgeries by providing reliable instructions based on the current situation of the patient. AI-based robots contribute to providing satisfactory care to patients.

As per the survey, pharmaceutical industries spend approximately 2.7 billion dollars for every drug that comes to the market. AI algorithms can contribute to supporting drug design with an accurate prediction of molecular dynamic therapy, improving the developmental efficiency and resulting in reduced costs. Apart from drug support from AI and IoT sensors, patients can also get the daily physical therapy sessionals of their orthopedic care on mobile devices. The application can guide them through the daily exercise routine, and can also connect to the desired doctors for better communication. This will provide flexible work workflow to the patients as well as doctors who can record their respective sessions and post them on the applications as per their comfort. Also, patient's movements during the sessions can be recorded and can be analyzed by the clinicians for guiding the patients.

F. Hospital Assets Tracking

IoT-based devices are mainly used in industries for providing effective and optimized inventory tracking and pointing out the required assets beforehand. Hospitals can integrate these applications into their system for managing medicinal stocks and other requirements of the types of equipment. The application can also be used from tracking the deliveries to enable users to purchase online using preferred networks. Hospitals can make sure that the required drugs are not misplaced in between the transportation process assuring reliability to the end-users. This application, if integrated with the main server, can help in analyzing the revenue pattern of the hospital and can take further actions based on it.

G. Leveraging Data Analytics

IoT sensors can provide biometric devices which can play a vital role in the security systems of the hospital. Smart devices like wearables and smartphones can track huge volumes of biometric data. Apart from the security checks, these biometrics can be used for analysis purposes where doctors can find more about the patient as well as the population. Analysis can provide insights into the quality of patient care and can boost up medical and medicinal research.

V. Limitations of SHMS

For the fully functional development of Smart Hospital Management Systems, various hurdles are discovered by the researchers and other authorities. These challenges are described in the upcoming literature of this section.

A. Patient Monitoring

Providing monitoring services to the clinical staff members for a better treatment process becomes one of the difficult tasks. Continuous monitoring of the patient, providing satisfactory healthcare, maintaining patient safety and proper regulatory compliance with minimum staff members, having a better relationship between doctors and patients becomes the challenging part of smart hospital management systems. To achieve the above points, a proper hold on the data analysis is required which will raise the appropriate alarms based upon the patient movements, round-the-clock care system by the doctors and staff members, efficient and fast-decision-making responses from the system, and optimized response systems are required. Developing such algorithms and sensors which can handle the above tasks, becomes a major concern for developing patient monitoring systems.

B. Data Accuracy

Data collection plays a crucial role in analyzing various patterns and the detection of diseases. Correct transmission of data from the nodes to the main server becomes a challenging part. This is indeed a difficult task because in case if wrong information or data is used for the detection in the AI and ML-based models, false predictions can be generated creating very severe side effects for the patients to suffer from. Proper collection of data and effective transmission of the same becomes the key to the smart hospital management systems and to make them fully automated ones. For ensuring that the collected data is accurate, EHR systems are used which helps in rectifying the same problem. However, there is still a scope of human error that can become a hurdle in some situations.

C. Security and Privacy

The data collected about the patient, staff, doctor's identity, treatment process, ongoing projects in the hospitals, healthcare data, inventory details, etc. should be used over a secure network. Maintaining such confidentiality, integrity, and availability of healthcare data becomes another challenge in building up smart systems. Storing these identification data, and other treatments on unreliable servers can cause damage to the hospital as well as can make the patients vulnerable to various problems which include chances of abuse, tempering of the data, etc. [70]. A compromise in the patient's or staff member's privacy can bring up hurdles and cause of various other problematic factors as well as various other implications in real-life.

D. Cost-Effectiveness

Healthcare treatment cost becomes another constraint for patients to come and rectify their problems. As per the survey, a huge number of patients come from a middle-class background and are not able to afford the treatment costs. These treatment costs include doctors and helping staff members' fees, facilities provided, medicinal charges, etc. With the integration of smart applications in the hospital, although the cost of integration becomes a one-time investment, proper maintenance and updating have costs that add to the treatment bills. From the past decades, there has been a clash between the user convenience and cost of the treatment [71]. However, there are ways by which these cost factors can be reduced in a long-term session. With the use of reliable cloud services, start-up expenses can be reduced and can be found very efficient in handling databases. EHR becomes the main component in building up a *Smart Hospital Management* system, however, security and privacy issues come into the picture with it.

E. Intelligent Data Preprocessing and Data Validation
All the IoT-based sensors send their collected data to the main node or server where every piece of information is stored depending upon the type of it. In real-life scenarios, there are many a time when data preprocessing becomes a crucial point before providing the data to any other algorithm for analyzing process. Having a variety of sensors and different sources of data collection, healthcare data becomes very diverse and heterogeneous making it difficult for the algorithms to predict accurate results. Extraction of useful information from the data cluster and validating the information becomes a challenging part. However, with the use of advanced AI-based algorithms, this process of information extraction can be made less stressful.

F. Management
Healthcare departments deliver various options to their end-users. These services include healthcare quality, safety measures, secured data services, financial productivity, regulatory standards, etc. With all these facilities, authorities have to divide the financial cost for each domain. Because of these measures and customizations in the facilities, there are conflicts of priorities as to which domain gives more importance. However, for building smart hospitals, these facilities can be embedded in a sequential order instead of installing all the applications in a single go. While the development of these applications takes place, data collection becomes another barrier as there are unstructured data integration problems. Another challenge faced by the staff members is to get acquainted with the new environment of automated functional applications and use them in an efficient way which requires quite a time for the staff members to get a hold of it.

9 Conclusion

With the aging population and advancements in the field of technology and medicinal development, improvising healthcare results has become the main focus of doctors and researchers. With every passing day, there is a new variant of chronic disease, increasing healthcare costs, and rising demands and expectations from the patients. As per the survey, approximately 8.8 trillion dollars were spent in 2020 by global health organizations. To meet the patient's satisfactory level and provide them effective treatment becomes the main objective of the *Smart Hospital Management Systems.* Smart hospital management system brings the revolution of the patients as well for the doctors and staff members. With the integration of various modern and efficient technology for the automation systems and innovations in the IT field, smart hospitals cover various aspects of the hospital which includes a variety of operations, building design, patient experience, and many more. With the help of AI and IoT, smart hospitals are developing at a faster rate, providing patient-friendly treatments, and a more affordable diagnosis process. The concept of a smart hospital system will reduce the time constraint for the patients and will have better healthcare systems to make use of. In this chapter, we provide various aspects of AI, IoT, applications of SHMS, and limitations. We also present the architectural block diagram which provides a basic idea about the working of the SHM systems. In our chapter, we also provide various challenges that are faced by Smart Hospitals and their respective mitigations. With the steady increase in the treatment costs and demands, smart hospitals have come out to be an efficient solution for providing more efficient diagnosis processes and a friendly environment to the patients. IoT and AI-based technology reduce the expense factor to a great extent making it feasible for the patients to take up their treatments without any further stress. With the rapid growth in technologies, namely, AI, machine learning, IoT, big data analytics, cloud services, and the development of smart hospitals systems will become smoother than ever.

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