Chapter 1
Intelligent Systems for Sustainable Development of Healthcare Industry

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Abstract The standards of the healthcare industry affect the economic performance and quality of life of a country. The new technological advancements and the services ensure patient's and practitioner's satisfaction. The remote monitoring, stress analysing, cancer detection and proactive diagnose has been made possible with the evolution of new technologies. This chapter highlights various technological aspects in the healthcare industry and discusses about the related work presented by different researchers. The aim, applications and challenges faced by the implementation of technologies like robotics and artificial intelligence, augmented reality, blockchain technologies, Internet of Things and three-dimensional printing have been highlighted. The chapter presents a quick glance at the various intelligent healthcare systems developed based on presented technologies along with significance and challenges of data analytics in the healthcare industry.

1.1 Introduction

The medical practitioners and the various smart facilities available for patient care focus on providing the effective and efficient healthcare system at the doorstep. The smart healthcare facilities aim at providing safe and secure environment to the patients as well as medical practitioners. The smart healthcare system not only provide customer satisfaction but also provide advanced patient care and focus on patient-centred experiences.

The smart healthcare technologies use smart, low-powered, miniature sized medical devices which are connected wirelessly through different wireless technologies. These devices are responsible for measuring different physiological parameters of the body like glucose level, body temperature, heart rate, blood pressure,

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oxygen level, body position, etc. The sensors used in the network are also capable of processing, capturing and security of medical data [1]. All the devices or the sensors used in the hospitals or clinics form "Internet of Medical Things". This is because different medical sensors placed on or implanted inside the body or embedded inside the hospital beds or medical equipment scan receive significant medical information of the remote patient and medical professionals act according to the situation and provide proactive solution to the problem.

The major objective of smart healthcare or Healthcare Industry 4.0 "is to allow for progressive virtualization in order to enable the personalization of health and care next to real time for patients, professionals and formal and informal carers" [2]. The major technological advancements in the field of healthcare as presented in Fig. 1.1 are robotics and artificial intelligence, augmented reality, blockchain technologies, Internet of Things and 3D printing [3–5].

The efficiency and effectiveness in the patient healthcare have improved due to the adoption of advanced technologies by various healthcare organizations. Before implementing the advanced technologies, the healthcare organizations must ensure the network requirements to handle critical medical data as the increasing demand may affect the performance of the network.

The chapter is organized as follows: Sect. 1.1 presents the introduction to the smart healthcare systems and their aim in accordance with the Healthcare Industry 4.0 guidelines. Section 1.2 discusses the advanced healthcare technologies like augmented reality, blockchain technologies, Internet of Things, robotics and artificial intelligence and 3D printing. This section also discusses the challenges and growth statistics of these technologies in past, present and future. The intelligent healthcare solution based on these technologies has been presented in Sect. 1.3. Section 1.4 discusses the role of data analytics and challenges in smart healthcare

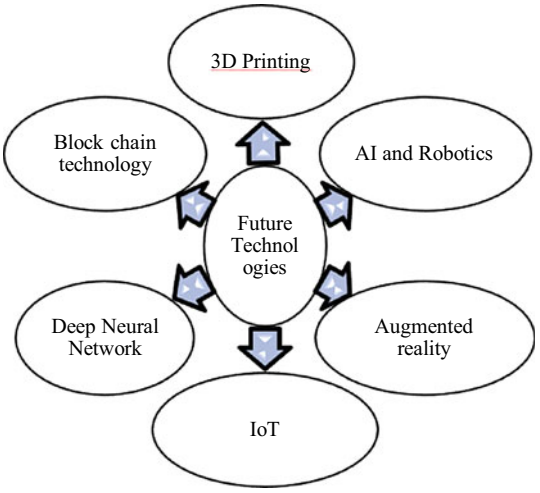

Fig. 1.1 Future healthcare technologies

industry. Section 1.5 concludes the chapter with future scope of these technologies in remote monitoring, surgical operations, customized prosthetics during normal and emergency circumstances.

1.2 Healthcare Technologies

The healthcare industry has seen tremendous growth with the advent and implementation of advanced technologies in surgical operations, telemedicine, remote patient monitoring, stress management and many more. The present section discusses about the advancements related to emerging technologies and the related work presented by different researchers. The objective and challenges faced by each technology have also been presented in Table 1.1 [5, 6, 11, 12, 18, 19, 25, 26, 29, 30].

Table 1.1 Outline of future healthcare technologies

S. No	Technology	Aim	Applications	Challenges
1	Augmented reality	Increase patient safety and decrease recovery time	Patient rooms, billing information, surgical operations, smart glasses, cafeteria design	Stress, overload, security, privacy, sometimes not user-friendly
2	Blockchain technology	Security, integrity, interoperability of data	Health insurance, drug supply, medical education, biomedical research	Latency, scalability, power limitations
3	AI and robotics	Perform human-like task and reduce patient discomfort	Recommend diagnosis, lab test, answer health-related queries, stress management, identifying cancer cells	Higher cost, fear of unemployment, lack of interoperability
4	IoT	Anytime, anyone, any place, anything, any network connectivity	Remote monitoring, interact with medical machines	Security, privacy, may cause accidental failures
5	3D printing	Additive manufacturing, treatment under direct supervision of experts	Bioprinting of tissues, organoids, 3D-printed models for surgery, surgical tools, customized prosthetics	Longer printing time, clinical investigations not accurate

1.2.1 Augmented Reality

It is one of the technologies helpful in providing virtual overlays to help the amateurs during any surgical operation and provide traditional learning environment. One of the applications is the use of smart glasses by both medical practitioners and helpers which not only view the medical statistics of the patient without consulting medical chart but also proved helpful in designing the patient rooms and providing billing information. It is also helpful in the patient insurance surgical operations and can also assist in cafeteria designing [6].

In another contribution by authors, the difference between virtual reality and augmented reality has been presented and it is stated that augmented reality is an extension of virtual reality only. The different biomedical applications of augmented reality like invasive surgery, mental healthcare have also been explained [7].

The authors in [8] have developed a mobile application named as Clinical Decision Support System (CDSS) based on augmented reality and deep learning concept for low-cost devices. This has been specifically designed for the patients suffering from bedsores. The decision has been taken based on the present situation of the bedsore. Also, three different situations of bedsore have been considered and two more stages have been added by CDSS. The three main functionalities proposed by the authors are bedsore classifier, its measurement and its time machine.

In another contribution, the authors have developed a prototype application based on augmented reality where virtual images of medical devices have been combined with real-time world images [9]. The presented work had been carried in three stages—assessment of user's need, development of the prototype and evaluation of the software. The work has been completed with the contribution of 11 nurses for focus group and 280 healthcare professionals for online available questionnaire. It has been concluded that augmented reality technology provides both safety and security to patients and improves the clinical support to the medical professionals. The major limitation of the work is that the app requires a prior information of the medical devices to be fed and updated regularly by professionals.

The authors in [10] have presented that the main aim of augmented reality is to enhance the patient's safety and decrease the recovery time. The authors have studied the impact of augmented and virtual reality in context to bone fracture for different stages like pre- and post-surgery including bone fracture healing, its diagnosis and rehabilitation. In [11], it is highlighted that both augmented and virtual reality technologies have the potential to be used for plastic surgery in preoperative applications which will help in improving clinical outcomes, operative time and cost-effectiveness.

1.2.2 Blockchain Technology

This is a technology behind Bitcoin and that aims to provide security, integrity and interoperability of data. The major advantage of this technology is that the data is not stored at a central location but is distributed all over the network participants [12]. Various industrial and manufacturing units like IBM and Deloitte have also developed products that ensure data integrity and accuracy using blockchain technology [12]. The major advantages of this technology are better and accurate diagnosis, provide effective treatment, patient satisfaction and enhanced security as data is immutable. The changes made in the data can be easily tracked by the experts. The blockchain technology has greater outcome related to data security and access by all network participants [13].

Data reports presented in Fig. 1.2 from BIS research estimate that blockchain technology is estimated to reach $5.61 billion by 2025, observing a double-digital growth during the period of 2018–2025 [14]. Blockchain technology apart from healthcare provides great help in e-commerce, education and manufacturing industry by allowing customer and company to keep online records for transactions and others.

In another contribution, the authors presented the various issues like delayed communications, lack of interoperability, availability and security of medical records stored in fragmented locations, in healthcare industry and application of blockchain technology to overcome these issues have been highlighted. The design considerations related to implementation of blockchain technology in healthcare have also been presented [15].

With the standardized regulations for protection of medical data of patients and healthcare data on cloud, various new options for managing health data have been developed using blockchain technology [16]. Various researchers have presented state-of-the-art of blockchain technology implemented in health insurance, drug supply, medical education and biomedical research [17].

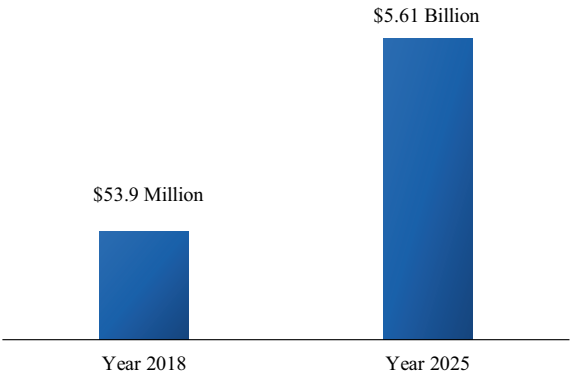

Fig. 1.2 Blockchain in healthcare industry [14]

1.2.3 Artificial Intelligence (AI) and Robotics

Robotics with artificial intelligence has proved to be the major technological trend in the health industry. Robotics machine like Da Vinci, Vasco Logic Venous Pro and many more help to perform the human-like tasks and has greatly reduced the patient discomfort [18]. This smart technology has also helped elders to find their best pal in case of loneliness and care. It has been found that robotics and AI have been accepted by both medical practitioners, patients, research as it provides advanced computer technology and can also recommend diagnosis perform lab test and answer any health-related question. The microphones, sensors and camera used in this technology allow the patient and the robot to talk to each other and provide a healthy communication between the two [19]. AI has been used to develop wireless powered sensor system which is used to send emergency messages to the medical practitioner to provide information about the patient suffering from ulcers and its ongoing pressure. In another work [20], machine learning algorithms have been used to classify the burns and ulcers of the patient using a support vector machine and pre-trained convolutional neural network.

Figure 1.3 shows that AI has significant role in healthcare. At the early stage, it helps to identify the illness and its algorithms help to assist improved decision-making procedure. With the help of previous records, it helps to provide better treatment plan. This gives a superior experience to patients. AI-based wearable provides a track of our daily routine link sleeping pattern, count of calorie, steps, etc. Robots with AI provided a better platform for old age patients for self-ruling life with the need of doctors.

Figure 1.4 shows the estimated and projected share of different countries of use of AI in healthcare industry. North America plays a key role of AI in healthcare industry due to existence on multinational companies like IBM, Microsoft, Intel and Google

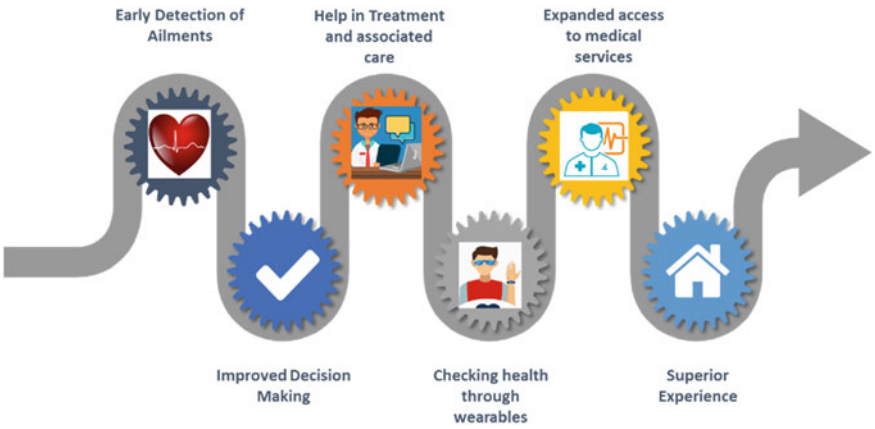

Fig. 1.3 AI in healthcare industry Source: https://www.botreetechnologies.com/blog/artificial-intelligence-in-healthcare-industry

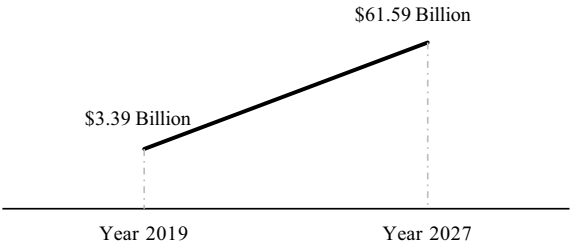

Fig. 1.4 AI in healthcare industry by region (USD Billions) [21]

[21]. United States, with greater number of hospitals, rely on AI for maintaining patient data and care. Due to increment in population and decrement in healthcare staff, demand of AI technology for treatment and diagnosis is obvious. Artificial intelligence has significantly helped in improving the different factors in healthcare industry. Using artificial intelligence, the cost of treatment is reduced, and quality of life is improved [21]. Results and decision taken from the patient data using AI have good response. AI provided better prediction and improved outcome. Besides good scaling of AI, its faster algorithm implementation process is lacking somehow. This is due to only patient security and for better tested accuracy.

Deep learning applications in medical domain have led to another drastic change that helps to automatically detect cancer cells. It has been proved by researcher's teams at University of California, Los Angeles, who built an advanced microscope that yields a high-dimensional data set used to train a deep learning application to accurately identify cancer cells [22]. Also, the estimation of stress can be analysed using a trained deep neural network [23].

1.2.4 Internet of Things

Internet of Things is another promising technology which has found applications in every field of life. This technology has found tremendous growth in health industry as it can interact with the machines like pacemakers and glucose monitoring systems implanted in the patient body. The miniaturization and tiny sensor nodes can detect diseases by regularly monitoring a patient and help paralysed persons to send signal through brain to different parts of the body. IoT systems are also helpful to the healthcare industry in terms of smart building technologies, remote monitoring and providing cost-effective solution to the patients [24].

The authors in [25] have presented a unique model as shown in Fig. 1.5 for IoT-enabled healthcare systems which can be applied to generalized systems as well as in specialized systems. The accessibility of medical data using Cloud has been stressed upon for future healthcare systems due to high processing speed despite limited resources provided by body sensors. But due to security and privacy factors associated while saving medical data on cloud, it has been stressed upon that IoT-based healthcare systems are best approach for immediate application.

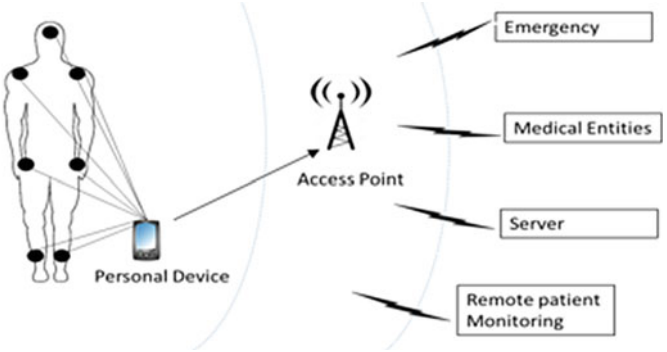

Fig. 1.5 Simple model for IoT-based healthcare system

The Internet of Things (IoT) is a concept that reflects a "connected set of anyone, anything, anytime, anyplace, any service, and any network". The basic characteristics of the IoT systems are mentioned as a real-time wireless solution in a global environment and monitoring of remote patients through tracking objects. But, IoT has helped in breaking geographic barriers, providing rapid clinical responses, medical consultation and communication links of medical images.

No doubt, the efficiency and effectiveness in the patient healthcare have improved manifolds. At the same time, the healthcare sector must have the ability to handle the increase in demand as latest technologies require more bandwidth that tangle the performance of the system. In such situation, the healthcare organizations must stay in contact with various network service providers to provide best possible bandwidth requirements for accurate diagnose to the patient. Another solution is the use of software-defined wide area networks (SD-WAN) that will support and manage multiple organizations on a cloud-based framework [26].

In 2018, IoT market size in healthcare industry was 147.1 billion and is anticipated to witness a Compound Annual Growth Rate (CAGR) of 19.9% over the forecast period as shown in Fig. 1.6 [27]. The abrupt increase in wearable technology, invest-

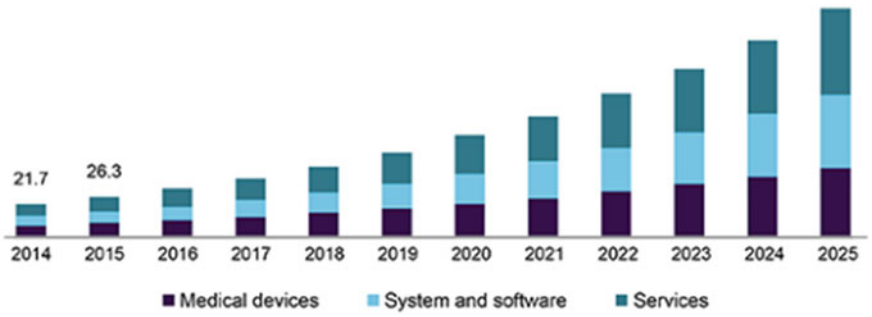

Fig. 1.6 IoT market in US (USD Billions) [27]

ments for establishing digital technologies in healthcare points and the emergence of connected care are the key factors boosting industry growth. Also, advancements in the technology and growing population day by day coupled with chronic conditions are also positively impacting the market expansion.

The major limitations that IoT-enabled health system to suffer from are computational limitations, memory limitations and energy limitations. Such devices face challenges related to the central processing unit (CPU), which is not very powerful in terms of its speed. In addition to this, these devices also face issues related to computationally expensive operations and low memory. Such devices are activated using an embedded operating system, system software and an application binary. A general IoT-based healthcare system includes various physiological sensors to measure body parameters and these sensors can conserve energy by switching on the power-saving mode when no sensor reading needs to be captured.

1.2.5 3D Printing

It has been predicted that the 3D printing technology in the healthcare field will grow by 17.7% and reach $2.5bn by 2026 in forecast 2021–2026 [28]. The major applications of 3D printing in medical fields are bioprinting of tissues and organoids, 3D-printed models for surgery, surgical tools and custom-made prosthetics [29].

The authors in [30] presented the way to explore 3D printing in personalized healthcare. The major challenges like longer printing time, accuracy in medical outcomes and applications of 3D printing have also been highlighted. It has been stated that drug 3D printing has also been the revolutionary word in the sustainable healthcare. The 3D printing technology helped in solving the issues related to complexity, sustainability in healthcare and in exploring possibilities offered by technology in healthcare variety management. An intelligent use of 3D printing technology in producing personalized medications and an industrial technological revolution of compounding pharmacy. The authors in [31] have presented a state of the art of 3D printing technology implementation in healthcare industry. 3D printing is also called as additive manufacturing in which the different materials are placed one over the other in layered architecture form. This technology has gained much recognition due to decline in the cost of 3D printers and enhanced printing accuracy and speed.

Figure 1.7 shows the market size of 3D printing technology in healthcare industry. It is expected to be 3700 million by 2025 and USD 1150 in 2021 showing more than 18% CAGR during the period [27]. Due to advancements in technology, the present-day hybrid 3D printing helps in more accurate diagnosis and surgery planning as compared to earlier available 3D printing technology which supported image modality only. The success of personalized scaffolds using different techniques has also grown with the advent of 3D printing technology. It has been popularly employed in making medical devices, human organs and for improving quality of medical treatment.

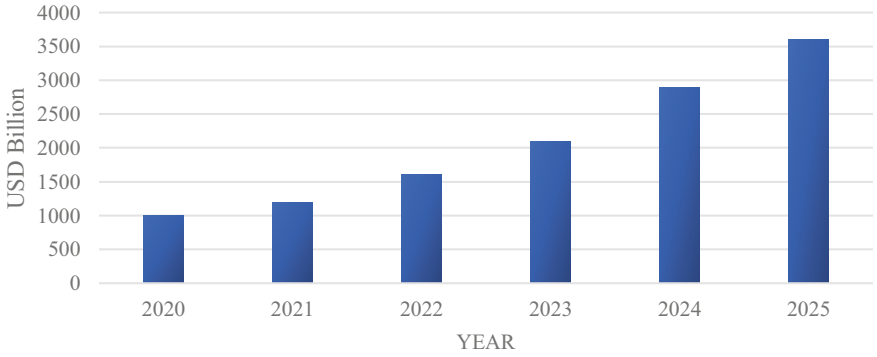

Fig. 1.7 Global healthcare 3D printing market size (USD Billions) [28]

Italy had developed 3D-printed respiratory valves for the Corona Virus Disease (COVID-19) which are effective for patients in their country [32]. Researchers in different countries have also developed 3D-printed artificial limbs, chest, abdomen, head, neck and other body parts required for anthroponomy training in medicals hospitals and institutes.

The authors in [33] have presented the various technologies, materials used in the 3D printing for different medical applications. The chapter also highlighted the advantages and disadvantages of each of these technologies. It has been concluded that 3D printing technology has provided the way to treat more patients with less time under direct supervision of medical experts.

Many authors have also worked upon the development of data fusion techniques to provide smart healthcare. The smooth combination of different data sets to make it representable, accurate and consistent for use is called data fusion. Data fusion techniques enhance the accuracy of individual data from different sources by integrating these data into single information. The authors in [34] have also proposed a technique using Complex Event Processing (CEP) technology which not only supports time-critical applications but also storage-limited IoT devices. A specialized beamforming antenna can also be used for transmission of data from various healthcare devices [35].

1.3 Intelligent Systems in Healthcare Industry

This section contributes towards the intelligent systems developed and implemented in healthcare industry based on the healthcare technologies. The augmented and virtual reality technology-based products have been developed by different countries. OxfordVR has been designed by United Kingdom based on virtual reality which helped the patients suffering from mental disorders and fears [36]. The system is

efficient enough to reduce the mental disorders by an average of 68% within few hours of treatment.

Israel has developed Augmedics [36] system which helped in providing guidance during surgical operations. The surgeons can see through patient's skin or tissue just like X-ray vision. Precision VR [36] has been developed for various neurosurgical procedures for pre-operation planning. A complete process based on VR scenario can be seen before the operation. Several smart systems based on blockchain technology have been developed. Some of them are Ethereum [37], Ripple [38] and Hyperledger Fabric [39]. These systems help in providing research and innovations through blockchain technology for commercialized solutions.

AI and robotics have given us Xenex Robot Disinfecting system [40] which has proved to control the infections acquired by the patients and reduced the risk to 70 percent. Another contribution in this domain is Riba [41], which helps in the movement of bed-ridden patients. The robot helps the patients to stand, sit and move in or out of bed to avoid any kind of bed sores.

3D printing helped in regeneration of tissues and skin damaged by any kind of burns, etc. The patients can get a new life through organ implant [42]. The orthopaedic implants developed in early 2000s got approval from Food and Drug Administration (FDA) to create organ implants. Germany developed surgical tool made from stainless steel alloy using 3D printing technique to remove the hip cups [43]. Copper3D NanoHack [44] mask is provided with an improved design and tested face mask to protect from COVID-19 virus. This mask has an input port for the flow of air and reusable filters hold by the screws. The design of the mask has also been modified with updated requirements.

Virtual wards and hospitals operated in many countries like Australia, UK and UAE during COVID-19 pandemic to provide remote monitoring and medical consultancy to the patients affected with chronic diseases and recovering from the COVID-19 virus infection [45]. A specialized thermometer, also called as connected inhaler, has been developed for the medical practitioners which provides a proactive approach to get in contact with the patients regarding appropriate use of inhaler and proper medication being taken.

1.4 Data Analytics and Challenges in the Healthcare

Data analytics is related to analysing present and past industrial data to improve and manage the industrial growth. In healthcare industry, healthcare analytics help in analysing the present technological trends, challenges in implementation and maintaining medical record. The analysis will improve the quality of service both for the patients and medical professionals. The healthcare industry will gain in terms of research and development, patient behaviour and their sentiment analysis, claims on medical cost, patient care and efforts, improving the conventional procedure [46]. Not only this, but data analytics in healthcare will also greatly help in detecting and

predicting frauds related to false insurance claims, unnecessary diagnose by hospitals and forged bills. The study and analysis of cyber-attack on medical data can also be predicted and cybersecurity can be provided as a precautionary measure.

1.4.1 Challenges in Healthcare Analytics

- The diverse nature of medical data makes it very difficult to compare, analyse and share the data. This is due to the use of vast varieties of medical software and their data formats. The interoperability of such record with different rules and regulations is very challenging.
- It was estimated by medical facility providers that 2314 exabytes of newer data will be generated by 2020 rising from the previous 153 exabytes of data in 2013 [46]. The storage of such a massive data is adding to the rise in cost of storage.
- Measurement of healthcare data need specialized data analysts which is again a factor that will add to the cost depending on the volume of the data.
- Other aspect of healthcare analytics is managing data related to donations, charity and grants. The optimization of this data is based on donor's previous contribution and retention.
- No doubt, with the advent of latest software tools and applications, the advantages of data analytics can never be questioned.

1.5 Conclusion and Future Scope

The healthcare ecosystem is becoming a technological hub to provide quality healthcare facilities at lower cost. This chapter directed about the various booming technologies like augmented reality, AI, robotics, blockchain technology, IoT and 3D printing in the healthcare industry. The intelligent systems developed based on various technologies have been discussed in separate section. The major aim, applications and challenges in implementing these technologies and impact of data analytics in healthcare industry are the key highlights of the chapter. It is concluded that the presented technologies can provide a proactive approach to many medical issues like remote monitoring, surgical operations, customized prosthetics during normal and emergency circumstances and have been globally accepted by researchers and medical practitioners for implementation. It is further concluded that data analytics in conjunction with the healthcare technologies will be beneficial for the mankind. Overall, there is a great interest and demand for these technologies to bring revolutionary changes in the healthcare industry.

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