Machine Learning with IoT and Big Data in Healthcare

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1 Introduction

Healthcare experts have taken a step ahead towards personalized healthcare, which incorporates artificial intelligence techniques with web-based and social media information, along with electronic health records (EHR), wearable devices, mobile devices, sensor devices and Internet of Things (IoT). Machine learning makes data collection easier and improves the tracking of disease propagation, effectively detects patterns and levels of transition, and ultimately builds the patient management systems with ease and at fast pace. The fundamental feature of learning models is to carry out analysis over collected sensor data and generate the patterns specifying behavioural characteristics and clinical requirements for the patients or affected population. Machine learning brings an automated image of healthcare systems. The theme of this chapter explains the significance of machine learning in healthcare. Learning models integrated with artificial intelligence and cloud computing create the foundation of IoT and big data technologies in healthcare.

The ambitions of artificial intelligence and machine learning have been greatly achieved in medical science. Artificial intelligence and automation have credited many discoveries to the various sectors of the digital industry globally, and machine learning has had its sway in recent times. Computer vision and image analysis are helpful in diagnostics. Deep learning plays a crucial role in applications used for diagnostics. It efficiently explores and updates the artificial intelligence process by utilizing the data sets of medical images. Microsoft carried out an InnerEye initiative. It works with the tools of image diagnosis. Big data uses business intelligence by data analytics for data-driven decisions. Predictive analytics assists in error-free treatment and minimizes fraud.

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Deep learning is extensively used to discover hidden patterns in clinical data and to explore potential strategies for treatment of patients. Thus, lowers the risks and efficiently diagnoses the life-threatening disease beforehand. IoT and wearable devices collect voluminous sensor data. These records and patient's information, treatment history, medical reports and insurance reports are processed by deep learning algorithms, and decisions are drawn. In recent scenarios around the globe, the COVID-19 outbreak has claimed the lives of more than 20 million people. Digital technologies involving machine learning, IoT, big data have become a powerful tool to tackle COVID-19. Effective monitoring, tracking, detection and prevention strategies have been developed using the digital framework.

2 Background

Machine learning is extensively used in various business domains. The techniques combined with artificial intelligence, deep learning, big data and data mining help researchers and scientists to understand relations and detect patterns in medical data. Knowledge Discovery in Databases (KDD) helps in analysing complex medical data generated from wearables, instruments and sensors. Machine learning facilitates the expert analysis of data. It accelerates the diagnosis and treatment of diseases with reduced time and reduced errors.

Ali Hasan in his work proposed efficient quality of service (QoS) methods through intelligent learning models for medical data processing [1]. Healthcare applications have been restructured with the development of machine learning in technologies such as IoT, cloud computing and big data. Idemen B.T., Sezer E. and Unalir M.O. presented how big data creates a scalable model in cloud application for data protection [2]. It uses machine learning algorithms to identify violations in data.

In the view of Yousefi S., machine learning provides efficient models in IoT to drive data analysis, communication and security in a healthcare system [3]. They also discussed challenges faced by machine learning approaches in IoT system. In the research published by Xie, he introduced a healthcare system that focuses on data optimization to save size and time during prediction [4]. Their work is concentrated on personalized healthcare with IoT. K. R. Dalal in his report presented an analysis of machine learning and how its implementation revolutionizes the healthcare industry [5].

3 Machine Learning

Machine learning handles massive medical data in a smart, fast and cost-effective manner with its learning models. It increases efficiency of data analytics for diagnostics, symptom research, pattern identification and patient treatment. Machine

learning contributes to intelligent healthcare for pattern analysis from big data and to study pathogens, viruses and symptoms of various diseases. Image-based diagnostics have gained accuracy with the help of machine learning models. Personalized healthcare and personalized treatment strategies are possible with machine learning.

Below are the machine learning algorithms widely used in Intelligent Healthcare framework.

1. Support vector machine (SVM) classifier: Support vector machine is a supervised learning model for classification and regression analysis. It builds a non-probabilistic, binary, linear classifier and separates input data by dividing it into categories as wide as possible. C. Venkatesan in their work presented how an SVM classifier is used for pre-processing and abnormality detection in ECG signal [6].
2. Naïve Bayes: It is a probabilistic classifier and assigns class labels to input data. B. A. Patel and A. Parikh developed a model by using Naïve Bayes classifier to predict anaemia [7]. They analysed different parameters of the complete blood count (CBC) test. In the study carried by N. Ravindran and O. A. Sheryl, they applied Bayesian classifiers to identify safe and unsafe scenarios when children play and generated a warning assistance [8]. The same methodology is applied to identify the normal and contraction time of a pregnant woman.
3. Decision trees: It is a predictive modelling machine learning approach. It splits input data into subsets based on an attribute value test. It does not require much computation to perform classification. Y. P. Sinha and P. Malviya in their work proposed a method for patient healthcare that acts as an automated, self-adapting and contextual care protocol [9]. T. Xie tested a research on Heartbeat Classification Algorithm Based on CART Decision Tree [10]. They proposed a new method for premature ventricular contraction (PVC) detection based on abnormal eigenvalues and decision tree.

Support vector machine algorithms have high accuracy rates compared to other algorithms of machine learning. But it also suffers with a drawback of a longer training period. It works with two classification algorithms, and SVM classifier would only classify whether the input symptoms are related to a disease or not.

Naive Bayes is extensively used for classifying reviews from patients in sentiment analysis. Naive Bayes helps in obtaining consumer and patients' thoughts as feedback on different drugs and medicines. Their sentiment helps to draw conclusions on whether a medicine is good or not effective for usage.

Application Areas of Machine Learning in Intelligent Healthcare

1. Pathogens – Machine learning has become a very efficient tool in detection of pathogens. The algorithms based on support vector machines and tools of feature selection are extremely popular to identify a set of pathogens and in discriminating their potential and impact. When a pathogen is identified early in a person's body, then it is far easier to initiate relevant treatment of the infectious pathogen. This reduces patient's panic, diagnostic, healthcare and medicine costs. The spread of microbial pathogens can also be controlled. Conventional methods of sampling a culture and tests are a week long process. The machine learning-integrated systems can perform detection and diagnosis in a time-efficient manner, with cost-effective steps. Learning models work with extremely huge and dynamic data sets. Therefore, they withdraw related information extremely fast. Artificial intelligence is a driver of machine learning. Together artificial intelligence and machine learning algorithms can determine various pathogens in effective computational time.
2. Shortage of doctors – Many countries face a serious shortage of healthcare service providers. Robots can serve the purpose and help solve this issue. Robotic process automation (RPA) is an emerging technological trend. RPA uses machine learning models, and in the healthcare sector, it provides a doctor-level medical knowledge. This is an excellent solution to overcome the shortage of qualified doctors.
3. Decision-making – Natural language processing (NLP) offers assistance to physically challenged and handicapped staff and paralytic patients. The integration of machine learning in IoT assists patients in their routine activities.
4. Clinical examination – Early diagnosis of high-risk patients is easily done in an intelligent healthcare system with machine learning. Cancer and tuberculosis can be identified in its early stage. Screen and cell mutation can be observed.
5. Diagnosis of heart diseases – Heart is the most vital organ of the human body. SVM and Naive Bayes are used to detect heart diseases. Early diagnosis is a remarkable achievement of machine learning algorithms in healthcare.
6. Diabetes prediction – Diabetic patients have drastically increased across the world in the past two decades. Diabetes damages other organs of the body and also hinders the treatment of any underlying disease. Diabetes prediction systems are created using classification algorithms, such as KNN, Decision Tree and Random Forests. The algorithms work fast and have excellent accuracy.
7. Liver diseases prediction – Liver is also a significant organ in the human body. It plays a very important role in metabolism. Liver diseases such as fatty liver, cirrhosis, liver cancer and hepatitis are prolonged and life threatening. Various classification and clustering algorithms of machine learning help in the liver disease prediction system.

8. Robot-assisted surgery – It is a modern surgical procedure done with a robotic system. A camera and surgical tools are attached to robotic arms. Machine learning allows robot-assisted surgery with minimal or no invasion from a surgeon.
9. Enhancing genomic sequencing – Deep learning algorithms could improve genomic sequencing processes, identify DNA methylation and any polymorphisms, which may later cause a disease. Machine learning algorithms can successfully perform prediction on large-scale genome data.
10. Detecting tumours and cancer prediction – Detection and classification of tumours are being successfully done by machine learning algorithms. Deep learning algorithms are capable of detecting cancer and reducing error percentage in diagnosis of cancer. CNN is widely applied in the classification of cancer by features extraction from gene sequence data.

Advantages of Machine Learning

1. Deep learning is a step-ahead technology to machine learning. Problems that could not be solved by machine learning have been proven solvable through deep learning. The driver of deep learning is neural networks. Neural networks give accurate results during illness diagnosis.
2. Deep learning is widely used in domains of NLP, speech recognition and face recognition. Recognition techniques also help to find patterns and to carry diagnostics.

4 Big Data in Healthcare

Big data has become a catalyst in the intelligent healthcare industry. The Process Insights Data (PID) approach of big data drives the transformation of conventional healthcare systems. Big data aims to re-engineer the healthcare industry to deliver automation and future-ready robust services for enhancing their business value and to gain intelligence in innovation. Healthcare data gathered from patients and healthcare professionals provide insights of analytics to give meaning of data. Big data addresses complex data and discovers patterns and meanings to help patients, researchers, health policy-makers, doctors, etc. Big data creates data reservoirs that subsequently become the source of knowledge to drive the engine of healthcare system. The analytics approaches integrated with artificial intelligence and machine learning aim to predict information and perform data discovery. Commercial enterprises utilize big data and analysis to research behaviour of consumers.

The visualization tools of big data are the potential prospects of intelligent healthcare. Data analytics with big data are giving a rapid momentum to healthcare services. Personalized medicine, EHR and clinical practices help to employ

fast learning models. e-Health technology is emerging and rapidly growing with wearable sensors. They also support the promising tools of cloud computing. With deep learning models and convolutional neural network (CNN), low-level input data are extracted to gain high-level features and business insights. A knowledge-based healthcare system transforms towards online analytical processing (OLAP) with big data storage and analysis technology. There is a significant shift in the biological domain with feature extraction algorithms. Big data has potential for the future of intelligent healthcare. Its tools could detect and research environmental factors, UV radiation exposure, pandemic infections and their spread. Its decision-making and pattern recognition tools will help in assessing diagnostics and tests. A guaranteed treatment with effective and quality assured health services is delivered with big data. Big data helps in medical practices to design strategies for treatments, to deeply understand risks and complex diseases, in detecting safe drugs and medicines, and to compare diagnostic and prevention schemes. A better personalized treatment is based upon accurate information of benefits and risks. Big data generates accurate patterns and evident discoveries of predictions to help in decision-making. Big data aims to fill the void between clinical researches and medical practices. It gains insights from existing data by formulating hypotheses and deriving the cause of disease. Machine learning helps to create models that learn from data and design approaches for treatment to work with different patients in different environments. The deep learning strategies help to identify suitable drugs for any underlying cause. They also help in predicting epidemics and pandemics. For example, the COVID-19 outbreak was studied by identifying the patient clusters, by studying their symptoms taxonomies and then by defining outcomes based on biological, clinical and behavioural characteristics.

Big data methods are a powerful tool to understand huge amounts of data. It provides insights of data integrated with mathematical and computational approaches. The predictions and decision-making are facilitated by big data. Big data combined with artificial intelligence and parallel computing revolutionizes personalized healthcare. Diagnostic errors are reduced, and complex medical imaging is possible with big data [16]. The magnificence of big data lies in its power to keep the complexity of data but remove the influence of physical and biological factors on it. Medical data are voluminous and complex. Researchers face immense challenges in data exploration and data prediction. Big data efficiently handles real-time data exploration and enables data scientists and data analysts to predict future trends accurately. Thus, they make significant improvements in life-saving treatment strategies and cost of treatment gets reduced. Data analytics derived from big data tools are hugely transforming the healthcare sector. It is helping medical practitioners to create the right treatment plan for the patients at the right time.

Big Data Characteristics for Intelligent Healthcare

In data warehousing and data mining, there are three dimensions of data. The medical data emerging in huge volumes since the last few decades also exhibit these dimensions. The three dimensions that define the characteristics of medical big data are as follows:

1. Volume:
   The size of medical data is considered by its volume. Medical data are increasing with a rapid rate. EHR, medical imaging, genome sequencing, diagnosis, biometrics, sensors, wearable devices etc. are increasing the volume of medical data. Wearable devices and sensors continuously produce medical data.
2. Velocity:
   Since the inception of the client-server model in computing, data streams flow in a continuous manner. Data in intelligent healthcare is also emerging and growing rapidly. Devices in real-time applications produce data without delay.
3. Variety:
   Data in the medical domain also arrive in all shapes and sizes. Apart from a patient's physical characteristics data, there is also a variety of medical data in healthcare. Blood pressure and pulse rate monitoring, X-rays, ultrasound, CT scan, MRI, cancer and tumour biopsy, genome sequencing, RNA sequences, drugs and pharmacy are a few examples of variety in medical data. These heterogeneous data can be structured, semi-structured or unstructured.

Stages of Big Data Analytics

As discussed in the paper by M. Ambigavathi and D. Sridharan, there are 5 stages in intelligent healthcare for big data analytics [11]:

1. Data Collection and Storage:
   As discussed earlier, medical data are heterogeneous in nature. There can be various sources of medical data. Hence, the formats of data vary (variety). Data collection must take into consideration the security prospects and data privacy. Finding the correct metadata, which describes what kind of health data is stored, is also very difficult. All these issues are considered and resolved during the first phase of data analytics.
2. Data Cleaning, Extraction and Classification:
   Data from various sources is voluminous, and some information is not useful many times. If the not useful data is passed onto further phases, it only leads to computation errors and increases processing cost. Doctor's prescription, sensor's data, medical image and scan data are collected in an unstructured format. This must be transformed into the structured format before beginning the analysis. Adding and removing missing values are carried out in this phase.

3. Data Integration and Representation:
   The data obtained in previous phases are integrated to obtain detailed knowledge for effective data analysis. For example, the precise information of an electronic health record consisting of a patient's personal data, data of record creation, health status, diagnosis and treatment history, count of patient's visit, etc. are aggregated and shared among data analysts, researchers, hospitals and government agencies. Health records are sensitive data; this phase utilizes a suitable representation model for data representation in real-time scenario.
4. Data Modelling with Analysis and Query Processing:
   Diagrams, text and symbols are readable and easily understandable. Modelling helps to view interrelated data and relationships. Data analysis for the health data begins with query processing. Individuals produce a query to know the patient's health status. Big data analysts perform analysis according to the complexity of the query.
5. Data Interpretation with Feedback:
   Data interpretation is the final and important phase. It produces clear results that are later utilized in decision-making. The health reports are generated. Feedback is obtained from patients and decision-makers.

The integration of machine learning and artificial intelligence with big data has proven an innovative trend to fight the global COVID-19 pandemic. It is helpful in efficient screening, tracking of patients, contact tracing and predicting symptoms. Early detection and diagnosis of ailments is the major application of big data with artificial intelligence. During coronavirus spread, the pace of developing drugs and vaccines has accelerated, and big data assisted healthcare practitioners to combat the disease. Raju Vaishya in their paper discussed the role of big data as a decisive technology for analysing, preventing and fighting against the COVID-19 [12]. The significant application of machine learning models helped to detect the clusters of positive cases and to predict the spread of virus-predictive analytics tools. The collection of patient's data, asymptotic patients and recovery rate helps to analyse the spread using big data technology. The proficiency of learning models grows with real-life situations and data-driven tools. With machine learning and AI, big data framework mimics human intelligence.

The integration of big data with IoT is producing remarkable outcomes in intelligent healthcare [13]. Data collection, storage and analysis are done among cloud services. Patients at remote locations are assisted by doctors through various smart devices, and the emergency cases are also handled appropriately. Big data is the leader in computing technologies, leading the framework of intelligent healthcare. Information extraction, analysis and decision-making are greatly impacted with the inception of big data. Together with machine learning, big data and IoT are helping medical professionals in diagnosis and treatment of several chronic illnesses. Caregivers can now offer immediate help to patients.

5 IoT in Healthcare

Traditional healthcare has observed a digital transformation. This shift has gained momentum due to continuously emerging sensor data. Connected devices exchange seamless data. Data analytics with IoT and big data creates an intelligent healthcare framework. The decision support system created over IoT brings a technology-efficient healthcare platform, which is robust and caters preventive medical needs. The key factors of a decision support system are a data set, inference engine and communication model. With deep learning tools, the insights of patients' data are utilized for treatment of a disease and to explore the diagnosis of related risks for predictive analytics. Early detection of chronic diseases is supported by decision support systems. They are now extensively used in automated analysis systems. IoT establishes a high-end connected network with devices and shares information. It aims to provide the following:

1. Better user experience.
2. Personalized healthcare.
3. Multiple stakeholders communicate at a single platform with information on multiple technologies.
4. Secure platform for a wide range of protocols and applications.
5. It plays an efficient role in diagnostics, monitoring and assistance.

IoT (Internet of Things) is a technology that connects smart devices and wearables to network applications. They track health records, medical history, diagnosis, treatment and risks. The entire hospital management system is being revolutionized with IoT [17]. Examples of IoT devices are fitness bands, fitness trackers, pulse oximeters, smart clothing, wearables, smart glasses, etc. IoT increases physician's engagement with patients, resulting in improved treatment results and reduced costs of healthcare. IoT benefits all elements of a healthcare system, that is, patients, families, physicians and insurance business. Patients are able to access personalized treatment and attention with wearables and digital devices. Patients have handy records of their calorie intake, workout information, blood pressure and heart rate reports. Healthcare providers are also equipped with IoT and monitoring systems. They keep track of the patient's fitness and well-being. Physicians stay alert with patients and connect with them proactively. With predictive analysis, the physicians could find the best treatment for patients. Hospitals utilize IoT technology to track hospital supplies and equipment. Wheelchairs, nebulizers, monitors, oxygen pumps etc. are labelled with sensors and their real-time location can be easily monitored. Infection control is also monitored with IoT-enabled devices. Data acquired by health monitoring sensor devices are supportive to health insurance companies. Claims handling, pricing underwriting and risk assessment process are enabled through IoT-driven framework. Fraud claims can also be detected early and valid claims are adhered to treatment measures.

IoT Application Areas in Healthcare

1. Electronic Health Records

   Data management is the most attractive essence of IoT. The global medical records are increasing with each passing data and bring along significant challenges in data management. It is estimated that compound annual growth rate (CAGR) of healthcare data will rise by 36% by 2025. The fundamental focus of the IoT paradigm is healthcare records. In the last few years, nearly 90% of medical set-ups have adopted electronic health records (EHR) and electronic medical records (EMR). IoT offers an efficient platform to collect, store and process data. The electronic health records store medical history of patients, their allergies and follow-up details. EHR is the most important and highly used application of IoT in healthcare. It offers robustness in record keeping and efficiently manages consistency in creation of records. It is also a cost-effective application that eventually makes saving in millions to stakeholders. Medical devices, fitness watches and wearable devices produce data that are integrated with the cloud network of healthcare systems. This data are used at patient, hospital, robot and network levels.
2. Pharma and Drug Discovery

   IoT in pharmaceuticals is an advanced technology to discover treatment opportunities for new emerging diseases. IoT enables management of medication and tracks records of improvement in patient health conditions. Development of drugs, management of supply chain and clinical trials are now based on IoT solutions. Sensor devices and connected technologies are improving the concept of personalized healthcare. IoT boosts competency and innovation among healthcare providers. Big data and analytics play a crucial role to improve a patient's quality of life. Time and costs of research and development are reduced. Data are handled in an efficient way with great speed in the development of medicines and drugs. The process of clinical trials and experiments gets shortened to find conclusions. IoT sensors handle chemicals and biomaterials flawlessly ensuring controlled manufacturing and preventing drug fraud. For example, Itransition is an expert software development company in the healthcare industry. It delivers custom healthcare solutions. Itransition builds IoT-based health applications and utilizes cloud data to collect and monitor data analytics. Pharma industry needs 24×7 monitoring of the drug discovery process. Maintenance of equipment is also crucial. IoT continuously tracks status information in drug manufacturing units for air compressors, vacuum pumps, sterilizers, temperature, pressure, pH probes, labels, RFID tags etc. The sensor devices of IoT technology are performance oriented and optimize predictive equipment maintenance. Small IoT sensors are produced by AntTail, a Dutch start-up, and these can be directly placed on drug packages. Thus, they monitor the manufacturing process down supply chain with GPS-enabled vehicles.

3. Personalized Treatment

   IoT framework is a great advantage for healthcare professionals in treating patients. It provides medical history through sensors, wearables, wireless technology and mobile networks. Entire data are stored in a single cloud network and are easily accessible. Personalized and custom-tailored treatment plans and diagnostics can be prepared. A patient with diabetes has a health record on a secure cloud. This is readily accessed by medical staff on mobile devices or desktop computers. Test samples record, lab results, prescription details are easily accessible, and in no time the patient will be suggested what things he has to avoid, medicine suggestions and work out details if needed. Remote care is also facilitated by IoT, as it provides a virtual hospital concept to patients. The medical facilities and healthcare entities are remotely accessed by patients with connected things remotely on an intelligent platform.
4. Decision Support Systems

   Decision support systems have increasingly become popular in providing evidence-based clinical decisions to healthcare providers. They examine electronic health records and suggest reminders to healthcare staff, providing information related to treatment protocol. Decision support systems are widely used in IoT-based data analytics. It not only suggests treatment strategies but also helps in building models for identifying risks and treatments. With data analytics, it is faster and easier to recognize risks, narrowing down the diagnosis and prescribing the treatment. Remote care platform can also be built upon this. A customized and efficient strategy for treatment can be devised by healthcare personnel. Artificial intelligence and machine-learning-integrated IoT framework executes without manual intervention and reduces the cost significantly. IoT devices monitor physiological parameters. The clustering of the records provides an impactful parameter to draw inference. The action plan of early detection, diagnosis, risks identification and treatment could be smoothly executed with decision support systems. K-means clustering has been extensively used to create decision support system models.
5. Remote and Virtual Care

   It is another cost and time effective healthcare model lying on the foundations of IoT. It offers not only consultation at home scenarios but also automated test procedures through IoT devices and sensors. Wearable devices have sensors that provide intelligent analytics and assist in remote monitoring of patients. With the concept of IoT in healthcare, patients do not depend exclusively on hospitals. They do not need to visit clinical settings. Remote patient monitoring (RPM) has emerged as a technology and sub-domain of IoT infrastructure. It is a virtual healthcare model. Patients can access care and treatment at the comfort of their home or in a remote area. Thus, the delivery cost for healthcare services decreases. It aims to deliver services through telecommunications. It not only decreases the hospital costs but also signals early health deterioration. Super quality virtual healthcare is offered with continuous monitoring of patient's health progress. Many elderly patients stay remotely or away from their families. Upon any variation in their routine activities, an alert signal is sent to family

members and concerned healthcare personnel. This is a benefit of IoT for remote healthcare. Physiological data obtained by wearable sensors help healthcare personnel in making medical decisions. It is also beneficial in passive medication and suggesting and monitoring healthy lifestyle. Remote healthcare has been proved accurate and efficient as conventional healthcare.

IoT-enabled healthcare platform and big data analytics establish an excellent communication collaboration link between patient and caregiver. Wearables, intelligent sensors and wireless technology promote the concept of distributed services in healthcare. Patients need not to be hospitalized for weeks or months. Patients are remotely monitored and virtual healthcare is provided with proactive treatment. Researchers have also observed that IoT and big-data-based healthcare services led to reduction in death toll of patients. Patients get freedom from being attached to heavy machines and syringe tubes. Portable devices offer ease of movement and comfort.

IoT Offers Following Advantages in Healthcare

(i) Reduced Cost

The real time monitoring is facilitated by IoT technology. This considerably reduces physical visits to clinics, OPD admissions and hospital stays.

(ii) Optimized Diagnosis and Treatment

Analytics help in pattern matching and decision-making. Real-time constant monitoring of patients helps in early diagnosis of disease, symptoms are identified and treatment plan is generated.

(iii) Proactive Treatment

IoT devices and sensors work 24 $\times$ 7 and offer proactive treatment in medical emergencies.

(iv) Management

Pharmacy, inventory, drugs and equipment management is challenging in the healthcare industry. IoT opens doors for effective management and efficient utilization of existing infrastructure.

(v) Reduced Errors

Healthcare operations are carried out smoothly and waste generation is reduced with IoT. This also leads to reduced errors in hospital services and creates a robust healthcare system.

(vi) Remote Access to Villages and Far Locations

Better healthcare services are in approach to remote towns and villages. IoT provides good healthcare to such areas upon integration with hospitals and governments.

(vii) Assistance in Health Insurance

Data collections, claims processing and fraud claims identification are carried out with transparency with device monitoring. IoT devices also

justify whether a patient was aligned with treatment guidelines by monitoring recovery phase.

IoT methodology is proved optimal and proficient in the fight against COVID-19 pandemic. Its tools offer adequate facilities to cope with a situation like global coronavirus outbreak. The Internet of Healthcare Things (IoHT) and Internet of Medical Things (IoMT) have emerged as the latest tools to resolve the pandemic situation. IoT has helped government bodies and medical authorities to prepare guidelines for safety and to develop facilities of treatment. IoT laid a monitoring system to keep track of infected patients in quarantine. It made biometric diagnostics easier with the internet-based network. The disease is still on its growing curve, and IoT ensures effective virus control with enhanced diagnostics and proper treatment. With IoT methodology, there are error-free scenarios as machine learning models and wearable devices work with integration to generate analysis and patterns. Infected patients are assured effective treatment with low expenses and accuracy. This technology resulted in workload reduction from clinical workers with a significant improvement in their work efficiency. Remote monitoring of patients becomes easier with IoT. Lockdown in various nations across the globe has posed challenges in healthcare. Virtual follow-up and consultation of mild health issues have been encouraged. With the growing spread of COVID-19, there is increased utilization of interconnected networks. IoT deployment allows connected services to work with effective flow of data and enables continuous exchange of data. Identification of patient clusters is optimized with mobile application. Several innovative ways for better quality of care have been identified. Indian government has launched the Arogya Setu mobile centric application. It is a digital framework to capture patient information. It tracks and alerts interconnected devices for an efficient health management system.

IoT and big data together helped health systems with predictive analytics models for determining the impact of coronavirus, disease outcomes and to gain insights of COVID-19 risk. Majority of the population is still vulnerable to COVID-19 disease. There has been a strong economic impact globally due to the virus outbreak. The biological race of Coronavirus is similar to SARS-CoV, which was observed in 2002. Less social distancing and higher mobility increase the risk of virus spread. The hospitalization risk can be calculated by a predictive analytics model. Asymptomatic patients are less likely to be hospitalized. Patients with underlying lungs diseases, diabetes, hypertension, children under the age of 10 years and citizens over 60 years of age are prone to be caught by the virus. The future of the COVID-19 crisis depends on genome sequences of patients and their social interactions. Population spread over a region is explored for identifying the virus spread. The healthcare services are focussed on patient-centric, cost-saving, accessible and customized workflows.

6 Challenges

It is challenging for deep learning models to present 'how' a prediction happened. How it arrives at a recommendation is not specified by the deep learning system. Training a model for massive and heterogeneous data is challenging with sparse noisy data. There are considerations for ethical practices, legal implementation of tools, healthcare worker's understanding of machine learning tools and data security.

There are challenges associated with the use of machine learning in IoT and big data. In the view of F. Ahamed F. Farid, data transmission and data security remain the issues in personalized healthcare [14]. Clinical response, lifestyle and behaviour of patients are very sensitive data. Learning algorithms cannot judge the bias involved in data collection and interpretation. This leads to incorrect decision-making. Lack of availability of domain experts and scientists is a global issue in intelligent healthcare. The domain of many diseases and medical conditions is complex and not much explored. Strong and efficient interoperable training models for image and speech analysis are yet to be developed and learned. In the context of routine clinical research, big data poses challenges in data analysis and data security.

According to research [15], reproducibility remains an obstacle in the progress of intelligent healthcare. The interpretation of new findings and their validation validated in context of their uses and complexity is an emerging issue in personalized healthcare. Multiple hypothesis, random analysis and incomplete documentation is challenging in reproducibility. However, underlying data access is restricted, but data could be replicated to train a learning model. Connected devices brought along the advantage of real-time monitoring of patients and have saved the lives of millions of patients during medical emergencies. But it also brings huge challenges. Continuous monitoring under IoT devices collects large volumes of data. This also captures sensitive information. Data security is the major concern with IoT in healthcare. Data protocols and standards often fail to meet compliance with government policies and regulations. Data ownership is a critical issue.

Delays and bandwidth insufficiency are also faced by IoT devices. In many countries, there is a lack of backbone support infrastructure for IoT frameworks. Techniques for delay tolerance are not incorporated in the system. Untrained medical staff is also a challenge in information collection. Most of the data are collected from sensors and wearable devices. Hence, interfaces must be simple and easily accessible. If the medical staff are not properly trained, then the information cannot be efficiently utilized. The quality of service will also get compromised.

7 Solutions and Recommendations

Healthcare and medicine are a profession involving lots of information. They are an excellent field for studying and investigating data science to learn clinical

research and examine findings. The programming framework of Hadoop is the first choice in the medical domain for learning, analytics, NLP, pattern finding and decision-making. Big data offers inexhaustible data sources to enterprises involved in medical research. IoT further leads to addition of massive data sets. Patients symptoms, functional behaviour, medical treatment, diagnostics, test reports, etc. emerge endlessly. Data quantity gives rise to security concerns. Safe measures need to be developed for resolving privacy issues. Data sharing runs in a continuous flow within a healthcare system. Therefore, a balanced model of data security is built to mitigate risks of cyber security and data theft.

Machine learning models in decision-making help to isolate unnecessary data and reduce study over redundant data. For example, the symptoms that adversely affect the patient are important. General symptoms that are not connected to complex health conditions are not executed during training of machine learning models. Predictive analytics plays a vital role in this scenario. It anticipates prediction for data that might raise a patient's risk by gaining insights from data. It also controls false predictions through advanced data analytics by revealing similarities and patterns. Image diagnostics and object classification is the excellent utility of machine learning models. It rapidly detects patterns through automated routines. This boosts the performance of an intelligent healthcare system through improved health services to patients and interactive automated processes.

Hospital expenses are skyrocketing, and medical professionals aim to develop innovative healthcare services that would communicate health-related issues among patients and doctors, report personalized insights by decision-makers, improve patient experiences and reduce treatment costs. The incredible potential of machine learning along with big data and IoT will harness the real value of artificial intelligence, sensor devices and predictive analytics. Deep learning, artificial intelligence and predictive analytics tools are helping early diagnosis of several infant diseases, autism, cancer, cardiac illness and heart failure diagnosis.

8 Future Work

The strength of big data will help to develop ready solutions with low costs for health practitioners in intelligent healthcare. The data obtained from electronic health records, sensors and wearable devices are the potential information in healthcare. The research practices will boost and will be carried at a fast pace. Diagnostics and predictive data analytics will meet the needs of healthcare workers, patients, clinicians, drug discovery and equipment designing in future. Machine learning in IoT and big data will contribute to build an intelligent healthcare system with continuously emerging patient records and experiences.

IoT framework and big data technologies give entries to heterogeneous data. Therefore, data with multiple dimensions arrive unexpectedly in the healthcare system. This brings challenges in data pre-processing. Advanced machine algorithms are needed to understand patient care factors. Patient's recovery after treatment, bio-

logical response and physical behaviour accelerate learning algorithms in generating predictions. Deep learning opens the door for a predictive healthcare framework and will support health practitioners in daily routine tasks.

Machine learning models can make predictions of required assistance for patients but also defer the decision of the human clinicians, based upon the human expert's experience and availability. Some situations pose obstacles with artificial intelligence tools. When an AI setting works with a new healthcare expert, it also needs to learn the expert's behaviour and other judgement parameters. Trust and biased instinct of experts become an issue to artificial tools.

Big data and its analytics tool will prove to be a powerful technology for improved population health management. The provision of comprehensive and holistic care to patients is defined under the principles of population health management. EHR, insurance claims, notes and records provide sufficient information for patient management. Big data strategies will help to build and improve the plan for population health management. Future trends are understood by analysing gender and age and living conditions, history of illness is reported and machine learning models implement such data at a wider scale. The socio-economic data are also a determinant to make predictions and define treatment plans.

9 Conclusion

Medical practitioners need to upskill and learn new tools developed from learning models and research in data analytics. It is also essential that they are trained to understand knowledge discovery and reports derived from new approaches. Nations must define a substantial budget and funding policies to enhance research in machine learning and to integrate expert systems in healthcare. Current era is the most promising time for promoting medical science to strengthen the patient care system and to gain a remarkable growth in intelligent healthcare.

The collaboration of machine learning with IoT and big data is the best opportunity to ensure qualitative patient care. Patients and healthcare providers are the major role players in a healthcare system. A technologically efficient system of healthcare ensures safety in diagnostics, drives error-free treatment plans and enhances value of the medicine science system. Speed of the automated computer-driven system is the fundamental factor to determine abilities of a healthcare framework. Efficiency is the second dimension. The accuracy of data analytics is examined during decision-making. Next important dimension is the quality of data. Big data floods healthcare systems with massive and complex data repositories. Data pre-processing models must intensify their proficiency to produce quality data and knowledge to aid prediction and pattern recognition.

Recent COVID-19 crisis has brought huge and immeasurable trouble to human society and especially to the economy. The disease was still observed on a growing curve until August 2020. There is a prediction that positive cases will further arise and the death toll might increase substantially. The pandemic caused great

challenges and serious problems in healthcare services. Machine learning models have been proved trusted and reliable so far. IoT and big data technology helped the medical domain to provide personalized care to patients, and resource monitoring is carried with ease. However, many times, uncertainties also arise. The learning algorithms basically rely on sensor data. These data are used to recognize patterns in behaviour of the patient. Each and every recorded activity from a patient's routine is crucial in determining patterns. In this context, there is often a skewed decision because the patterns could judge sensitive data incorrect. Collection of data and its interpretation can be biased without human knowledge.

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