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Role of Artificial Intelligence in Medicine and Clinical Research

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Abstract: Artificial Intelligence is a branch of computer science that enables to analyse complex medical data. The proficiency of artificial intelligence techniques has been explored to a great extent in the field of medicine. Most of the medications go to the business sector after a long tedious process of drug development. It can take a period of 10-15 years or more to convey a medication from its introductory revelation to the hands of the patients. Artificial Intelligence can significantly reduce the time required and can also cut down the expenses by half. Among the methods, artificial neural network is the most widely used analytical tool while other techniques like fuzzy expert systems, natural language processing, robotic process automation and evolutionary computation have been used in different clinical settings. The aim of this paper is to discuss the different artificial intelligence techniques and provide a perspective on the benefits, future opportunities and risks of established artificial intelligence applications in clinical practice on medical education, physicians, healthcare institutions and bioethics.
Keywords: Artificial intelligence, clinical trials, medical technologies, artificial neural networks, diagnosis.

I. INTRODUCTION

Artificial Intelligence can be defined as a field of science and engineering that is concerned with the computational understanding of what is commonly known as intelligent behaviour, and with the creation of artefacts that exhibit such behaviour [1]. The British mathematician Alan Turing (1950) was one of the founders of modern computer science and AI. He defined intelligent behaviour in a computer as the ability to achieve human-level performance in cognitive tasks, which later became popular as the 'Turing Test' [2]. Medical technology is used to arrange a range of tools that enable health professionals to provide patients and society with a better quality of life by performing early diagnosis, reducing complications, optimising treatments and reducing the length of hospitalizations. Currently, modern medicine is facing the challenge of acquiring, analysing and applying the large amount of knowledge necessary to solve complex clinical problems. Development of medical artificial intelligence is related to the development of AI programs which are intended to help the clinician in the formulation of a diagnosis, making of therapeutic decisions and prediction of the outcome. Such systems include Artificial Neural Networks (ANN), fuzzy expert systems, hybrid intelligent systems and evolutionary computation. The development of intelligent medical technologies has enabled the development of a new field in medicine – augmented medicine. Augmented medicine is not only enabled by AI-based technologies but also by other digital tools, like surgical navigation systems for computer-assisted surgery [3], virtuality-reality continuum tools for surgery, pain management and psychotic disorders [4].AI based systems are designed to support healthcare workers in their everyday duties and assisting them with tasks that rely on manipulation of data and knowledge.

II. ARTIFICIAL INTELLIGENCE BASED SYSTEMS IN MEDICINE

Artificial Intelligence is not one technology, but rather a collection of them. Many of these technologies have immediate relevance to the healthcare field. Some important AI technologies widely used in the healthcare domain are defined and described below:

A. Artificial Neural Networks

An artificial neural network (ANN) is a piece of computing system that is designed to simulate the way the human brain analyses and processes information. They comprise of networks of highly interconnected computer processors called 'neurons' that are capable of performing parallel computations for data processing and knowledge representation. They have the ability to learn from historical examples, analyse non- linear data, handle imprecise information and generalize enabling application of the model to independent data. These self -adaptive models were first developed in the 1960s, but they reached great popularity only in the mid – 1980s after the development of back propagation algorithm by Rumelhart et al. [1986]. Neural network research has its origins in the work developed by McCullough and Pitts [1943], who developed mathematical models based on observational studies of real neurons. The next important milestone came from Frank Roseblatt, a psychologist developed the perceptron in 1958 as a practical model [5]. These networks are made up of layers of neurons, which consists of an input layer, one or more middle or hidden layers and an output layer, each of which are completely connected to other layers. Neurons are connected by links and each link has a numerical weight associated with it. An important characteristic of ANNs is that they can learn from their experience in a training environment.

The diagnosis, treatment and the prediction of outcome in a clinical situation is dependent on a complex interaction of clinical, biological and pathological variables which necessitates for analytical tools like ANN that can exploit the intricate relationships between these variables. The medical literature also has numerous examples of neural network models. They have been employed as statistical tools in solving problems that include prediction of diagnoses such as giant cell arteritis, prognoses, such as valve-related complications in heart disease and several types of cancer. Baxt was one of the first researchers to explore the clinical potentials of ANNs [6]. He developed a neural network model that could accurately diagnose myocardial infarction. Since then, ANNs have applied in every field of medicine [7].

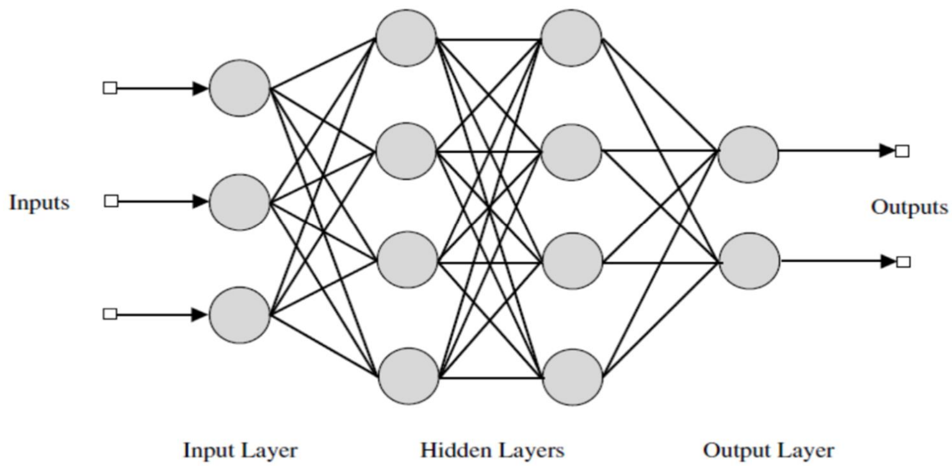

Fig. 1.1 A multilayered feedforward artificial neural network.

B. Natural Language Processing

Natural language processing is the ability of computers to understand the latest human terms speech and text. NLP includes applications such as speech recognition, text analysis, translation and other goals related to translation. There are two approaches to it – statistical and semantic. Healthcare language processing uses specialized engines that are capable of scrubbing large sets of unstructured health data to discover previously missed or improperly coded patient conditions. The development of open-source NLP software specifically tailored to clinical text has led to increased adoptability. The field of mental health has shown an increase in the use of NLP strategies and methods because most of the clinical documentation is in free text arising from the increased availability of other types of documents that provide behavioural, emotional and cognitive indicators as well as cues on how patients are coping with different treatments and conditions [8]. Such text sources include social media, doctor-patient interactions and online therapy. NLP systems can analyse unstructured clinical notes on patients, prepare reports (as in radiological examinations) and also conduct conversational AI.

C. Fuzzy Expert Systems

Fuzzy logic is the science that involves the reasoning, thinking as well as the inference which recognises and uses the real word phenomena. Fuzzy systems have been successfully applied in healthcare because of their ability to infuse human expert knowledge as well as granular computing to describe the behaviour of complex systems without requiring a precise mathematical model. Medical datum is a single observation of a patient, hence medical data is a combination of different observations of a patient. Medical data analytics is a term which describe the medical analysis activities that can be undertaken on medical data. Although medical analysis is one of the important aspects of life, it is impossible to give the exact definitions and symptoms of medical concepts and the relationship between the concepts in most of the cases. This uncertain nature of medical field necessitates the use of fuzzy logic or its combination with other AI techniques. Fuzzy logic was popularised by Lofti Zadeh (1965) an engineer from the University of California [9]. Fuzzy logic makes use of a continuous set membership from 0 to 1 in contrast to Boolean or conventional logic that uses sharp distinctions like 0 for false and 1 for true. Torres and Neito [10] have explained in their paper that diagnosis of a disease involves several levels of uncertainty and inaccuracy. Moreover, a single disease can appear in many forms based on the patient, and with different intensities. A single symptom may also correspond to different diseases. To deal with this inaccuracy and uncertainty, fuzzy logic uses fractional truth values between YES and NO.

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The techniques of Fuzzy Logic have been explored in several medical applications. FarzanaIslamet al.[11] used adaptive neuro-fuzzy inference system with a fuzzy C-mean classifier in order to predict risk for stroke which is useful for medical experts. Schneider et al. [12] showed that fuzzy logic performed better than multiple logistic regression while diagnosing lung cancer in tumour marker profiles. Application of fuzzy logic has also been explored in the diagnosis of acute leukaemia [13], breast cancer [14] and pancreatic cancer [15]. Moreover, fuzzy controllers have been designed for the administration of vasodilators that can control blood pressure in the peri-operative period [16]. They are also used for administering anaesthetics in the operating room [17].

D. Robotic Process Automation

Robotic Process Automation (RPA) is an emerging form of business process automation technology based on the notion of software robots or artificial intelligence (AI) workers [18]. This technology relies on the combination of workflow, business rules and 'presentation layer integration' with information systems to act like a semi-intelligent user of the systems. The main entities of healthcare are patients, doctors, insurance companies, etc. In order to maintain a balance between the increasing number of patients and paperwork that is needed for follow up and insurance claim, there is a requirement of a more efficient and accurate back-office space process. RPA can help healthcare organizations increase operational efficiency, lower costs and limit the possibility of human error while processing information like Physician Credentialing, Coding, Claims Administration, Clinical documentation, Medicare billing and compliance, Secondary claims Management, Accounts receivable and denial recovery, and Patient self-pay administration [19]. In addition, the healthcare companies face challenges in bringing new drugs to the market since they need to maintain their quality along with efficiency and profitability. The innovation processes in the healthcare industry often face regulatory and reporting challenges which can be addressed using the process automation solutions. These solutions help the healthcare companies to improve safety and bring effective drugs to the market [20].

E. Evolutionary Computation

Evolutionary computation is the term for several computation techniques that are based on natural evolution process which imitates the mechanism of natural selection and survival of the fittest in order to solve real world problems. A widely used form of evolutionary computation that has been used in many medical applications include 'Genetic Algorithms' that was proposed by John Holland [21]. Genetic algorithms are probabilistic search procedures designed to work on large spaces involving states that can be represented by strings. These methods are inherently parallel, that uses a distributed set of samples from the space (a population of strings) to generate a new set of samples. They basically work by creating random solutions to the problem at hand; this population of solutions then evolve from one generation to the next, thus arriving at a satisfactory solution to the problem. Overtime, the best solutions are added to the population whereas the inferior ones are eliminated. Genetic algorithms are employed to perform several types of tasks like diagnosis and prognosis, medical imaging and signal processing, planning as well as scheduling. These algorithms have been widely used to predict outcome in critically ill patients [22], melanoma [23], lung cancer and response to warfarin [24]. Moreover, they have been used for analysing computerised 2-D images to diagnose malignant melanomas and MRI segmentation of brain tumours to measure the efficiency of treatment strategies.

III.CURRENT APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN MEDICINE

Some of the areas of medicine where AI has been used to a great extent are described below:

A. Artificial Intelligence in Cardiology

Despite the significant advances in diagnosis and treatments, cardiovascular diseases (CVD) still represent the leading cause of mortality and morbidity worldwide. In order to improve and optimize CVD outcomes, AI techniques have the potential to radically change the way of the practise of cardiology, especially in imaging, offering us novel tools to interpret data and make clinical decisions.

1) *Cardiovascular Risk:* Considering the electronic patient records, AI has been able to predict the risk of cardiovascular diseases like acute coronary syndrome [25] and heart failure better than the traditional scales.
2) *Atrial Fibrillation:* One of the first applications of AI in medicine include the early detection of atrial fibrillation. Atrial fibrillation is the most common cardiac arrythmia and is associated with multiple health risks including stroke and death. Screening for and identifying undetected atrial fibrillation is critical to ultimately prevent strokes. In 2014, AliveCor received FDA approval for their mobile application Kardia , allowing a smartphone-based ECG monitoring and detection of artificial fibrillation [26]. The recent REHEARSE-AF study showed that remote ECG monitoring with Kardia in ambulatory patients is more likely to identify atrial fibrillation than routine care [27].

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B. Artificial Intelligence in Endocrinology

AI/ML based algorithms have been extensively utilized and validated for diagnosis and classification of diabetic retinopathy. Continuous glucose monitoring enables patients with diabetes to view real-time interstitial glucose readings and provides information on the direction and rate of change of blood glucose levels [28]. ML algorithms have demonstrated the ability to incorporate associated risk factors such as duration of diabetes and insulin use into risk-stratification of diabetic retinopathy that could potentially facilitate the development of better clinical decision support systems. A proprietary system IDx (Iowa City, IA) that uses ML technology to analyse retinal images with diabetic retinopathy had a sensitivity of 87% and specificity of 91% for autonomous detection of disease and received FDA approval in 2018 [29]. Today AI technologies like artificial pancreas for management of diabetes have already become a reality. Major efforts from academia and the information technology industry can push for further development of AI/ML technology in endocrinology.

C. Artificial Intelligence in Neurology

Neurological disorders are the diseases that are connected with peripheral and central nervous systems. The abnormal or the anomalous neurological conditions are identified by a neuropathological examination. Epilepsy, a chronic neurological disorder is defined as "disorder of brain characterized by enduring predisposition to generate the epileptic seizures." The overall incidence of epilepsy is found to be 23-190 per 100,000 of population. MS, a disorder caused by a condition called inflammatory demyelinating of the nervous system is the most common among neurological disorders. Authors have been advocating a research ideology that computer – aided diagnosis (CAD) system trained using lots of patient data and physiological signals and images based on adroit integration of advanced signal processing and artificial intelligence (AI) / machine learning (ML) techniques in an automated fashion can assist neurologists, neurosurgeons and other medical providers to make better clinical decisions [30]. A typical ML based CAD system comprises of the five stages: Signal transformation, Feature extraction, Feature dimensionality reduction, Optimal feature/selection ranking and Classification.

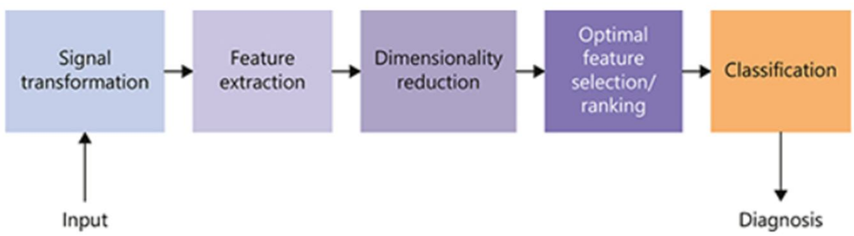

Fig. 2.2 General block diagram of a typical ML-based CAD system

At times, highly trained and specialized neurologists and associated facilities for the diagnosis of neurological disorders may not be available in remote towns and villages. Fig. 1.3 given below shows a prototype for a cloud-based CAD system for diagnosis of neurological disorders using Internet of Things. The signals or images of the patients are transmitted to the cloud where a trained ML-based CAD can provide the diagnosis.

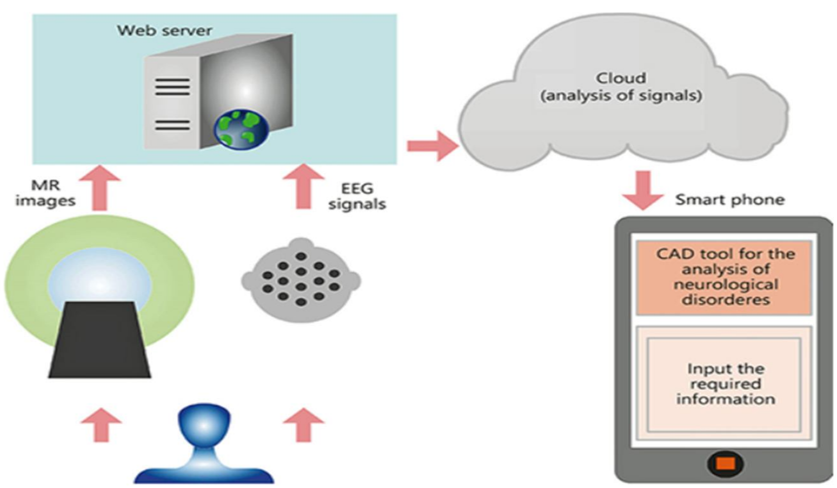

Fig. 3.3 Prototype of a cloud based CAD system for diagnosis of neurological disorders.

D. Artificial Intelligence in Precision Oncology

Precision oncology is defined as the precise targeting and characterization of individual tumor cells. It is a treatment strategy in the fight against cancer which is focussed on the finding of specific molecular targets. The recent advances in clinical oncology involve AI based novel molecular strategies. One such platform is Next-generation sequencing (NGS) which can generate high throughput datasets. In addition, it involves the input of designing algorithms for early-stage cancer detection by identification of novel biomarkers and target sites, precise diagnosis by NGS sequencing and identification of selective target N sites. NGS data can guide the algorithm to suggest effective therapy, taking into consideration the personalized genetic factors. Depending on the genetic variability, precision oncology drugs are designed to target specific cancer cells. [31]

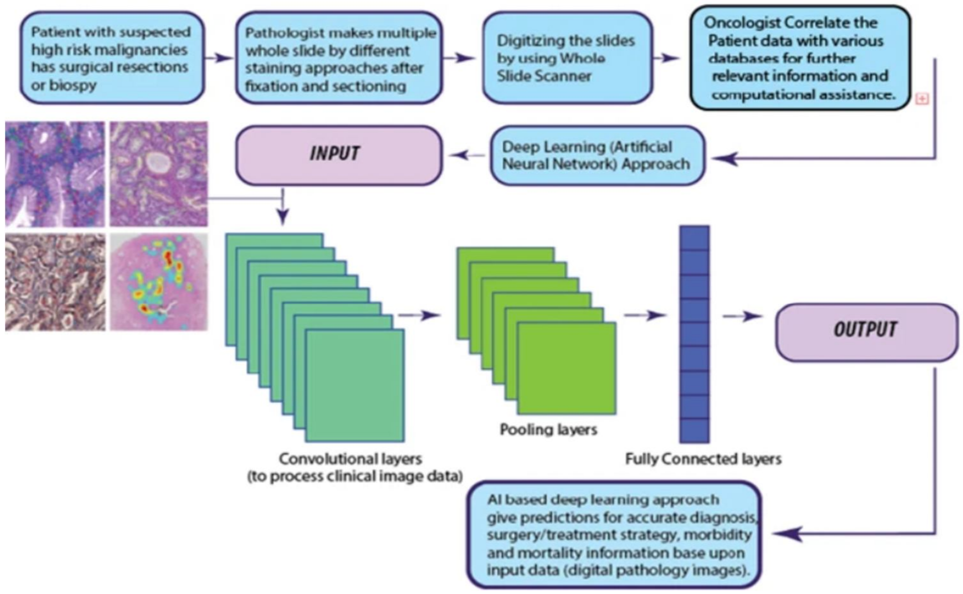

Fig. 4.4 Workflow for Artificial Intelligence Approach for digital pathology

AI has been ranked among the top futuristic therapy for precise cancer diagnosis, prognosis and treatment after systematic processing of data from clinical big datasets. Digital healthcare is believed to transform the use of algorithm base AI assistance for e-health records, data mining and radiology image analysis to deliver a more precise solution for cancer treatment.

IV. ETHICAL IMPLICATIONS OF ARTIFICIAL INTELLIGENCE IN HEALTHCARE

Artificial Intelligence has a substantial impact on the healthcare processes. It can affect treatment and diagnosis showing serious ethical considerations. The therapeutic innovations of AI range from virtual psychotherapists to social robots in dementia and autism disorder. A huge number of therapeutic chatbots, social assistive devices are translated into clinical application. Their ethical concerns primarily include their long-term application which can lead to complete patient dependence in the future. One of the most important concerns in today's AI include transparency. Many algorithms, particularly deep image analysis algorithms are even impossible to explain or interpret. Medical technology has been one of the most promising markets of the 21st century with an estimated market value approaching a thousand billion dollars in 2019. In the last couple of years, several wearable companies have been concluding important deals with insurance companies or the government to organize initiatives that are aimed to induce lifestyle change in large populations. With many western countries continuing to evolve toward health systems that are centred around patient's individual responsibility of health and well-being, the ethical implications of the ongoing monitoring with the help of medical devices are often discussed. For e.g., ongoing monitoring and privacy violations have the potential to increase stigma around chronically ill or disadvantaged citizens [32] and possibly penalise those citizens that they are unable to adopt new standards of a healthy lifestyle. However, little to no debates have been focussed on these potential pitfalls in health policy making. Under such circumstances, the issue of data protection and ownership becomes more crucial. Although some works argue for the common ownership of patients' data to profit personalized medicine approaches, consensus has been slowly shifting towards patient ownership since it has a positive impact on patient engagement. Moreover, it improves information sharing if a data use agreement between the patient and healthcare professionals is developed [33].

V. CONCLUSIONS

The implementation of artificial intelligence in medical healthcare is a promising area of development that has rapidly evolved together with modern fields of precision medicine, genomics and teleconsultation. Optimal decision- making intelligence and continuous upgradation with artificial neural networks and deep learning are excellent tools which can assist physicians in the diagnosis and exploring of various ailments. However, AI based deep learning tools have some limitations which include unregulated training set algorithm, unsupervised learning limitations, data set size, patient confidentiality which demand significant attention towards human computer interface (HCI) and the use of AI. Another significant obstacle in molecular drug discovery includes reproducibility of clinical experimentation which can take many years for effective formulation in the market after clinical trials. In addition, the evaluation of a large set of complicated and diverse health care data can be managed by the analysis of big data and ML tools to minimize limitation and false-positive data. The Food and Drug Administration (FDA) considers AI/ML based software as a medical device. FDA would expect the AI innovators to comply with the requirements of clinical, analytical and technical validation, good machine learning practice, assurance of safety and assurance and real-world performance monitoring. Any new AI technology that proposes to improve the efficiency of clinical trial design and conduct should be validated by testing alongside the existing technology which it claims to complement or substitute. The regulatory agencies and the end users expect that AI technology is easily understandable, ethical, replicable and scalable. AI is not fully autonomous and cannot override human involvement. AI in the medical profession is a novel and a potential too which can help to achieve a specific treatment performance and identify the correct diagnosis at the highest possible level.

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