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Review of fundamentals of Artificial Intelligence and application with medical data in healthcare

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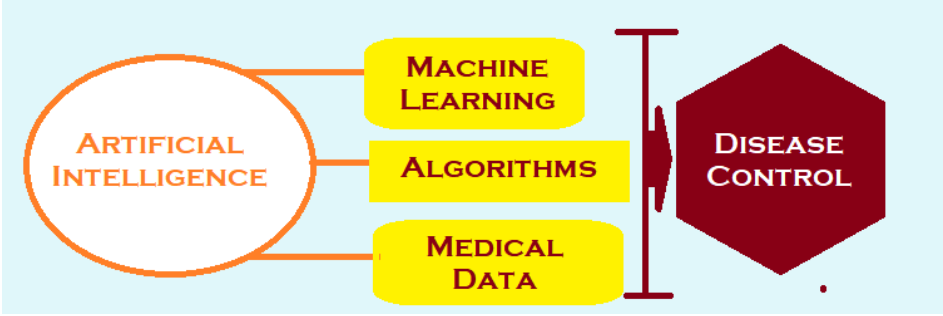
ABSTRACT



Artificial Intelligence (AI) can identify substantial interactions by considering the datasets in the emerging era of technologies. It is widely applied in various applications, and healthcare is among them. AI plays a vital role in clinical applications in predicting the disease type, treating the disease, managing chronic situations, and diagnosing the same. AI has simplified the lives of doctors, patients, and administrators at hospitals in the healthcare environment by operating various tasks with lesser computation time and accurate results. The unique challenges such as AI's availability, accessibility, and affordability have contributed to the success of healthcare applications. Another factor that enhances the functionality of AI is based on the sourced medical data, which is analyzed, and a model is built to predict the disease by the application of Machine Learning (ML). The other reason for the successful application of AI in the healthcare environment is Computational Intelligence (CI), which is an analysis, design, theory, and development of linguistically and biologically motivated computational techniques. The functionality of CI is identified on the three pillars Fuzzy Systems, Neural Networks, and Evolutionary Computation. This research mainly discusses AI's various applications in the current healthcare environment. The discussion also includes the different branches of AI with their applications and working principles.

Keywords: Machine Learning, Computational Intelligence, Fuzzy Systems, Neural Networks, Evolutionary Computation

INTRODUCTION

One of the branches of science called Artificial Intelligence (AI) evolved in the mid of 1960s, growing exponentially over two decades. AI is a simulation of human intelligence into machines to behave like humans. It is also a computer or robot controlled by a computer to perform tasks such as game playing, driving, speaking, etc. AI comprises subdomains such as Machine Learning (ML) and Deep Learning (DL), frequently applied in various technology fields. The relation and definition of AI, ML, and DL are described with the help of a diagram as in Figure 1. AI assists machines in thinking and performing tasks without human beings' involvement.

The phrase "Artificial Intelligence" was coined by John McCarthy in 1956.[1] Before 1956, it was named "Computational Intelligence." Since then, John McCurthy has been called the "Father of AI." In 1948, he completed his graduation, and in 1951, he was awarded a doctorate in the AI domain from Princeton University. In the Mythic Dartmouth Conference organized by McCurthy, the name Artificial Intelligence was coined, and he defined it as the Science and Engineering of building intelligent models or machines.[1]

AI has already taken a vital role in all aspects of our daily life. It is also considered a requisite portion of all the domains such as e-commerce, watching and collecting the images and videos, tracking the location through the Global Positioning System (GPS), etc.[2] AI is also applied to predict many diseases during their early stages and helps heal the diseases at the earliest[3–5] ML (for data analysis) and DL (for building the model using the neural networks) play an

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essential role in predicting diseases. The neural network is a subdomain of Deep Learning that mainly imitates the human brain's neurons. Figure 2. brings a relation between big data and neural networks.

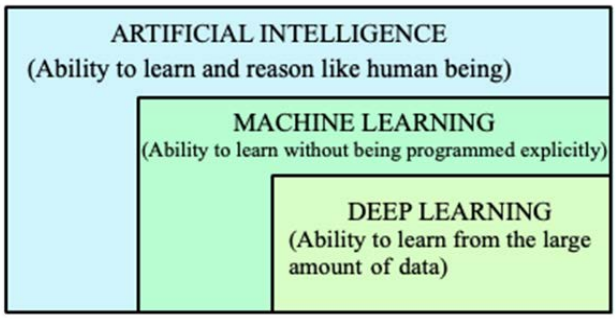

Figure 1. Relation between AI, ML, and DL

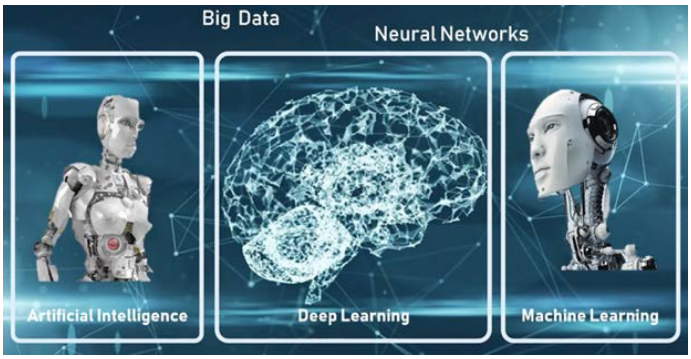

Figure 2. Relation between Bigdata and Neural Networks

II. Types of AI

AI is differentiated as Strong (General) AI and Weak (Narrow) AI. The Strong AI is classified as Artificial General Intelligence (AGI) and Artificial Super Intelligence (ASI). AGI supports the machines in learning, acting, and understanding so that human beings are indistinguishable from them in an assigned task. It covers more than one application area: problem-solving, reasoning, and abstract thinking. The classification of AI is as in Figure 3.

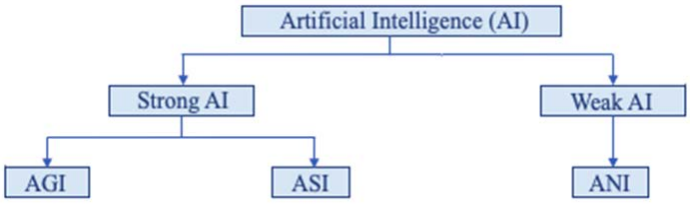

Figure. 3 Classification of AI

ASI is a theoretical AI based on which the machines exhibit intelligence, which outshines human intelligence. It surpasses human intelligence. Examples of ASI are machines that act as agents with super intelligence, which are masters in all the aspects such as thinking and acting like a human being.

Table 1. Differences between Strong AI and Weak AI

Parameter	Strong AI	Weak AI
Functionalities	Strong AI performs all the functionalities.	It performs limited functionalities.
Thinking	Strong AI thinks and reacts in the same manner how human being does.	Weak AI does not possess thinking or reasoning abilities like human beings, but they perform the specific task for which they are trained.
Modelling	They conclude that their intelligent performance or behaviour cannot be modelled.	Weak AI concludes that their intelligent performance or behaviour can be modelled.
Examples	Google Search Engine.	Google Assistant, Siri, and Alexa.

The Weak AI also called a Narrow AI, is designed to perform only one task. It is a goal-oriented AI. Artificial Narrow Intelligence is related to one or two applications or functional areas. ANI is not self-conscious or self-aware intelligence. It appears to be decision-making, but it is math or static in action. Some ANI examples are Smartphone Apps, AlphaGo, tools used for image identification and speech recognition, Google translator, self-driving vehicles, and spam filters. The differences between Strong AI and Weak AI are tabularized in Table 1.

III. General Applications of AI

Over two decades, AI has been adopted in various domains with different applications. Some are Image Recognition, A/B Testing, Language Translation, Product Analytics, Sentiment Analysis, and Speech Recognition.

Simarjeet Kaur et al. (2020) conducted a review of the existing literature from the year 2009 to 2019. The eight most often used databases yielded a total of 105 papers for the research. A thorough examination of those publications was carried out to categorize the most often utilized Artificial Intelligence algorithms in medical diagnostic systems. Several illnesses were examined, as well as Artificial Intelligence approaches such as Machine Learning, Fuzzy Logic, and Deep Learning.[6]

Erico Tjoa et al., (2021), published an assessment of the interpretability offered by various research studies. The many categories depict various aspects of interpretability research, ranging from methodologies that produce "clearly" interpretable material to complicated pattern investigations. It is intended that by using the same category for interpretability in medical research, clinicians and practitioners would be able to approach with the care of understanding.[7]

Mobeen Nazar et al., 2021, identified a point of confluence between the domains of artificial intelligence and human-computer interaction. A literature review was undertaken in this study to get a knowledge of Explainable Artificial Intelligence, which is a connecting point between human-computer interaction and artificial intelligence. The application of human-computer

interaction, explainable artificial intelligence, and artificial intelligence in healthcare was also a prominent emphasis of the research. Consequently, the literature suggests that XAI in healthcare is still a relatively new concept that needs to be further investigated in the future.[8]

Kehua Guo et al. (2020) introduced a new medicinal-supported diagnostic standard as a service and developed a model procurement approach built on traditional models. The authors have also created a reliable model-based recommendation approach for medicinal supported diagnosis standards as a service for the consumer, which will aid medical institutions in rapidly and effectively obtaining accurate medical-assisted diagnostic models. Extensive tests are conducted to authenticate the efficacy of the suggested standard, which is based on the medical-assisted diagnostic paradigm as a service.[9]

S.J. Fakih et al., (2006) created a learning-based system that proposes test(s) that optimum an acceptable measure of diagnostic performance based on patient information. The cost of testing, the morbidity and mortality connected with the tests, and the time it takes to get a diagnosis are all factored into a complete performance metric. The diagnostic ability of the tests is also taken into consideration in the performance measure.[10]

Mufti Mahmud et al., (2018) presented an overview of the use of deep learning, reinforcement learning, and deep reinforcement learning approaches in biological data mining. Furthermore, the results of deep learning algorithms when applied to diverse data sets in various application fields are examined. Finally, the unresolved difficulties in this demanding study field were presented, and future development options were discussed.[11]

Uzair Khan et al., (2021) highlighted machine learning principles that are important and appropriate to medical hyper-spectral image analysis, including some have been deployed since the deep learning surge. This will include an overview of the application of deep learning for detection, classification, and segmentation in medical hyperspectral image analysis. Finally, existing, and future medical concerns were reviewed, as well as prospective solutions.[12]

Justin Ker et al., (2017) examined machine learning methods for medical image processing, with an emphasis on convolutional neural networks and a focus on clinical elements of the aea. In an era of medical big data, machine learning has the benefit of allowing substantial hierarchical links within the data to be uncovered algorithmically rather than by handcrafting features. The important study fields and applications of medical image classification, registration, localization, segmentation, and detection were discussed by the author.[13]

Ying Yu et al. (2019) provided a review of research that uses the deep-learning model to be dealt with medical data. Various forms of medical data (e.g., medical photos, medical notes, laboratory findings, and demography information) are described, and details of selected public medical datasets are presented, based on an examination of medical data features. A summary of typical deep-learning models and their characteristics is presented.[14]

Hanqing Sun et al. (2019) developed a deep learning-based data analysis algorithm for medicinal pictures and transcript that may be used to intelligently identify and diagnose illnesses. The model selects and optimizes model parameters using vast medical big data, and then automatically learns the pathological analysis process of physicians or medical researchers through the model, before intelligently conducting illness judgment and effective decision-making based on the analysis findings of medical big data.[15]

The Figure 4 summarizes the applications of AI in various domains.

Image Recognition: this is about recognizing objects, people, places, and other actions in the given image.[16]

Speech recognition: allows the human being to communicate with the machine or software using their voice.[17]

Language Translation: translating an original sentence or a word from one language to another by ensuring that the translated sentence or a phrase is linguistically and culturally correct.[18]

Product Analytics: allows a human being or company to learn about services or products. It is also applied to track the various activities related to the likes and dislikes of humans or users.[19]

A/B Testing is also called split test and is a process of comparing two different versions like A & B of the web page that delivers the better or best performance.[20]

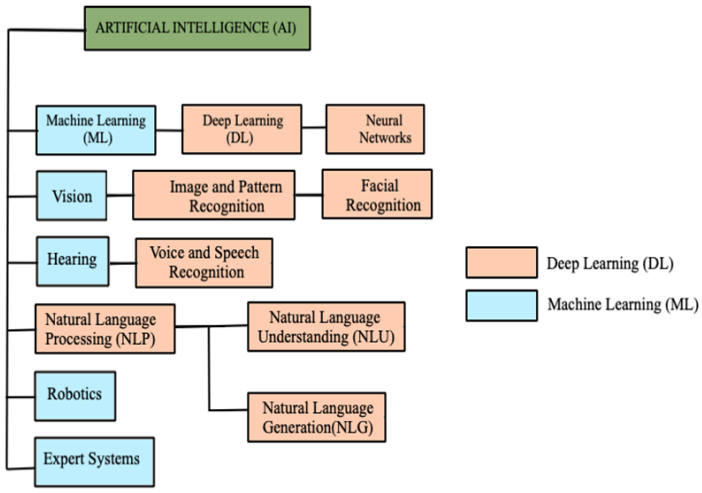

Figure. 4 Summarizes the applications of AI in various domains.

Sentiment Analysis: An analysis of a text to identify the writer's attitude.[21] This Sentiment Analysis is categorized as positive, negative, and neutral. Some of the famous examples of AI applications are;

a. Siri: is a well-known personal assistant adopted by Apple company. It is implemented based on Machine Learning (ML) and Natural Language Processing (NLP), which can communicate with the user and understand the queries asked by the user.[22]
b. Cogito is one of the best examples to improve customer support representatives' intelligence. This analyses the human voice and provides real-time guidance.
c. Netflix: is one that uses predictive technologies to offer movie recommendations based on the choices or interests of the end-user.

HEALTHCARE APPLICATIONS OF AI

The demand for healthcare services is never-ending. In some of the world's countries, healthcare experts like physicians are scarce. The advanced research in wireless networks, smartphones, and related technologies provides health care services on-demand by working with many applications or apps used to track health. These technologies also offer remote interactions and are made available anytime and anywhere.

The research in the healthcare domain indicates that AI provides a substantial improvement from treatment to diagnostics. A considerable dataset acts as evidence to prove that AI is performing better than humans in healthcare applications.[23] Here are some of the healthcare applications of AI.

Precision Medicine: This provides healthcare instructions to the group of patients or individual patients depending on their disease. This also tracks prognostic information and the patients' response to the treatment. The main objective of precision medicine is to apply individual biological features instead of group biological features in all the patients' medical treatment steps. This is achieved by collecting individual patients' health information, physiological data, and EMR report and adapting the disease curing methods to the advanced models.[24] By following these steps, it is possible to reduce the cost of healthcare, drop the rate of adverse drug response, and enhance the rate of drug action effectivity, which are treated as the advantages of precision medicine. The novelties in precision medicine have led to the best benefits for patients and changed the delivery of health services. Based on the sequencing genome and application of AI, precision medicine allows many methods to advance in the association of genetic mutations.

There are three types of precision medicines: Digital healthcare applications, Omics-based testing, and Complex algorithms.

a. **Digital healthcare applications**: These applications play an essential role in healthcare applications by recording the patient's data and processing this recorded data. Some examples of data recording are food consumption, patient emotions, and activities carried out by the patient like walking, jogging, playing, cycling, and so on. These recorded data, when processed, result in the prediction of a patient's health and helps for the treatment for the same.[25,26]
b. **Omics-based testing**: This testing is used to predict the patient's disease based on the genetic information collected from the population pool. The biomarkers such as gut microbiome, protein expression, metabolic profile, and genetic data are retained to enable personalized treatments.[27,28]
c. **Complex algorithms**: The large datasets, including demographic data, genetic information, electronic health record, demographic data, and Machine Learning algorithms, are applied to specify the prediction of disease treatment and diagnosis approaches.

The ML opportunities with drug discovery[27] and the development process have been explained in Figure 1.[29] According to this, the time taken for drug discovery is two to three years. After this stage, the prediction period for diagnosing the disease is half a year. In the third stage, the physical and chemical properties[30] of the drug are analysed, and it consumes one to three years. The fourth stage is the final phase, where the drug is completely developed and ready to deploy to the market.

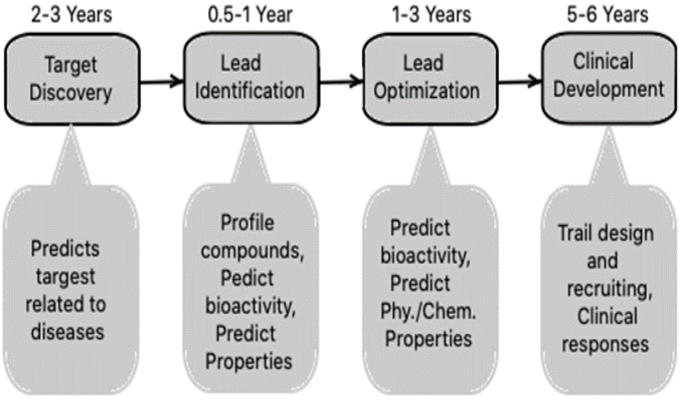

Figure. 5 ML opportunities with drug discovery and development process

Generic-based Outcomes: The healthcare companies apply AI in all the steps, such as target discovery, toxicity evaluation, lead optimization, and innovative sample design of drug development and discovery methods.[31,32] Most inherited diseases result in symptoms without diagnosing and understanding the complete genome. A big challenge for genetic profiles is the wrong results of inherited disease symptoms and their interpretation.

Drug discovery and development is one of the costliest, longest, and most complex processes, which takes more than a decade to identify the targets of molecules till a drug is developed, approved, and marketed. Suppose any of the failures in these steps lead to a significant effect on the company's economy. The loss is mainly during the development of drugs and not in catching the market. Above all, the regular increase in the regulatory obstacles and the struggles in the continuous process of identifying drug molecules are better than currently marketed.[33]

Figure 6. explains the roadmap of medical data collection during Natural Language Processing (NLP).[34] In the roadmap of medical data collection, Artificial Intelligence and Machine Learning play an essential role in Electronic Medical records (EMR), Electrophysiology (EP) phases. They are also applied to adopt the best-suited NLP method for the healthcare problem statement.

Over a couple of years, the growth in data availability rate for accessing the drug compound procedure has increased due to the automation and a new technique called Hidden Markov Model, which supports text-to-speech synthesis. During the 1990s, the Machine Learning methods such as Random Forest, Neural Networks, and Support Vector Machine (SVM) were incorporated to implement the ML models[35] to aim for drug discovery and development. The associated features of the drug and its molecules are used in the silicon models and converted into vector format, which the learning systems read.

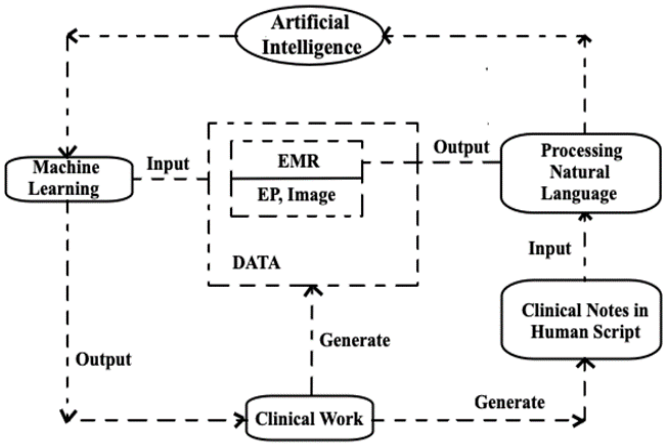

Figure. 6 Roadmap for medical data collection

IV. Effects of AI on Society

Artificial Intelligence greatly benefits society by enhancing throughput and efficiency while creating new opportunities for job creation, revenue generation, and cost savings. Some of the effects are discussed here.

Self-Driving Car: a machine that involves sensors, radars, and cameras and can sense the environment and direct to the destination without the involvement of human-being.[36]

The rise of AI in society enhanced the lifestyle of human beings and created an efficient business platform in all domains. The statement that robots and AI will destroy jobs is more fiction than fact. In turn, this field of science and technology gradually enhanced the job market. It is also proven that; human beings work better with AI's help. Also, in worldwide health care applications, AI plays a vital role by involving expert Doctors from various parts of the world to analyze the disease before its diagnosis.

Conversely, the AI techniques used to design the monitoring systems for specific areas and situations have replaced human power leading to the job recession. This is one of the significant effects of AI on Society.

In general, AI platforms provide real-time insights combined with the explosion of computer power. This will help health professionals diagnose the patients faster and more accurately. In this manner, AI has influenced society in a positive aspect.

V. AI Techniques

Artificial Intelligence is categorized into four techniques based on the machine's capacity.

- Machine Learning is also considered a subset of AI, and in machine learning, machines learn and predict the future based on past data. They are not programmed explicitly.
- Natural Language Processing: is cultivated to interact with human beings and machines. Here the computers are programmed to process the natural language.
- Automation and Robotics are to achieve the productivity rate with efficient results and cost-effectiveness in all the fields of science and technology. For example, using CAPTCHA techniques, automation significantly prevents fraud issues during bank transactions.[37]
- Machine Vision: With this AI technique, machines capture and analyze visual data. This technique is also applied to convert the images into digital data. Digital signal processing is made used to process this converted digital data.[38] This processed data is later fed to the computers. These techniques are represented in Figure 7.

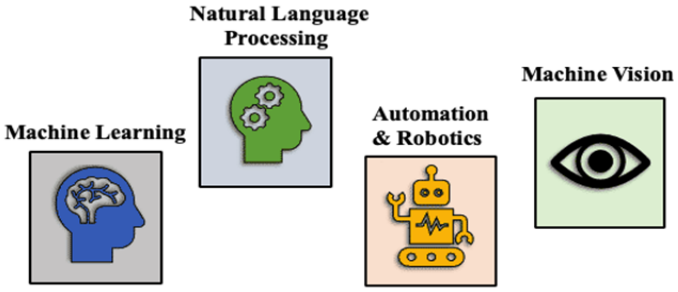

Figure. 7 Artificial Intelligence Techniques

Achievements of AI

Many tech companies and branded companies adopt AI to improve efficient services, enhance the customer experience, and engage the customers. The various achievements of AI are.

- Face recognition: Pattern recognition and image processing are significant research areas in the AI domain.[39] The simplest example of this face detection implemented is in a smartphone that is unlocked by detecting the mobile owner's face. Face recognition has also played a vital role in identifying the criminal. Google search engine by giving images as input is another face detection application. This is used to determine the name of the objects by providing the image as an input to the program.
- Drug discovery and development: AI is considered a domain that reshapes the complete drug discovery and detection process. This technology, combined with automated data analysis, robotics, and microfluidics, has enhanced laboratory efficiency. For example, automation maximizes the rate of efficiently testing the more significant number of hypotheses faster.[40–43]
- Speech recognition: some virtual assistants such as Alexa, Siri, Google Assistant, and Microsoft Cortana interact with human beings, which are achievements of AI through speech recognition.
- Text Generation: The programs and robots such as Generative Pre-trained Transformer 3 (GPT-3), are called auto-regressive language models, and these tools are for the text generation, which is applied to identify the emotions, themes, and sentiments based on the help-desk feedback, live-chat reviews, and surveys. They are processed by using Natural Language Processing (NLP).

Advantages of AI

The growth of AI has pulled boundaries for all the fully machine-enabled functionalities. This boundary of machines assists in acting with the rate of autonomy, which results in the effective execution

of complex tasks more straightforwardly. This also concludes that these machines perform functions that humans cannot carry out. AI also assists in creating a workplace for the next generation, which thrives on the association among individuals and an enterprise system.

The following are some of the primary advantages of AI:

- AI enables multi-tasking and reduces the workload of human beings by the usage of limited resources.
- AI functions all around the clock without any interruptions and downtime.
- It assists in the execution of complex tasks without a high cost.
- AI can be deployed in various industries, platforms, and domains because of its market potential and advantages.
- Due to its smarter and faster processing speed facilitates it as the decision-maker.

DISADVANTAGES OF AI

AI is to mimic human intelligence into machines and make them intelligent. Some software-based AI, such as Google Search Engine, Azure, TensorFlow, Cortana, IBM Watson, and so on, have helped humans get the information at their fingertips. However, it is also analysed by considering the darker side of AI. These are the disadvantages of AI implementation.

- Not economic to implement: Building up or designing the AI-based machines or models requires a considerable cost, and further, the expenses involve maintenance and repair.

For example, the cost for Apple to procure SIRI, a virtual assistant, is $200 million, and for Amazon to procure Alexa is $26 million. This software-based virtual assistant requires a timely update and maintenance. They involve a lot of time and care costs for recovering or re-installing the software.

- AI does not replace human beings: It is analyzed and accepted that machines compute tasks more efficiently than humans. Even then, machines or AI cannot replace human beings as human intelligence cannot be simulated to devices completely.
- AI does not improve with experience: The most amazing characteristic of human power is its ability to adapt and correct mistakes with experience and age. The machines do not adopt these changes though they are more efficient than humans in performing tasks. Changes to be made in the devices must be re-designed, re-built, re-trained, and re-assessed.
- Lack of creativity: AI machines follow the instructions fed to them. Hence, they are not adopted for the creative field such as interior design, fashion design, etc.
- High risk of unemployment: With the rapid growth in AI technology, AIs are replacing the human being where the repetitive tasks are to be carried out.

Based on these disadvantages, it is concluded that the origination of AI evolves with its specific set of risks. It is also supposed that machines cannot judge what is wrong and right.

VI. OVERVIEW OF MACHINE LEARNING

Machine Learning is the subdomain of Artificial Intelligence that uses statistical learning methods to develop an intelligent decision-making model.[44,45] These ML models are built explicitly without being programmed explicitly. The ML applications consist of an algorithm set of instructions to perform a specified task.[46–48] These algorithms are designed so that they learn by themselves without the involvement of human beings. Without re-programming, these algorithms increase their prediction accuracy. The ML algorithms are function based on three critical components: Data Representation, Model Evaluation, and Model Optimization.

- Data representation: involves the process of collection of data and classifying this collected data based on the model building requirements.
- Model Evaluation: tests how the classified data helps in model building.
- Model Optimization: is the process of designing the best ML model that best suits the given problem statement by yielding accurate and effective results.

A. Types of Machine Learning

ML algorithms allow the model to go through the learning procedure. These algorithms automatically alert the model whenever it passes through the data and detects different patterns. This process results in more accurate and effective prediction accuracy. Machine Learning algorithms are classified as.

- Supervised algorithms define the group of problems that learn by using the model and mapping input variables with the target variable. There are two types of supervised learning algorithms: Classification (Predicts the class label) and Regression (Predicts the numerical label).[49]
- Unsupervised algorithms describe the group of problems involving an ML model to extract or describe the relationships between the data sets. These unsupervised learning algorithms function only on the input data without the target variables or the outputs. The unsupervised learning algorithm has a classification called Clustering (a learning model that works only on data groups).
- Reinforcement algorithms define the group of problems involving an agent that functions using the feedback.

These algorithms are represented in Figure 8.

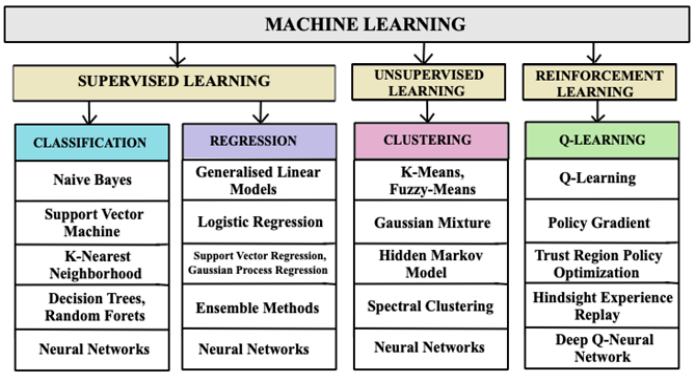

Figure. 8 Different ML Algorithms

B. Healthcare Applications of ML

Machine Learning algorithms have set their own identity in the field of healthcare. Following are some areas in which ML algorithms are highly recommended for the applications of ML in healthcare.[50]

- Record Maintaining: ML algorithms are applied to maintain the electronic health record (EHR), used to manage the patient's details, improve the patient's case, reduce the administrative cost, and so on.[51]
- Data Integrity: ML algorithms in healthcare are applied to optimize surgery planning, Preparation, and execution. Some of the applications of ML in healthcare are.[52]
    - Identifying and diagnosing the disease
    - Diagnosis of medical imaging
    - Robotic surgery
    - Robotic patient support task
    - Personalized medicine

CONCLUSION AND FUTURE SCOPE

The adoption of AI in all the domains and applications has achieved customer experience and engaged the customers to enhance efficiency and service. Some applications where AI has been cultivated and made human life comfortable are driverless cars, intelligent houses to manage the electricity, water, and cooking-gas usage, techniques to analyze the health of human beings, diagnose the illness, and so on. This research work concludes that AI has made the life of human being completely automated.

When it comes to illness diagnosis, precision is crucial for planning, successful treatment, and assuring patients' well-being. Artificial intelligence is a huge and diversified domain of data, algorithms, analytics, deep learning, neural networks, and insights that is continually evolving and adapting to the demands of the healthcare business and its patients. According to the study's findings, AI techniques in the healthcare system, particularly for disease diagnosis, are critical. The current study has been divided into several sections that cover the diagnosis of Alzheimer's, cancer, diabetes, chronic diseases, heart disease, stroke and cerebrovascular disease, hypertension, skin disease, and liver disease, with the goal of illuminating how machine and deep learning techniques work in various disease diagnosis areas.

The reported work on multiple diseases, as well as the comparative analysis of different techniques with the used dataset, as well as the results of an applied machine and deep learning methods in terms of multiple parameters such as accuracy, sensitivity, specificity, an area under the curve, and F-score, has also been depicted. Finally, as in the future scope, the study that aided researchers in selecting the most effective way for detecting diseases is completed. In a nutshell, medical specialists now have a better understanding of how AI may be used to diagnose illnesses, which leads to more relevant ideas for the future development of AI-based procedures.

Despite significant advances in recent years, the field of reliable clinical diagnostics has various challenges that must be handled and enhanced on a continuous basis in order to successfully treat new illnesses and diseases. Even medical specialists realise the obstacles that must be solved before disease may be recognised using artificial intelligence. Even doctors are sceptical about AI-based treatments at this moment since they are unsure of their capacity to predict diseases and accompanying symptoms. As a result, substantial effort is necessary to train AI-based systems so that the accuracy of approaches for identifying illnesses improves. As a result, in the future, AI-based research should be undertaken while keeping the problem described before in mind in order to deliver a mutually beneficial outcome.

CONFLICT OF INTEREST

Authors declared no conflict of interest for this work.

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