International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 04 Issue: 07 | July – 2025 DOI: 10.55041/ISJEM04745
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Machine Learning in Healthcare System: Role, Importance and its Applications

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Abstract: With the growth of technology in the healthcare field, medical services are becoming faster, smarter, and more reliable. Machine Learning (ML) plays a very important role in this improvement. It helps doctors and hospital staff to handle large amounts of patient data easily and make better decisions in less time. Machine Learning provides new tools and smart techniques that help doctors get useful information from real-time data. This helps them give the right treatment at the right time, avoid mistakes, and take better care of patients. ML also helps in reducing the workload of healthcare workers by supporting them with accurate results and predictions. ML is now commonly used in healthcare for analysing medical data, finding hidden problems, recognizing patterns, and helping in the early detection of diseases. This paper reviews some the major researches that have been carried out recently in the field of health care with enhanced technology of artificial intelligence.

Keywords: Machine learning, Healthcare, Artificial Intelligence, Supervised Learning, Unsupervised Learning, Electronic Health Records.

1. Introduction

The term “Machine Learning (ML)" refers to various statistical techniques that allow computers to learn from experience without being explicitly programmed. Machine learning is a subset of Artificial Intelligence (AI) that enables computers to learn from data, identify patterns, and make decisions with minimal human intervention. In recent years, Machine Learning (ML) has emerged as one of the most transformative technologies in the healthcare sector. Machine Learning (ML) is transforming healthcare by enabling early disease detection, predictive analytics, personalized treatments, and drug discovery. It automates administrative tasks, enhances remote patient monitoring, and improves mental health support. Overall, ML makes healthcare more efficient, accurate, and accessible. Healthcare is one of the world’s largest industries that can benefit from this technology. The main area of machine learning is to use advanced algorithms and statistical techniques to access the data and predict accuracy instead of a rule-based system. The healthcare industry generates an enormous amount of data every day—from electronic health records (EHRs), medical imaging, genomic sequences, to data from wearable devices and clinical trials. Traditional data analysis methods often fall short in handling such complex and high-dimensional data. This is where machine learning plays a crucial role. Machine learning algorithms can help in disease diagnosis by analysing data and predicting the underlying causes of an illness by employing disease-causing variables from electronic health records. Machine learning has recently demonstrated outstanding results in a variety of tasks, including the identification of body organs from medical images, interstitial lung diseases classification, reconstruction of medical images, and segmentation of brain tumours.

Unsupervised learning and supervised learning are the two major branches of ML. Supervised machine learning trains the algorithms on known input and output data to predict future outputs. Unsupervised machine learning discovers hidden patterns or internal structures within the input data. Supervised machine learning can perform both classifications and regression tasks, while unsupervised machine learning tackles the clustering tasks. Machine learning gained popularity in terms of classification, prediction, and clustering tasks over the traditional bio statistical approach for analysing and integrating enormous amounts of complicated healthcare data. The healthcare industry has always been a strong supporter of cutting-edge technologies. AI and ML have found several applications in the healthcare industry, just as they have in business and e-commerce. There are virtually limitless possibilities with this technology.

ML is assisting in transforming the healthcare industry for the better with its cutting-edge applications. The dataset is a primary component of machine learning accuracy prediction. As a result, the data are more relevant and the prediction is more accurate. Machine learning has been used in different fields, such as finance, retail, and the healthcare industry. The rising use of machine learning in healthcare provides more opportunities for disease diagnosis and treatment. Machine learning has a great feature of continuous improvement for data accurate prediction and classification purposes for disease analysis. The prediction model will learn to make a better decision for accurate prediction as the increasing data are gathered. Patient datasets recorded in electronic healthcare records can be used to enable the extraction of pertinent data using machine learning techniques. The significance of Machine Learning in healthcare lies in its ability to extract meaningful insights from vast datasets, which can be used to enhance clinical decision-making, optimize operations, and personalize patient care. For instance, ML algorithms can assist in the early detection of diseases such as cancer, diabetes, and heart conditions by analysing imaging results, lab tests, and patient history. These models often outperform or complement human diagnostics by identifying subtle patterns that may be missed by clinicians. Moreover, ML is instrumental in the development of precision medicine. By analysing genetic information along with lifestyle and environmental data, ML models can help predict how individual patients will respond to specific treatments, enabling more targeted and effective interventions. In drug discovery, ML accelerates the identification of potential compounds and predicts their effectiveness, significantly reducing the time and cost involved in bringing new drugs to market. Operationally, ML contributes to improved resource management in hospitals, predicting patient admissions, readmission risks, and optimizing treatment plans**.** It also enhances remote patient monitoring and telemedicine, enabling real-time analysis of patient data and timely intervention, especially in chronic disease management. Despite its enormous potential, the integration of Machine Learning into healthcare also presents challenges, such as data privacy concerns, algorithm bias, and the need for regulatory oversight. However, ongoing advancements and ethical frameworks are steadily addressing these issues. However, the significance of machine learning in healthcare cannot be overstated. It is reshaping the way healthcare is delivered, making it more predictive, preventive, personalized, and participatory. As ML technologies continue to evolve, their integration into healthcare systems will likely become even more essential in improving patient outcomes and overall public health**.**

2. Role and Importance of Machine Learning in Healthcare.

Machine Learning (ML) is a branch of Artificial Intelligence (AI) that helps machines or computers learn from data and make smart decisions without being directly programmed. In simple words, ML allows computers to learn from past information (Data) and predict future outcomes. Today, ML is playing an important role in improving the healthcare system all over the world. Healthcare is one of the most important fields where technology is being used to save lives and provide better treatment [12]. However, healthcare still faces many challenges like finding the right treatment for every patient, early disease detection, and managing large amounts of medical data and many other facilities. Machine learning helps in solving these problems in a faster and more accurate way. ML has become even more important after the COVID-19 pandemic, where hospitals needed quick solutions to handle patients, predict risks, and manage limited resources. Many hospitals and organizations are using ML to improve their services and provide better patient care and this number is rising rapidly.

3. Applications and Benefits of Machine Learning in Healthcare

Machine learning is helping healthcare in many different ways. Some of its important uses are:

3.1. Identifying and Preventing Diseases: ML can study patient data like medical history, test reports, or health records and predict if a person is at risk of developing a particular disease or not based on its history and symptoms. This helps doctors to take early actions and prevent the disease by making cure more efficient.

3.2. Disease Detection and Cure: Machine learning tools are used to analyse medical images like X-rays, CT scans, and MRI reports. These tools can help doctors in diagnosing diseases faster and more accurately. It also helps in choosing the best treatment plan based on a patient's personal health condition.

3.3. Patient-Specific Treatment: Every person's body reacts differently to medicines. ML can suggest the best medicine and dosage for a patient by studying their medical history, age, genetics, and other factors. This makes treatment more effective and safer.

3.4. Smart Decision Making in Healthcare: Machine learning is also used in decision- making systems in hospitals. These systems provide suggestions to doctors and help them in making better decisions about a patient's treatment.

3.5. Improving Healthcare Services for the Public: ML can analyse health data from a large population and find patterns or trends. This helps government and healthcare agencies to plan public health programs like vaccination drives or awareness campaigns.

3.6. Paediatric Care: ML is also used in child healthcare where there is less clinical research available. It helps doctors to give the right treatment to children by studying their specific needs and health conditions [10].

Benefits of Machine Learning in Healthcare

- Early disease detection
- Better and faster diagnosis
- Personalized treatment for patients
- Reduced medical errors
- Efficient management of healthcare resources
- Improved patient care and satisfaction
- Helps doctors in making smart and informed decisions

Machine learning has brought a positive change in the healthcare system. It is helping doctors and hospitals to provide better treatment and improve patient health. As technology continues to grow, ML will become an even more essential part of healthcare. It not only helps in treating diseases but also plays a big role in preventing them and managing healthcare systems effectively. In the future, ML will continue to support medical professionals and make healthcare smarter, faster, and more personalized for everyone [8, 9].

Fig. 1: Applications of Machine Learning in Healthcare

4. Literature Review

This section discusses literature review of various works that have been carried out recently and have good citations on machine learning in healthcare system.

Choi et al. [1] created a machine learning model using a type of neural network called RNN to predict heart failure in patients. They used patients' past health records over time to train the model, and it was able to predict health problems more accurately and earlier than traditional methods. This kind of early warning system can help doctors start treatment sooner.

Litjens et al. [2] reviewed over 300 research papers and found that deep learning models, especially CNNs, are great at analysing medical images. These models can detect problems like tumours or eye diseases with very high accuracy—sometimes even better than doctors. This technology is helping make faster and more reliable diagnoses from X-rays, MRIs, and other scans.

Miotto et al. [3] developed a system called 'Deep Patient' that studies patterns in patient data to understand individual health risks. By learning from medical histories, the system helps predict who might develop certain diseases and allows doctors to customize treatments to fit each person better.

Rajkomar et al. [4] used a deep learning model to analyse electronic health records and predict important health events like hospital readmissions or complications. Their system worked well even with the messy and complex data in real hospital records. This shows how ML can help doctors make better decisions using everyday patient data.

Char et al. [5] pointed out the ethical challenges of using ML in healthcare. They talked about the risk of biased results, the importance of making ML decisions understandable, and the need to protect patient data. Their work reminds us that while ML is powerful, it must be used carefully and responsibly.

5. Main Objectives of the Research

This research paper focuses on understanding the role of machine learning in the healthcare system. The key objectives of this study are:

1. To understand the role and need of ML in healthcare .This objective is to study how machine learning works in healthcare and why it is necessary for today's medical services.
2. To study the features of ML that can improve healthcare system. This objective focuses on understanding the special features of ML that help in making the healthcare system stronger and better organized [6, 7].
3. To study the importance of applications of ML in healthcare. This objective aims to explore the various areas where ML is used in healthcare like disease prediction, patient monitoring, medical imaging, and personalized treatment.

5.1. Core Features of ML Enhancing Healthcare Systems

Machine Learning (ML) is playing a transformative role in the healthcare sector by introducing intelligent solutions that help improve patient care, optimize hospital operations, and support medical research. With the integration of advanced technologies like Artificial Intelligence (AI), cloud computing, and data analytics, healthcare services are becoming more efficient, accessible, and cost-effective. Electronic Health Records (EHRs), automated report generation, digital note-taking, and smart record management are just a few examples of how ML is simplifying the workflow of healthcare professionals and ensuring better patient care. One of the most remarkable applications of ML in healthcare is in the early detection and prevention of diseases. ML systems can analyse vast amounts of data from social media, satellite sources, and online health updates to predict possible disease outbreaks in different regions. This is highly beneficial for countries with limited healthcare infrastructure, enabling timely action and resource management. Moreover, ML helps address several challenges in traditional healthcare systems, such as long waiting times, high treatment costs, complex appointment procedures, and difficulties in finding the right medical expert. Intelligent search algorithms and pattern recognition techniques in ML assist in diagnosing diseases accurately and personalizing treatment plans based on a patient's medical history, genetics, and lifestyle. ML-driven hospital management systems aim to combine empathy with efficiency, ensuring that patient care is not only technologically advanced but also human

centred. These systems leverage powerful algorithms like deep learning, neural networks, and reinforcement learning to offer personalized treatment recommendations, predict health risks, and support clinical decision-making. Additionally, ML contributes to faster diagnosis through image analysis, such as detecting anomalies in X-rays or MRI scans. With the increasing digitalization of healthcare data, ML tools can process unstructured patient information like previous treatments, family history, and medical records to generate actionable insights for doctors. Clinical decision support systems powered by ML help in analysing large datasets to assist in disease detection, treatment planning, and risk prediction. These systems improve the accuracy of diagnoses and reduce the chances of human error, especially in repetitive tasks like data entry or report generation. Machine Learning also plays a vital and enhanced role in medical research and clinical trials. Predictive analytics helps in identifying suitable candidates for trials, analysing their medical records, monitoring progress, and reducing time and cost associated with the process [12, 13]. Furthermore, ML aids in preventive healthcare by identifying potential health risks before they become critical. This is particularly important in diseases like cancer and other diseases, where early detection significantly increases survival rates. Smart patient records powered by ML not only store medical data but also provide valuable insights that help in better treatment planning and health monitoring. Overall, ML is revolutionizing healthcare by enhancing patient care, improving operational efficiency, enabling early disease detection, and supporting medical research. Its ability to process large datasets, recognize patterns, and provide accurate predictions makes it an essential technology for the future of healthcare.

5.2. Machine Learning Algorithms in Improving Healthcare

Machine learning is playing a very important role in the healthcare sector. With the help of machine learning techniques, the healthcare system is becoming smarter, faster, and more accurate. Supervised learning helps doctors and medical staff to predict diseases, identify health risks, and provide correct treatment by learning from past data. It is widely used in detecting diseases like cancer, heart problems, and diabetes. On the other hand, unsupervised learning helps in grouping patients based on their health conditions, finding hidden patterns in medical data, and analysing medical images without any labelled data. These techniques are very helpful in handling large amounts of medical data and giving useful information to improve patient care. But along with these advantages, there are some challenges too, like data privacy issues, lack of availability of good quality data, high cost of technology, and the need for technical knowledge for operating machine learning systems. In the coming years, we may see more advanced healthcare systems where patients will be monitored in real-time using smart devices. Machine learning can help in providing personalized medicines according to the patient's medical history and genetic information. It will also help in early detection of dangerous diseases like cancer, Alzheimer's, and heart problems. Moreover, robots powered by AI may assist doctors during surgeries and patient care. Machine learning will also help in faster drug development and better hospital management systems which will save time, cost, and human effort [14, 15].

5.3. Supervised and Unsupervised Learning in the Medical Field

Supervised learning and unsupervised learning are two popular techniques that can help doctors, hospitals, and medical researchers to provide better treatment to patients. In supervised learning, the machine is trained using labelled data. It means the machine already knows the input and its correct output. This method is very useful in medical diagnosis, where the machine can be trained to identify diseases by learning from past patient data. For example, supervised learning can help in detecting cancer, predicting heart diseases, or identifying patients based on their medical reports, X-rays, or blood test results.

On the other hand, unsupervised learning works with unlabelled data. This means the machine does not know the correct answer and finds patterns, similarities, or hidden structures on its own. In the medical field, unsupervised learning helps in grouping patients based on their symptoms, medical history, or lifestyle habits. It can help discover new diseases, detect rare medical conditions, or group patients for personalized treatments. It also helps in analysing large sets of health records to find hidden trends, which can help prevent diseases at an early stage [14].

6. Evaluation of Machine Learning Models in Healthcare

When we use machine learning models in the medical field, it is very important to check whether the model is giving correct results or not. This is done by using different evaluation methods [10, 11]. These methods help us to know how

well our machine learning model is performing in predicting diseases, analysing patient data, or giving medical suggestions. There are different types of machine learning algorithms like supervised learning (classification & regression) and unsupervised learning (clustering). Each of them has different evaluation techniques.

6.1. Evaluation of Supervised Classification Algorithms

Supervised classification is used in healthcare when we want the machine to identify a disease or predict if a patient is sick or healthy. For example, predicting if a patient has cancer or not by looking at their medical reports. In order to check how accurate these models are, we use:

a) Accuracy: Accuracy show how many predictions made by the model are correct. Example: If out of 100 patients, the model correctly predicts the disease for 90 patients, then accuracy is 90%.

Accuracy = (True Positive + True Negative) / (Total Patients)

b) Sensitivity (Recall or True Positive Rate): Sensitivity depict how well the model is able to find out the people who are actually sick. Example: If 50 patients have cancer, and the model correctly detects cancer in 45 of them, then sensitivity is 90%.

Sensitivity = True Positive / (True Positive + False Negative)

c) Specificity (True Negative Rate) Specificity measure how well the model is able to detect healthy people correctly. Example: Out of 50 healthy people, if the model correctly says 48 are healthy, specificity is 96%.

Specificity = True Negative / (True Negative + False Positive)

6.2. Evaluation of Supervised Regression Algorithms

Regression is used in healthcare when we want the machine to predict continuous values like a patient's blood pressure, sugar level, heart rate, or risk score of a disease. In order to check how accurate regression models are, we use:

a) Mean Absolute Error (MAE): MAE is the average of the mistakes that model makes. Example: If the model predicts a patient's sugar level as 140 but the actual value is 150, then the error is 10.

MAE = Average of |Actual Value - Predicted Value|

b) Mean Squared Error (MSE): MSE is similar to MAE but it squares the error, so big mistakes are punished more.

MSE = Average of (Actual Value - Predicted Value) ^{2}

c) Root Mean Squared Error (RMSE): RMSE is the square root of MSE.

RMSE = √MSE

d) Mean Absolute Percentage Error (MAPE): MAPE suggests the error in percentage. MAPE = (|Actual Value - Predicted Value| / Actual Value) × 100%

6.3. Evaluation of Unsupervised Clustering Algorithms

Unsupervised learning is used when the machine groups patients without knowing the disease labels. For example grouping patients with similar symptoms, lifestyle habits, or disease patterns. To check how well clustering works, we use:

a) SSE (Sum of Squared Errors): SSE shows how close the data points are within a group (cluster). Smaller SSE means better performance. For example, in healthcare if we group diabetic patients based on age, lifestyle, and diet, smaller SSE means patients in the same group have very similar conditions.

b) Calinski-Harabasz Index: This measures how separated the clusters are from each other and how compact they are inside. A higher value means good clusters.

c) Silhouette Coefficient: This score is between -1 to 1. The closer to 1, the better the clustering.

d) Rand Index and Fowlkes-Mallows Score: These are used to compare the clusters created by the model to the actual known groups.

All these evaluation techniques help in building machine learning models that doctors and healthcare systems can trust. Supervised classification models help in disease detection like cancer, heart disease, or virus detection. Supervised regression models help in predicting health scores, future risk factors, or patient survival rates. Unsupervised clustering models help in grouping patients for research, personalized treatment, or finding new medical patterns. By using these evaluation methods, we can build accurate, reliable, and life-saving machine learning models that will improve healthcare services, patient safety, and medical research.

7. Conclusion and Future Scope

To improve overall health, health organisations recognise that they must address the entire communities, including lifestyle and environment. ML models can identify patients at a higher risk of developing preventable chronic diseases like heart disease, diabetes, etc. In addition to clinical applications, ML is also enhancing operational efficiency within healthcare institutions. From automating administrative tasks and managing patient records to optimizing hospital resource allocation and predicting patient admissions, ML is reducing the burden on healthcare professionals and improving patient experience. Furthermore, the integration of ML with wearable technology and remote monitoring devices is expanding access to healthcare services, especially in underserved areas. These advancements support preventive care and chronic disease management, allowing for continuous monitoring outside traditional clinical settings. While challenges such as data privacy, algorithm transparency, and the need for robust regulatory frameworks remain, the benefits of ML in healthcare are undeniable. With ongoing research and ethical implementation, ML has the potential to reshape the future of medicine, making healthcare more proactive, personalized, and precise. The future scope of Machine Learning (ML) in healthcare is incredibly promising and poised to revolutionize the way medical services are delivered, diagnosed, and managed. Drug discovery stands to benefit enormously from ML, with accelerated research timelines and more accurate predictions of efficacy and side effects. However, these advancements face challenges including data privacy concerns, ethical considerations around algorithmic bias, and integration with existing healthcare systems. As these technologies mature and overcome implementation hurdles, we can expect healthcare delivery to undergo a significant transformation, resulting in more accurate diagnoses, personalized treatments, improved patient outcomes, reduced costs, and decreased administrative burden over the next decade. ML and its predictive analytics component can play an essential role in individualised treatments. Clinicians can choose from a restricted number of diagnoses or estimate the risk to their patients based on their clinical history and genetic information. ML techniques will generate several therapy alternatives in the future by leveraging patient medical history. Further, medical schools should explore incorporating coursework on ML and its applications in their curricula. ML and data science should be taught to medical students, residents, and fellows during their training.

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