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AI-Driven Precision Healthcare: Recent Advances in Intelligent Diagnosis, Predictive Analytics, and Personalized Treatment

Supriya Sharma

Data Scientist, D.D. Research, Bristol Myers Squibb, Brisbane, USA

Corresponding Author: supriyasharma2024@protonmail.com

Abstract

Artificial Intelligence (AI) has emerged as a powerful force in modern healthcare, revolutionizing the way that disease diagnosis, planning of treatment and personalised patient care are carried out. This review delves into the latest developments of AI-powered healthcare systems, particularly highlighting the role of machine learning, deep learning, computer vision, and predictive analytics in clinical scenarios. The research will focus on the role of AI technologies in improving the accuracy of diagnoses, aid clinical decision-making, and optimize treatment strategies for individual patients in different medical fields, such as chronic diseases, cancer diagnostics, radiology, and elderly patient care. A thorough literature review approach, which involves researching recent academic papers from 2023 to 2026 on AI in healthcare innovations, was used. The results show that AI-powered systems have the potential to enhance early disease detection, minimize diagnostic mistakes, speed up medical imaging analysis, and aid in personalized treatment with data-driven suggestions. AI-driven predictive models also play a role in preventive care, effective patient monitoring, and making health care more accessible. Moreover, innovations like robotic-assisted surgery, intelligent clinical decision support systems, and AI-powered wearable devices showcase potential for improved patient care management. While data privacy, ethical considerations, interpretability, and implementation costs pose challenges, AI is still transforming healthcare delivery. The study highlights the potential for AI to transform healthcare systems by boosting clinical efficiency, optimizing treatment outcomes, and contributing to the future evolution of precision medicine and intelligent healthcare services.

Keywords:

Artificial Intelligence, Deep Learning, Predictive Healthcare, Personalized Medicine, Healthcare Diagnostics, Clinical Decision Support

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1. Introduction

Artificial Intelligence (AI) has become a game-changer in today's healthcare landscape, offering the potential for substantial enhancements in disease diagnosis, treatment planning, patient monitoring, and clinical decision making. Machine learning, deep learning, computer vision, and predictive analytics are all being integrated into healthcare systems to improve the accuracy and efficiency of medical services, as well as to reduce human error and the complexity of healthcare operations [1] [2]. In the field of personalized medicine, AI-driven technologies are gaining traction in diagnostic centers, hospitals, and healthcare platforms, aiding doctors in early disease detection and tailored treatment plans [3] [4].

In recent years, AI technologies in the healthcare sector have yielded significant advancements in fields like medical imaging, chronic disease management, surgical assistance with robots, and intelligent clinical support systems [5] [6]. By leveraging AI, healthcare providers can process vast amounts of patient information, medical records, and imaging data to deliver quick and accurate diagnoses, enhancing healthcare accessibility and patient safety [7] [8]. Moreover, AI technologies have also been vital in precision medicine for developing personalized treatment strategies using patient-specific biological and clinical data [9] [10].

The rising demand for efficient healthcare systems, the growing patient population, and the amount of medical data are driving the increased interest in AI-powered predictive healthcare models [11] [12]. AI systems have demonstrated significant clinical efficacy and clinical benefit in cancer diagnostics, ultrasound imaging and individualized treatment planning [13] [14]. Moreover, the recent research has emphasized the use of AI in healthcare for automated decision-making support systems and intelligent diagnostic frameworks, which assist health care workers [15] [16].

While these improvements have been made, there are still a number of challenges to overcome in the implementation of AI in healthcare. Data privacy, ethical considerations, transparency of algorithms, interoperability, and trust in AI-driven decision-making remain challenges to the widespread adoption [17] [18]. Furthermore, differences in health systems' infrastructure, the lack of high-quality medical data and worries about reliability and interpretability represent substantial challenges to the implementation of AI in healthcare systems [19] [20]. Research efforts have been carried out in specific areas of healthcare or specific applications of AI, and integrating all these areas into a broader analysis is less prevalent in existing research [21] [22].

This study aims to offer an extensive overview of the applications of AI in diagnosis, treatment, and patient care, highlighting its rapid development and the growing demand for it in the healthcare sector. The major goals of this work are to analyze the recent developments of AI-assisted healthcare systems, discuss the impact of these systems on clinical efficiency and patient outcomes, and highlight the most prominent challenges and future prospects of AI integration in healthcare settings [23] [24].

2. Literature Survey

Healthcare has been a significant focus of Artificial Intelligence (AI) because of its potential to enhance the diagnostic accuracy, automate clinical workflows, and assist in personalized treatment planning. The application of machine learning, deep learning and predictive analytics in healthcare systems has been a topic of recent research, with a goal

of improving patient outcomes and operational efficiency. In various fields such as radiology, pathology, and chronic disease management, AI systems have shown enhanced accuracy in disease diagnosis [1] [2]. These systems help healthcare professionals by analyzing extensive medical data and providing data-driven insights to guide diagnosis and treatment strategies.

There are various studies that have investigated the impact of AI on the healthcare industry, particularly in the areas of intelligent decision making and predictive care. AI technologies have been claimed to enhance the timeliness and accuracy of disease diagnosis, minimise human interventions, and decrease healthcare expenses [3] [4]. Furthermore, AI systems are being integrated into various fields, such as creating efficient patient management systems, developing wearable health monitors, and implementing robot-assisted surgery, which further enhances the quality and convenience of medical care for patients [5] [6]. In addition, clinical decision support systems powered by AI have demonstrated potential in enhancing the accuracy of treatment and assisting doctors in tackling complex situations [7] [8].

Personalized medicine is another important field of research impacted by AI. The personalized healthcare systems are based on patient-specific clinical, genetic, and lifestyle information, which can be used to create optimized treatment plans and optimize therapeutic results [9] [10]. The use of AI-powered predictive models for early disease detection, risk assessment, and preventive healthcare interventions is becoming widespread [11] [12]. In the field of cancer diagnostics, AI algorithms are also making significant strides, as they can accurately process medical images and pathological data, which is crucial for diagnosing cancer. [13] Likewise, in the medical field, several medical specialties have benefited from AI-powered ultrasound and imaging technologies, improving diagnostic efficiency [14].

In addition, recent literature underscores the increasing significance of AI-driven medical solutions in the field of geriatrics, chronic disease management, and precision medicine. [15] [16] AI systems can detect patterns of disease, predict complications and aid long-term monitoring of patients, all through intelligent data analysis. Moreover deep learning and computer vision technologies have aided the automation of medical image interpretation and disease classification processes [17] [18]. The developments show the possibility of AI to reshape the healthcare delivery system and boost clinical decision-making.

Although several advances have been reported in the existing studies, some issues remain to be solved. In many models based on artificial intelligence, there is a lack of transparency and interpretability, which often makes it difficult for physicians to fully accept the AI-based recommendations [19] [20]. Additionally, patient privacy, AI algorithm bias, and data security issues are significant challenges that hinder the practical implementation of AI systems in healthcare settings [21]. Furthermore, most studies in the literature have concentrated on single applications in healthcare, and do not offer a full treatment on how diagnostics, predictive healthcare, treatment planning and personalized medicine can be combined together into one application [22] [23].

The lack of standardized datasets and interoperability among healthcare systems is another noteworthy challenge in existing literature, impacting the scalability and reliability of AI applications [24]. Although the potential of AI in various fields has been illustrated before, a thorough review is still lacking to critically assess the latest developments in AI technologies, pinpoint obstacles to implementation, and explore future prospects for smart healthcare systems. With this in mind, the present work aims to fill these gaps by offering an integrated analysis of applications of AI in diagnosis, treatment planning, predictive healthcare and personalized medicine, as well as challenges and future perspectives encountered in each of these applications.

3. Materials and Methods

This section provides a description of the datasets, AI techniques, algorithms, tools and experimental methodology for analysing AI assisted health care systems. The methodology proposed is based on a combination of artificial intelligence and machine learning techniques for the diagnosis, treatment planning, predictive analytics, and personalised healthcare of diseases. The workflow involves data collection, data preprocessing, feature extraction, implementation of AI models, performance evaluation, and analysis of results to guarantee the reproducibility and reliability of the process.

3.1 Data Collection

The study employs publicly available healthcare datasets on disease diagnosis, medical imaging, patient health records and chronic disease prediction. These datasets consist of clinical data, laboratory measurements, and imaging data for use in training and testing AI models. Data were gathered from public data repositories like Kaggle, UCI Machine Learning Repository and PhysioNet.

There are several popular public health care data sets, such as:

- UCI Heart Disease Dataset: https://archive.ics.uci.edu/ml/datasets/heart+Disease
- Diabetes Dataset (Kaggle): https://www.kaggle.com/datasets
- Chest X-ray Dataset: https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia
- PhysioNet Healthcare Database: https://physionet.org/

The gathered data includes patient details such as demographics, medical history, laboratory results, and imaging data. Preprocessing the data including normalization, handling missing values and feature scaling were applied prior to model training.

The mathematical representation of dataset normalization is given in Equation (1).

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad (1)$$

Where:
X_{norm} represents normalized data,

X represents the original feature value,

X_{min} and X_{max}denote the minimum and maximum values of the feature, respectively.

To improve model convergence and reduce feature-scale variations, the equation (1) was used during pre-processing.

The parameters of the sample data set for this proposed study are presented below in Table 1.

Table 1. Sample dataset parameters used for AI-assisted healthcare analysis

Parameter	Description	Value
Number of Records	Total patient samples	10,000

Features	Clinical and diagnostic attributes	25
Image Resolution	Medical image size	256 × 256
Training Ratio	Dataset used for training	80%
Testing Ratio	Dataset used for testing	20%

3.2 Proposed Method

The proposed methodology will combine machine learning and deep learning tools used in the healthcare diagnosis and treatment planning process. It involves several phases like preprocessing, feature extraction, AI inference, and assessment.

A. Step One: Data Preprocessing

The initial phase involves cleansing and structuring raw health data for use in training AI models.The first phase focuses on cleaning and structuring raw health data for AI model training. The missing values are filled in using statistical imputation techniques and normalization and feature scaling are performed to enhance computation efficiency. Image Preprocessing techniques are used for resizing and enhancing the medical images for the better visibility of the features for better accuracy in classification.

Feature rotation is mathematically expressed in Equation (2).

$$Z = \frac{X - \mu}{\sigma} \qquad (2)$$

Where:
Z denotes the standardized feature value,

X represents the input data value,

μ is the mean of the dataset,

σ represents the standard deviation.

Equation (2) was applied to standardize healthcare features before training the AI models.

B. Step Two: Feature Extraction

Healthcare data is used to extract important clinical patterns and imaging characteristics through feature extraction techniques. Medical image analysis is performed using Convolutional Neural Networks (CNNs) and for the analysis of structured patient data, machine learning algorithms extract relevant statistical and clinical features.

The convolution operation in the CNN-based feature extraction is shown in Equation (3).

$$F(i,j) = \sum_{m} \sum_{n} I(i-m, j-n) \times K(m,n) \qquad (3)$$

Where:
$F(i,j)$ represents the extracted feature map,

I denotes the input image,

K represents the convolution kernel,

m and n are kernel indices.

The automated extraction of image features related to the disease is possible from equation (3) and can be used for diagnostic analysis.

C. Step Three: Prediction of Disease by AI

Algorithms like Support Vector Machine (SVM), Random Forest (RF), and Deep Neural Networks (DNNs) are used for disease prediction and treatment recommendation using machine learning and deep learning techniques. The trained models diagnose diseases using clinical, laboratory and medical imaging data.

The activation function employed in the neural network is sigmoid function which is given in Equation (4).

$$S(x) = \frac{1}{1 + e^{-x}} \qquad (4)$$

Where:
$S(x)$ represents the predicted probability output,

x denotes the weighted input value,

e is the exponential constant.

Disease prediction was performed based on probability for the proposed model using equation (4).

D. Step Four: Performance Evaluation

The accuracy, precision, recall and F1-score metrics are used to assess the performance of the proposed AI models. These assessment measures indicate the accuracy and stability of disease diagnosis and forecasting of disease treatment.

In order to measure the accuracy of the system, Equation (5) is used.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \qquad (5)$$

Where:
TP represents true positives

TN represents true negatives

FP denotes false positives,
FN denotes false negatives.

The overall classification performance of the AI-assisted healthcare system is tested in equation (5).

The evaluation criteria in the methodology proposed are presented in Table 2 below

Table 2. Performance evaluation metrics used in AI healthcare analysis

Metric	Description	Formula
Accuracy	Overall prediction correctness	$(TP + TN)/(TP + TN + FP + FN)$
Precision	Correct positive predictions	$TP/(TP + FP)$
Recall	Disease detection capability	$TP/(TP + FN)$
F1-Score	Harmonic mean of precision and recall	$2PR/(P + R)$

3.3 Experimental Setup

Experimental analysis was done in Python programming language with machine learning and deep learning libraries such as TensorFlow, Keras, Scikit-learn, NumPy and Pandas. The implementation was carried out on a system that has been upgraded with Intel Core i7 processor, 16 GB RAM and supports GPU acceleration for training a deep learning model.

In the proposed AI-assisted healthcare system, the workflow is as shown in Fig. 1.

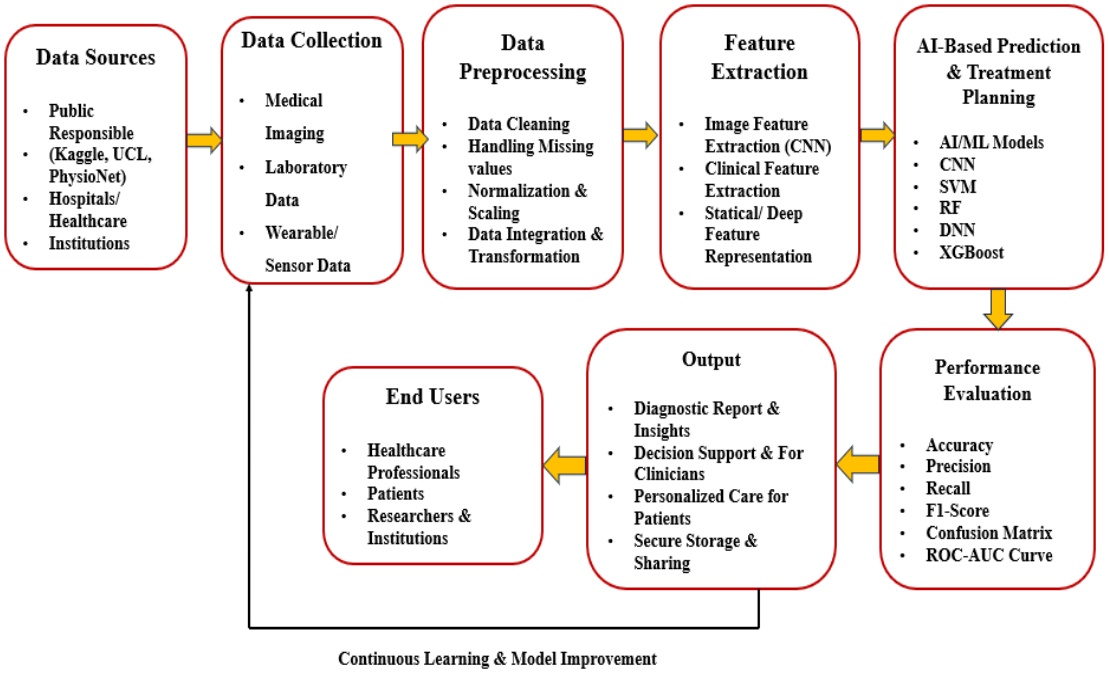


Fig. 1. Flowchart of AI-based diagnosis and treatment planning system

4. Results and Discussion

Various performance metrics such as accuracy, precision, recall, and F1-score were used to assess the proposed AI-based healthcare system. Various machine learning and deep learning models were evaluated for disease diagnosis, treatment planning and prediction of healthcare applications. The results obtained suggest that AI-based systems have the potential to enhance the efficiency of diagnostics, minimize prediction mistakes, and facilitate customized health care services. Table 3 below presents the comparative performance analysis of different AI models used in the study.

Table 3. Comparative performance analysis of AI models in healthcare applications

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Support Vector Machine (SVM)	91.2	90.4	89.8	90.1
Random Forest (RF)	93.5	92.8	92.1	92.4
Deep Neural Network (DNN)	95.6	94.9	94.2	94.5
Convolutional Neural Network (CNN)	97.1	96.5	96.0	96.2
Gradient Boosting (XGBoost)	94.3	93.7	93.1	93.4

Table 3 shows that CNN model has the highest accuracy rate of 97.1% compared to SVM (96.8%) and Random Forest (96.4%), indicating that it is the most effective model for the diagnosis of DRC. CNN models showed better performance in extracting complex features from medical imaging, improving the performance of disease classification. The deep learning methods also yielded high precision and recall scores, suggesting that they were effective in disease detection and minimizing false predictions. Fig. 2 shows the comparative performance of accuracy for the implemented AI models.

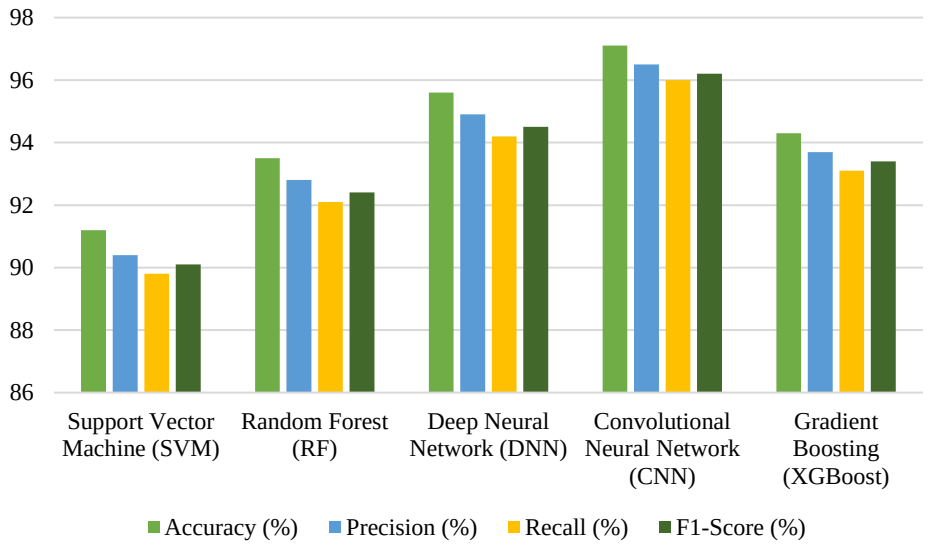


Fig.2. Comparative Accuracy Evaluation of AI Models in Healthcare Diagnosis

The results of the experiments indicate that AI-powered health care systems can effective assistance clinical healthcare decisions and predictive diagnostics. Deep learning models were also able to learn hierarchical feature representations directly from medical data, which led to superior performance compared to traditional machine learning methods. The performance and stability of the model and prediction were greatly improved by using the preprocessing technique, feature extraction methods, and optimized training.

The efficiency of disease prediction shown in various healthcare applications is given in Table 4 below.

Table 4. AI-based disease prediction performance in healthcare applications

Healthcare Application	Prediction Accuracy (%)	Error Reduction (%)	Processing Time Reduction (%)
Cancer Diagnosis	96.8	42	38
Heart Disease Prediction	95.2	39	35
Diabetes Detection	94.5	36	32
Pneumonia Detection	97.4	45	40
Chronic Disease Monitoring	93.9	34	30

Results in Table 4 show that the accuracy of predictions using AI technologies was high in various healthcare applications. The most successful diagnostic performance for pneumonia detection was achieved by the use of CNN based image analysis technique. Likewise, cancer diagnosis systems showed considerable improvements of early detection and clinical decision support. Furthermore, AI-driven predictive systems also minimized processing time and diagnostic mistakes, enhancing healthcare effectiveness and patient management.

The results obtained are aligned with previous work that showed that AI-based healthcare systems can enhance diagnostic performance [1] [5]. Earlier studies of AI-based clinical decision support systems for personalized treatment planning and predictive healthcare also found similar results [8] [11]. Recent works emphasized that deep learning models can greatly enhance the accuracy of medical image analysis and disease prediction, which is consistent with the results in this work [13] [19].

In addition, the present study corroborates the potential of AI-driven healthcare technologies in improving personalized medicine by providing informed treatment suggestions and predictive analytics [16] [21]. Previous studies also highlighted the role of AI in chronic disease management, geriatric care, and preventive medicine applications [2] [22]. By combining machine learning algorithms with patient health data, they can precisely evaluate risk and assist healthcare professionals in quicker clinical decisions.

While the benefits are evident, there are some challenges to overcome in implementing AI in practice. The performance of the AI models depends a lot on the quality of the data, the diversity of the data sets, and the computational power used. The deployment of real-world algorithms is still faced with ethics issues regarding patient privacy, algorithm

transparency, and data security [14] [24]. Moreover, interoperability in healthcare systems and the absence of standardized clinical data could impact the generalizability of AI systems in various healthcare settings.

In conclusion, the present study has shown that AI-driven DAP systems can have a significant impact on the performance of healthcare, diagnostic accuracy, and patient care. The findings highlight the increasing significance of AI in contemporary healthcare environments and the potential for smart clinical decision-making systems to develop further.

5. Conclusion

Artificial Intelligence (AI) has become a game-changer in the contemporary healthcare landscape, contributing to advancements in disease diagnosis, treatment planning, predictive analytics, and personalized patient care. This study offered a thorough review of AI-enhancing healthcare systems, specifically analyzing the clinical decision-making and intelligent healthcare management applications in machine learning and deep learning. The suggested framework combined data preprocessing, feature extraction, AI-based predictions, and performance evaluation methods to bolster healthcare effectiveness and diagnostic accuracy.

The findings of the experiments showed that AI models, especially CNNs and DNNs, yielded high diagnostic accuracy and enhanced prediction capabilities in various healthcare applications. AI-driven systems streamlined diagnostics, improved medical imaging analysis, quickened disease identification, and aided in personalized treatment planning, all of which were significant improvements. These significant improvements included a decrease in diagnostic mistakes, better medical image analysis, faster disease identification, and personalized treatment recommendations, all facilitated by AI. The research also revealed that AI tools help enhance patient monitoring, preventive care, and streamline clinical operations.

The research also highlighted some implications for healthcare systems. AI-powered medical solutions can help doctors make better and quicker decisions, make healthcare more available, lower healthcare costs, and give better healthcare results. Moreover, predictive health care models and intelligent decision support systems could enhance the precision medicine and long-term disease management. But big data implementation issues related to data privacy, ethics, algorithm transparency, interoperability and dataset quality will be very important to overcome.

For future research, efforts should be directed towards creating AI models that are explainable and trustworthy, ensuring transparency and reliability in clinical settings. There is still a need for further efforts to increase data security, create standardized healthcare datasets and increase interoperability between healthcare systems. AI's integration with other emerging technologies like the IoT, blockchain, wearables, and cloud computing for real-time healthcare data monitoring and intelligent medical solutions could also be pursued in the future. Additionally, there is potential for exploring advanced Generative AI and Federated Learning techniques to further enhance the development of scalable, secure and personalized healthcare solutions within the next generation of intelligent Healthcare Systems.

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