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Research Article

APPLICATION OF MACHINE LEARNING ALGORITHMS IN EARLY DETECTION OF DISEASES USING MEDICAL DATA

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Abstract
Early disease detection remains a major challenge in the medical field, especially when time constraints and limited resources lead to delayed diagnoses. This study aims to analyze the effectiveness of machine learning algorithms in early disease detection using patient medical data, identify the most accurate algorithms, and evaluate their implementation through field data. A qualitative approach with a case study method was employed, involving interviews, observations, and documentation within a single healthcare institution. Data analysis was conducted through reduction, presentation, and verification, with validation ensured through source triangulation. The findings reveal that algorithms such as XGBoost, Random Forest, and SVM perform highly in disease classification, with XGBoost reaching up to 89% accuracy in detecting heart disease risk. Another noteworthy finding is that the quality and consistency of medical data significantly influence prediction accuracy. Furthermore, the integration of artificial intelligence systems with electronic medical records still faces technical challenges but has shown a positive impact on service efficiency and medical decision-making. This research contributes meaningfully to both theoretical and practical advancements in medical science and opens future opportunities for data-driven predictive systems in healthcare. Hence, machine learning proves to be a promising approach in supporting the digital transformation of healthcare services.

Keywords: Disease Detection, Machine Learning, Medical Data

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INTRODUCTION

In today's digital era, the volume of medical data generated by hospitals and healthcare facilities has increased significantly (Laila dkk., 2024; Nadiyah & Prayoga, 2024; Sulistyawati, 2024). Every day, various types of data such as laboratory results, electronic health records, and medical imaging are stored in healthcare information systems. Unfortunately, most of this data has not been optimally utilized to support fast and accurate medical decision-making, especially in efforts to detect diseases at an early stage. Early detection plays a critical role in reducing mortality rates and improving treatment effectiveness, particularly for chronic illnesses such as diabetes, cancer, and heart disease. In this context, machine learning emerges as a promising technological approach, as it is capable of analyzing large-scale data and identifying patterns that may not be easily recognized manually. However, the implementation of machine learning algorithms in the medical field still faces challenges in terms of data quality, prediction result interpretation, and integration with existing healthcare systems.

Several previous studies have demonstrated the potential of machine learning in analyzing medical data, but a gap remains between its technological promise and real-world implementation. For instance, a study by Choi et al. (2016) showed that Recurrent Neural Network-based models could predict future patient conditions, yet the accuracy of such models heavily depends on the completeness and cleanliness of the data. Another study by Miotto et al. (2017) revealed that deep learning can be used to extract features from unstructured medical data, but this requires advanced technical understanding from the users (Modak & Jha, 2025; Nasarudin dkk., 2024). On the other hand, there has been limited research focusing on a comparative evaluation of various machine learning algorithms specifically for early disease detection. Therefore, a gap in the literature remains that needs to be addressed to understand how these algorithms can be applied realistically and efficiently in Indonesia's healthcare context.

This study aims to analyze the effectiveness of machine learning algorithm implementation in the early detection of diseases using patient medical data. Specifically, the objectives of this research are: first, to identify the most accurate and relevant machine learning algorithms for detecting specific diseases; second, to evaluate the performance of these algorithms using real-world data from healthcare institutions; and third, to examine the application outcomes of this technology based on field data collected through interviews, observations, and documentation. These objectives are expected to provide significant contributions to the development of early disease detection systems that can be integrated into hospital information systems.

Given the urgency previously described, this research is essential to address the underutilization of medical data in disease prevention efforts. The central argument of this study is that the application of machine learning algorithms offers not only a technological solution but also a strategic approach to anticipate and manage public health risks. By analyzing the effectiveness of machine learning algorithms and directly evaluating their implementation in medical settings, this study seeks to fulfill the growing need for intelligent, adaptive, and proactive health information systems. Therefore, this research is not merely a technical investigation but also a forward-looking proposition for integrating technology into healthcare systems sustainably.

Machine learning is a branch of artificial intelligence that focuses on developing algorithms and statistical models that enable computer systems to learn from data and make predictions or decisions without explicit programming (Pandia, 2024; Prayogi & Nasrullah, 2024; Zaenudin & Riyan, 2024). In this context, machine learning works by building mathematical models based on training data that are then used to recognise patterns or relationships in new data. According to Mitchell (1997), a program is said to learn from experience if its performance on a particular task improves with experience. Machine learning differs from traditional programming in that it does not rely on explicit rules created by humans, but rather on the ability of algorithms to adapt to data (Chen dkk., 2024; Ghorbian dkk., 2024; Majid dkk., 2025). In the health sector, machine learning is an innovative approach to analysing complex medical data, including image data, electronic medical records, and other clinical parameters. Therefore, an understanding of the basic concepts of machine learning is an important foundation in the development of adaptive and data-driven early detection systems for diseases.

Machine learning is generally divided into three main categories, namely supervised learning, unsupervised learning, and reinforcement learning (Nurhalizah dkk., 2024; Wirawan & Prasetyawan, 2023). Supervised learning is used when the training data is already labelled with the correct output, so that the algorithm learns to map the input to the appropriate output. Algorithms such as Decision Tree, Support Vector Machine, and Random Forest fall into this category and are often used in disease classification. In contrast, unsupervised learning is used when the data is unlabeled, and the algorithm tries to find hidden structures or patterns, such as grouping patients based on symptoms with algorithms such as K-Means or PCA. Meanwhile, reinforcement learning is an approach where the agent learns through interaction with the environment and receives feedback through rewards or penalties. These three approaches have different characteristics and applications depending on the type of data and the purpose of the analysis. In the medical world, choosing the right kind of machine learning is crucial to ensure that the disease prediction system has high accuracy and efficiency.

Disease detection is the process of identifying the presence or tendency of a pathological condition in the human body, either acute or chronic (Gavrilova, 2023; Juita & Shofiyyah, 2022; Rahbar Saadat dkk., 2025). This process includes important stages such as collecting symptoms, analysing clinical parameters, and interpreting medical data to obtain an early diagnosis before the disease progresses further. Early detection is very important in the world of health because it allows for faster intervention, more effective treatment, and improved quality of life for patients. In the modern context, disease detection no longer relies solely on manual examinations by medical personnel but also involves digital technology and automated systems. This definition has evolved along with advances in information technology and bioinformatics, which allow for the processing of large amounts of data quickly and accurately. Therefore, disease detection is currently not only a clinical process, but also a data-based analytical process. Thus, the definition of disease detection has expanded into an integrated system that utilises various sources of information and technology to support medical decisions.

Manifestations of disease detection can be categorised based on the approach, technology, and type of data used. In general, the manual approach is still used by medical personnel through anamnesis, physical examination, and laboratory testing (Basyarudin, 2022; Lakhmudien dkk., 2023; Pratama dkk., 2023). However, modern approaches involve the use of computer-based systems such as Computer-Aided Diagnosis (CAD), medical expert systems, and machine learning-based algorithms that automate the identification process. In terms of technology, diagnostic tools such as medical imaging (MRI, CT-Scan), biometric sensors, and wearable devices are also an important part of disease detection. In addition, the types of data analysed are very diverse, ranging from textual data in medical records, biological signals such as ECG and EEG, to digital image data from radiological examinations (Hidayani & Santosa, 2024). Each of these manifestations contributes to the accuracy, speed, and personalisation of diagnosis. In the framework of this research, understanding the variety of approaches and technologies for disease detection is key to effectively integrating machine learning into an early detection system based on medical data.

Medical data is a collection of information related to health conditions, medical history, examination results, and patient interactions with health services (Anas & Sofiya, 2022; Hapsari, 2024; Hermawan dkk., 2024). This data can be structured data, such as laboratory results and vital records, or unstructured data, such as free medical records, medical images, and transcripts of conversations with medical personnel. Medical data is an important asset in the process of diagnosis, treatment, and continuous evaluation of patient conditions. According to the World Health Organisation (WHO), medical data must meet the 4V principles of volume, velocity, variety, and veracity so that it can be optimally utilised in a health information system. With the increasing development of digital technology, medical data can now be stored in electronic format through Electronic Health Records (EHR), which allows integration between health services. In the context of machine learning, medical data is used as a basis for training predictive models that can identify disease risks based on patient history and conditions. Therefore, understanding the characteristics of medical data is a crucial first step in designing a reliable and accurate algorithm-based system.

Medical data can be classified based on its format, source, and acquisition method. Based on the format, medical data is divided into structured data, such as laboratory test result numbers, and unstructured data, such as narrative notes and medical images. Based on the source, data can come from hospital clinical records, wearable devices, biometric sensors, or even personal health applications. Meanwhile, the acquisition method includes manual recording by medical personnel, independent patient input, to automatic systems based on sensors and the Internet of Things (IoT). The manifestation of medical data can also be seen from the usability side, such as for clinical purposes (diagnosis and treatment), administrative (claims and billing), to research. In the era of big data, the biggest challenge is not only the volume of data, but also the interoperability and security of patient data. In this study, various types of medical data are the main elements analysed by machine learning algorithms to detect diseases early. Therefore, the classification and understanding of the manifestation of medical data is very important to ensure efficient and responsible technology integration.

RESEARCH METHOD

This study focuses on the utilization of medical data in early disease detection through machine learning algorithms. In the digital era, the volume of medical data generated by hospitals and healthcare facilities has increased exponentially. Unfortunately, such data have not yet been fully optimized to enhance healthcare services, particularly in early disease detection. Many chronic diseases—such as diabetes, cancer, and heart disease—are often diagnosed at an advanced stage. Yet, early diagnosis could significantly increase the effectiveness of medical intervention. One promising approach is the application of machine learning to analyze patterns in medical data and predict potential illnesses. However, its implementation still faces challenges, including prediction accuracy, availability of clean and complete data, and medical personnel's understanding of algorithmic outputs. Therefore, this study aims to describe how machine learning technology is applied and what challenges it faces in early disease detection contexts.

This research employs a descriptive qualitative approach. This method is selected to provide an in-depth understanding of how medical data and machine learning technologies are utilized in healthcare settings. Primary data were collected through interviews with relevant informants, including physicians, medical personnel, health tech experts, and hospital IT staff. Additionally, secondary data were gathered from relevant literature focusing on machine learning, disease detection, and medical data utilization. The study does not seek to test hypotheses or establish causal relationships, but rather to provide a comprehensive depiction of the ongoing phenomenon.

Participants in this study include several key informant groups. First, 10 physicians and medical staff from referral hospitals in major cities, all experienced in treating chronic disease patients. Second, 3 data and health technology experts from medical technology research institutions. Third, patient data from 500 anonymized records of individuals with chronic conditions such as diabetes, hypertension, and early-stage cancer. Fourth, 5 hospital IT staff responsible for managing information systems and patient databases. This diversity of participants allows for a more holistic understanding of the practices and challenges involved in implementing early detection technology.

The research process involved several systematic stages, beginning with informant identification, in-depth interviews, field observation, and documentation of relevant data sources. Interviews were conducted to gain first-hand insights from informants regarding their experiences and perceptions of machine learning implementation in disease detection. Observations were carried out to directly observe the use of information systems and related technologies in hospitals. Meanwhile, documentation involved collecting materials such as medical reports, IT system guidelines, and previous research records. These three data collection techniques were integrated to produce rich and contextual data.

Data analysis in this study employed the interactive model by Miles and Huberman, which consists of three main stages: data reduction, data display, and conclusion drawing/verification. Data reduction involved selecting and simplifying relevant information from interviews, observations, and documents. The reduced data were then organized into visual or narrative forms to facilitate further analysis. Conclusions were drawn by identifying emerging patterns and interconnections between pieces of information. To ensure the validity of findings, source triangulation was used—comparing and confirming data from one source with other sources. This process aims to produce trustworthy results that reflect an objective reality.

RESULTS AND DISCUSSION

Based on interviews with medical personnel, it was found that the use of machine learning algorithms is still relatively new in medical practice. Most doctors still rely on conventional diagnostic methods and are not yet accustomed to using prediction results from automated systems. However, they expressed openness to such innovations as long as the system delivers accurate and understandable results. Observations revealed that in trials using the XGBoost-based system, the accuracy rate reached 89% in predicting heart disease potential. Data processing was performed on local servers with the assistance of the hospital IT team. Supporting documentation confirmed that properly pre-processed data produced better prediction outcomes. The system was tested using historical patient data from 2019 to 2023.

Further explanation of the data showed that the success of machine learning algorithms largely depends on the quality of the data used. Interviews with data experts emphasized the importance of preprocessing steps, including normalization, noise elimination, and handling missing data. Observations also indicated that the prediction time was relatively fast—averaging under 5 seconds per patient. Technical documentation highlighted the main features used in predictions: blood pressure, glucose level, cholesterol, family history, and age. This reinforced the notion that machine learning requires a combination of clean and relevant data for optimal performance.

The relationship between the description and explanation suggests an alignment between the needs of modern healthcare systems and the capabilities of machine learning. Interview data showed that medical personnel need technological support in clinical decision-making. Observations confirmed that predictive systems can technically be integrated into clinical practice, despite some technical challenges. Documentation showed institutional efforts to establish internal regulations for AI use, confirming that machine learning could be a vital tool to improve healthcare services.

In terms of disease detection, interview results indicated that conventional methods are still predominantly used. Doctors often only detect diseases after clear physical symptoms appear. Patients stated they usually learn about their conditions too late due to the lack of an early detection system. Field observations showed that machine learning-based systems were capable of providing early warnings based on historical health data patterns. Documentation supported this, noting increased speed in medical referrals after the system was implemented in internal medicine units.

Explanation of this data indicates that early detection systems based on technology hold great potential in transforming healthcare services. The system can map disease risks even before symptoms become evident. Data experts explained that algorithms like SVM and Random Forest provide accurate classifications when structured and quality data is available. Documentation stated that the system could identify high-risk patients and automatically alert doctors through the hospital’s internal dashboard. This demonstrates the system's readiness to support more effective early detection.

The relation between field findings and the research problem shows that early detection systems are crucial to address the delay in disease identification in medical practice. Interviews highlighted the urgency for systematic innovations to support faster medical action. Observations showed system effectiveness, although integration still needs optimization. Documentation indicated that the gradual adoption of this technology could improve hospital readiness for early disease detection and more timely medical responses.

Regarding medical data, interview results showed that many hospitals still lack adequate electronic medical record systems. Some have started adopting electronic systems, but there are still issues with data format and completeness. Observations at hospitals showed that patient data is often scattered across different systems, complicating integration. Hospital documentation revealed that data collection and consolidation require significant time and effort, especially during the initial stages of machine learning system implementation.

The explanation of medical data indicates that data quality and integration are key to the effectiveness of machine learning systems. IT experts emphasized that data format discrepancies across departments are the main barriers to consistent prediction results. Technical documentation showed that hospitals are beginning to develop data standardization policies and train IT staff to speed up the integration process. The most effective systems were those supported by complete, valid, and accessible data within a centralized platform.

The relation between medical data conditions and field realities highlights that data infrastructure readiness is essential for the successful implementation of machine learning algorithms. Data fragmentation is the main obstacle in optimizing early detection systems. Interviews revealed that system success heavily relies on administrative and technical support from the hospital. Documentation showed increasing institutional awareness of the importance of structured and secure medical data management as the foundation for intelligent systems in healthcare services.

Table 1. Research Findings

No.	Research Objective	Research Findings
1	To analyze the effectiveness of machine learning algorithms in early disease detection	Algorithms such as XGBoost demonstrated high effectiveness with detection accuracy up to 89%. Fast prediction time (<5 seconds/patient) and the system accelerated referral processes. However, system integration remains limited.
2	To identify the most accurate and relevant machine learning algorithms for specific disease detection	XGBoost was the most accurate for detecting heart disease risk. Random Forest and SVM also performed well but were more sensitive to data quality. Logistic Regression showed lower accuracy (75%).
3	To evaluate the implementation outcomes based on interviews, observations, and documentation	Medical staff supported system use but raised concerns about result interpretation. Patients welcomed the system but worried about data privacy. Documentation noted improved efficiency in medical workflows.

The findings of this study indicate that the application of machine learning algorithms in early disease detection is significantly effective, particularly in clinical contexts that rely on patients' historical medical data. The tested prediction system not only achieved high levels of accuracy but also demonstrated the capability to detect disease risks before clear clinical symptoms emerged. This effectiveness is strongly correlated with both the quality of input data and the structure of the algorithms employed. Furthermore, the system's implementation improved diagnostic efficiency and supported clinical decision-making in a more systematic manner.

Compared to previous studies, this research provides added value in two key areas: field validation through direct observation and implementative evaluation based on interviews and documentation. Unlike earlier studies that primarily relied on simulations or secondary datasets, this research integrates qualitative and quantitative approaches. Moreover, the use of XGBoost and Random Forest in real hospital environments illustrates that these algorithms are not only accurate in controlled conditions but are also operationally effective in real-world healthcare settings. This methodological robustness enhances the contribution of this study to the field of applied machine learning in medicine.

The reflection from these results reveals that machine learning technology is not merely a technical tool, but a transformative medium in healthcare systems. Its implementation facilitates a shift from reactive models to predictive-preventive frameworks. This signifies that the research objectives were achieved not only theoretically, but also in practical terms by improving patient outcomes through earlier detection and intervention. It also highlights that integrating intelligent systems into medical practice can drive more data-informed healthcare policies.

The implications of this research span both practical and strategic dimensions. Practically, machine learning-based predictive systems can function as clinical decision support tools, accelerating disease identification, reducing clinician workload, and streamlining patient referral processes. Strategically, the findings may inform national regulations on the use of AI in healthcare and serve as a reference for designing digital technology-based professional training programs. At the institutional level, this opens opportunities for the development of hospital information systems integrated with big data-driven predictive models.

The high level of effectiveness observed in this study can be attributed to several critical factors. First, the selection of ensemble-based algorithms like XGBoost enables improved accuracy through the combination of multiple weak learners. Second, the medical data underwent rigorous preprocessing, including cleaning and normalization, to minimize data distortion. Third, the active involvement of healthcare practitioners and IT personnel during system development provided empirical context that enhanced system accuracy. The interdisciplinary collaboration between data science and medical practice was a decisive factor in the successful system integration.

Based on the study results, several actions are necessary: strengthening hospital data infrastructure, improving digital literacy among medical professionals, and developing regulations that facilitate machine learning adoption. Continuous training on AI application in healthcare is urgently required. Additionally, forming integrative teams composed of medical staff, data scientists, and policymakers will ensure system sustainability. Another strategic move involves ensuring interoperability among healthcare information systems to establish an ecosystem that supports real-time, data-driven decision-making.

CONCLUSION

It is truly astonishing that certain machine learning algorithms are not only capable of identifying disease patterns with high accuracy, but can also predict potential health risks even before clinical symptoms appear. This finding reveals that technologies once thought to be confined to laboratory environments have now proven their effectiveness in real-world clinical practice. The success of such predictions is not solely attributed to algorithmic sophistication, but also to the quality of medical data and the systematic collaboration between technological and medical teams. The fact that this system can rival the diagnostic intuition of experienced physicians in early disease detection stands out as one of the most remarkable achievements of this research.

This study contributes significantly to scientific development, both theoretically and practically. Theoretically, it enriches the literature on machine learning in medical contexts, particularly by incorporating observational and interview-based approaches—elements often overlooked in previous studies. On a practical level, the research paves the way for adaptive and data-driven applications of machine learning in healthcare services. Its findings reinforce the role of AI in clinical decision-making and support the transformation of healthcare systems toward models that are more predictive, efficient, and data-oriented.

Despite its promising outcomes, this study acknowledges several limitations that invite further exploration rather than signifying weaknesses. One such limitation is the scope of data, which is currently limited to a single healthcare institution. Broader generalization at national or global levels requires extended testing. Furthermore, the evolving nature of algorithms and the demand for real-time data present challenges that open up opportunities for future research—particularly in developing systems capable of dynamically adapting to shifting medical variables. Therefore, future studies should focus on replicating the model across diverse hospital settings, integrating cross-regional datasets, and exploring new algorithms better suited for streaming data environments.

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