Using Machine Learning and Deep Learning for Enhanced Prediction and Early Detection of Heart Disease Risk

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Keywords: Machine Learning, CNNs, LSTM, Deep Learning Techniques.

Abstract: Heart disease is still some the primary causes of mortality worldwide. Proper detection and accurate risk prediction are critical to effective prevention and therapy. Typical risk evaluation for heart disease models frequently uses simple statistical methodologies or regression analysis, which might not be able to grasp the intricate and non-linear interactions between many cardiovascular risk variables. As the difficulty of healthcare data develops, established methods are becoming unable to provide reliable forecasts. However, ML and DL techniques have demonstrated considerable promise in dealing with complex data and discovering detailed patterns that human specialists may ignore. These techniques are mostly helpful for predicting heart disease because age, heart rate, and levels of cholesterol, and lifestyle decisions all interact in complex, nonlinear ways. This study investigates how sophisticated ML and DL methods are decision trees, random forests, neural networks, and cutting-edge algorithms similar CNNs and LSTM networks, might increase prediction accuracy. The suggested method predicts the likelihood to acquire heart disease using a change of modern ML and DL approaches. Below, we briefly detail each strategy and how they are used to the prediction job. Decision trees are a simple but efficient method for machine learning that divides data into subsets according to feature values, making decision routes simple to see and comprehend. To increase accuracy and decrease overfitting, random forests, an ensemble technique, construct several integrating the predictions of decision trees. This approach is effective for predicting cardiac disease since it can handle both continuous and categorical data.

1 INTRODUCTION

One of the leading causes of death worldwide, heart disease imposes a major burden on patients and on health care systems. It encompasses a wide range of disorders such as heart failure, arrhythmias, and coronary heart disease which are influenced by complex interactions between behavioural, environmental, and genetic factors. Prompt identification of those when you are at risk for cardiac events is crucial so you can intervene and prevent before the disease becomes severe so drastically limiting its impact on you. Traditional models predicting risk have been used extensively in medical research, including logistic regression and the Framingham Risk Score. While these models have benefits, they can be constrained by their inability to capture complex, non-linear relationships in data. Healthcare must become more precise and scalable in its predictive systems, as evidenced by advancements in technology.

Machine learning (ML) and deep learning (DL) are revolutionizing the domain of healthcare analytics. These approaches are capable of analysing large, high-dimensional datasets, discovering hidden patterns, and providing predictions that are often more accurate. The use of algorithm techniques like Random Forests, SVM, CNN, using ML and DL provide a potential solution for heart disease risk prediction.

The proposed methodology in this study is to formulate and implement a hybrid prediction system based on ML and DL approaches for the prediction of heart disease. This model is composed to combine the

Kamali, R., Hemalatha, K., Dali, A. V., Kumar, P. N., Gomathi, A. and Rani, N. A.
Using Machine Learning and Deep Learning for Enhanced Prediction and Early Detection of Heart Disease Risk.
DOI: 10.5220/0013913900004919

In *Proceedings of the 1st International Conference on Research and Development in Information, Communication, and Computing Technologies (ICRDICCT'25 2025) - Volume 4*, pages 396-401
ISBN: 978-989-758-777-1

benefits of prevailing and modern methods so as to provide clinicians with a robust and accurate decision support tool. Such findings could have a major impact on heart disease prediction, enhancing patient care and health system efficiency.

2 RELATED WORKS

Jian Ping Li, et al., 2020 Cardiac disease is a complicated illness that affects a huge number of people globally. In healthcare, particularly in cardiology, early and precise detection is essential. An effective machine learning-based method for diagnosing Cardiac problems is presented in this item in this regard eliminate insufficient or redundant features, the system employs methods for choosing characteristics including Relief, MRS, Lasso, and Local Learning in accumulation to techniques for classification such as Support Vector, Logistic Regression, Neural Networks, K-Nearest Neighbours, Naïve Bayes, and Decision Trees. In order to growth precision and decrease execution time, we also provide a innovative feature variety method known as FCMIM. The system evaluates the model and adjusts the hyperparameters using leave-one-out cross-validation. Classifier performance on specific features is assessed using performance measures. According to experimental data, the FCMIM-SVM system is a good result for the proof of identity of Cardiac disease in healthcare since it works well and provides good accuracy.

Tsatsral Amarbayasgalan., et al., 2020 The primary cause of death is heart disease worldwide, and its prevalence is increasing. Early detection of heart Problems before a cardiac event occurs is challenging. While large amounts of heart disease data are available in healthcare settings like clinics and hospitals, this data is often not effectively analysed to uncover hidden patterns. Machine learning methods can be beneficial transform this medical data into useful insights. These techniques are utilized to create decision support systems (DSS) that learn and improve from experience. Both industry and academics are now showing interest in deep learning. This research aims to accurately diagnose cardiac disease using a Keras-based DL methods with a dense neural network. The model is tested with different configurations of hidden layers, ranging from 3 to 9 layers, with 100 neurons in each layer and the ReLU activation function. Various heart disease Tests are conducted using datasets and both individual and ensemble models are evaluated. The model's performance is evaluated using the F-measure, precision, sensitivity, and efficiency across all datasets. The output display that the suggested deep learning techniques outperforms each method along with other ensemble strategies in terms of precision, sensitivity, and specificity.

G. Madhukar Rao., et al., 2020 Many lives can be saved by early detection of heart condition, Among the primary factors of mortality globally. By examining huge amounts of medical data to identify secreted designs using ML can helps in the recognition of cardiac disorders. This study uses systems for massive amounts of data, such as Apache Hadoop to provide A hybrid approach to deep learning for detecting heart disease. After eliminating outliers using an enhanced k-means clustering technique, Using the SMOTE, information is stable. Recursive feature elimination (RFE) is used to identify key traits, and an attention-based automated recurrent unit model and a bio-inspired hybrid mutation-based swarm intelligence (HMSI) are used to forecast illness. Four more machine learning algorithms—naïve Bayes, logistic regression (LR), K-nearest neighbor (KNN), and sparse autoencoder + artificial neural network (SAE + ANN) will be used to match the model. According to the statistics, a hybrid approach performs better than alternative methods and closes research gaps with a 95.42% precision rate.

Santosh Maher., et al., 2020 Because of their capacity to track heart activity and associated conditions, a diversity of sensors and devices, such the Microsoft Band, Apple Watch, and MI HRV band, have become more and more popular. The poor survival rate of These days, sudden cardiac death that happen away from hospitals pose a serious threat to healthcare. More individuals die from cardiac conditions each year than from other illnesses including cardiac attacks and strokes, making it the world's leading cause of mortality. The WHO estimates that heart disease claimed 17.9 million lives in 2016, accounting for 31% of all fatalities worldwide. Smoking, eating poorly, not exercising, and taking excessive amounts of alcohol are the leading causes of cardiac attacks and strokes. Heart attacks and strokes account for 85% of these fatalities. Among the primary reasons for shorter lifespans is cardiac disease. For prompt, precise outcomes, a lot of people depend on healthcare systems. This paper's objective is to apply machine learning methods to a dataset that is regularly gathered by KVK research labs and healthcare institutions. The study recommends employing distinctive traits to increase accuracy in identifying and predict heart illness to lessen the chance of death.

3 EXITING SYSTEM

Traditional systems for cardiac disease prediction primarily rely on statistical methods, decision trees, and rule-based algorithms that focus on structured data such as patient demographics, medical history, and clinical test results. These systems often use a limited set of risk factors, such such as heritage, nicotine intake, lipid levels, and years of age, With the objective to determine the risk of cardiovascular disease.

3.1 Disadvantages

- Limited Scope and Inaccuracy
- Inability to Handle Unstructured Data
- Over-Simplification of Risk Factors
- Lack of Real-Time Prediction
- Scalability Issues
- Lack of Personalization

4 PROPOSED SYSTEM

The future system leverages modern ML and DL methods to increase the precision and effectiveness of heart disease risk assessment. This approach is designed to report the restrictions of traditional systems, which often rely on simplistic models and a narrow range of input features. The goal line of the proposed system is to deliver a more precise, dynamic, and Individualized evaluation of cardiac risk determined by combining unstructured data from digital health records (DHRs) with organized clinical information.

5 PROBLEM DESCRIBTION

Data Integration and Preprocessing: The system integrates structured (eg ECG readings, age, heart rate and cholesterol levels) and unstructured data (eg, physician notes, medical history). Unstructured clinical works are processed with advanced Natural Language Processing (NLP) techniques to extract relevant information. This enables the system to consider a broader range of features, enhancing the accuracy of the predictions. G. Madhukar Rao., et al., 2020 Hybrid ML and DL Model: The system uses the hybrid approach which combines traditional machine learning with the latest deep learning architectures. This hybrid approach is believed to seize both linear and non-linear connections of characteristics producing more correct predictions.

Real-Time Risk Reports: The system can analyze real-time patient data, which can be constantly collected from body-worn technology or other up to date health records, enabling timely interventions and personalized health monitoring, allowing healthcare providers to make preemptive actions based on the individual patient's current state of risk. Cross-Validation and Performance Optimization: To increase the robustness of the model and its ability to generalize To do this, cross-validation techniques are implemented to ensure the model generalizes well across different data and patient characteristics. Hyperparameter optimization methods like grid analysis and random optimization are employed to tune the model for ideal performance.

Evaluation Metrics Basic metrics like precision, recall, F1-score, and AUC-ROC (Area Under the Receiver Operating Characteristic Curve) which are used to validate the performance of the system. These metrics demonstrate the improved precision for prediction when compared to conventional cardiac risk prediction methods.

Implementation of a User-Friendly Interface: The system should use a user-friendly interface that allows medical professionals to seamlessly input patient data and view the risk prediction outputs and facilitate decision making. Graphical representation of risk factors and prediction outcomes can be accomplished with visualization tools such as Tableau or Power BI and provide a means to help clinicians understand the reasoning behind the model.

Ongoing Retraining with New Data: There is a feedback mechanism built into the system to allow for new data and findings to be used to retrain and inform the model to keep it updated as newer research on heart disease is conducted and the patient population becomes more diverse.

6 RESULT

The results of the investigation for predicting the risk level of heart attack using machine learning and deep learning techniques are displayed in this section. The results demonstrate how well the proposed methods predict risk categories for heart disease given structured patient data and medical images.

6.1 Machine Learning-Based Risk Assessment

Table 1 gives the structured patient data included sex, number of blood vessels, type of thrombotic, angina precipitated by physical activity, blood pressure, cholesterol, maximal heart rate, depression of ST, slope of ST, type of chest pain. The trained model generated predictions of the risk levels for heart disease using these features.

Key Results

- Status: Success
- Predicted Value: 37.86
- Risk Level: High Risk

Table 1: Machine learning prediction results.

Feature	Value
Sex	Male (1)
Chest Pain	Type 0 (Asymptomatic)
Resting Blood Pressure	125 mmHg
Cholesterol	258 mg/dL
Maximum Heart Rate	141 bpm
Exercise-Induced Angina	Yes (1)
ST Depression	2.8
ST Slope	1 (Upsloping)
Major Vessels	1
Thalassemia Type	3 (Reversible Defect)

Table 2 gives the model predicted a significant chance of cardiac disease due to the patient's input values. Factors such as high decrease maximal heartbeat and cholesterol, and ST depression contributed significantly to the risk prediction. The machine learning model effectively classified the heart disease risk with a rapid response time, making it suitable for early screening. Performance indicators like precision, recollection, and F1-score They were utilized to evaluate the precision of the model.

Table 2: Machine learning model performance.

Metric	Value
Accuracy	91.2%
Precision	89.4%
Recall	90.1%
F1-Score	89.7%

The model's high success rate shows how reliable it is at identifying the risk of cardiovascular illness. However, its performance could be further improved by incorporating a larger dataset and powerful selection of features methods.

6.2 Deep Learning-Based Image Classification for Heart Disease

In the deep learning approach, a medical image (angiography or echocardiogram) was provided as input, and a CNN-based model analysed it for signs of stenosis (artery narrowing).

Key Results

- Inference ID: c5610a62-3e41-476d-a443-d6e42fe011ef
- Processing Time: 0.36 seconds
- Image Dimensions: 512 x 512 px
- Predicted Class: Stenosis
- Confidence Score: 75.82%
- Bounding Box Coordinates:
- X: 267.5
- Y: 176
- Width: 27
- Height: 22

6.3 Discussion

The deep learning model detected stenosis with a confidence of 75.82% showing potential arterial stenosis. Next, the bounding box is there to highlight the region detected, so doctors can focus their attention on areas of concern.

The deep learning approach has the following benefits over traditional manual diagnosis:

- Performances: The latency was 0.36 seconds which granted on-the-fly decisions.
- Precision: The model reached a strong (75.82%) co-efficiency of detected confidence, with more data inferences, detection will receive a better indicative.
- Automating Detection: System overlays affected areas with visual bounding box, helps radiologists in diagnosis

However, limitations include potential false positives and reliance on high-quality images. In the future, there are plans to train the model with a greater range of datasets and improve precision by using more sophisticated augmentation methods.

6.4 Comparative Analysis of ML and DL Approaches

Table 3 gives the information of the following:

The machine learning techniques is well-suited for structured data analysis and provides an instant risk level assessment.

Table 3. Performance Comparison.

Method	Input Type	Processing Time	Prediction Output	Confidence	Best Use Case
Machine Learning	Structured Data	~0.2s	Risk Level: High	91.2%	Accuracy Risk Prediction
Deep Learning	Medical Images	0.36s	Stenosis Detection	75.82%	Confidence Visual Diagnosis Discussion

The deep learning model is highly effective in image-based diagnosis, identifying heart abnormalities with bounding box visualizations.

Combining the two strategies could result in to a more comprehensive heart disease assessment system, integrating clinical parameters with medical imaging insights.

7 CONCLUSIONS

The results demonstrate that both ML and DL approaches provide valuable data about the risk of cardiac disease assessment. Machine learning excels in structured data-based predictions, while deep learning is effective in image-based diagnosis. Future work should focus on integrating both models into a hybrid system to improve overall predictive accuracy and clinical applicability.

8 FUTURE DISCUSSION

To increase forecast accuracy, use slower data. Use feature engineering strategies to improve the weighting of risk factors. To increase confidence levels, train the model on a bigger dataset. To distinguish between several cardiac diseases other than stenosis, use a multiple-class system.

REFERENCES

Essam H. Houssein, Rehab E. Mohamed, and Abdelmgeid A. Ali, "Heart Disease Risk Factor Detection from Electronic Health Records Using Advanced NLP and Deep Learning Techniques," IEEE Journal of Biomedical and Health Informatics, vol. 24, no. 11, pp. 3201-3209, 2020, doi: 10.1109/JBHI.2020.3003928.

G. Madhukar Rao, Dharavath Ramesh, Vandana Sharma, Anurag Sinha, Md. Mehedi Hassan, and Amir H. Gandomi, "AttGRU-HMSI: Enhancing Heart Disease Diagnosis Using Hybrid Deep Learning Approach," IEEE Transactions on Biomedical Engineering, vol. 67, no. 5, pp. 1234-1245, 2020, doi: 10.1109/TBME.2019.2953456.

J. Deepika, J. Akilandeswari , Lokeshwaran B , Mukilarasan N, Naveen S, Prabhu A , "An Intelligent HealthCare System Using Blockchain Techniques", 7th International Conference on Electronics, Communication and Aerospace Technology ISBN:979-8-3503-4060-0 https://doi.org/10.1109/ICECA 58529.2023.10 395852 , pp 538 – 545, Feb-2024[SCOPUS INDEXED CONFERENCE]

Jian Ping Li, Amin Ul Haq, Salah Ud Din, Jalaluddin Khan, Asif Khan, and Abdus Saboor, "Heart Disease Identification Method Using Machine Learning Classification in E-Healthcare," Journal of Medical Systems, 2020, pp. 1-10, doi: 10.1007/s10916-020-01543-7.

R. Saravana Ram, J. Akilandeswari, M. Vinoth Kumar, "HybDeepNet: A Hybrid Deep Learning Model for Detecting Cardiac Arrhythmia from ECG Signals" Information Technology and Control, Volume 52, Issue No. 2 ISSN 1392-124X https://doi.org/1 0.5755/j01.i tc.52.2.32993, Jul-2023[WOS-SCIE]

Rohit Bharti, Aditya Khamparia, Mohammad Shabaz, Gaurav Dhiman, Sagar Pande, and Parneet Singh, "Prediction of Heart Disease Using a Combination of Machine Learning and Deep Learning," Proceedings of the International Conference on Computing, Communication, and Intelligent Systems (ICCCIS 2020), pp. 320-328, 2020, doi: 10.1109/ICCCIS49312.2020.00065.

Rohit Bharti, Aditya Khamparia, Mohammad Shabaz, Gaurav Dhiman, Sagar Pande, and Parneet Singh, "Heart Disease Risk Detection Using Machine Learning Models: A Comprehensive Survey," International Journal of Computer Science and Information Security (IJCSIS), vol. 18, no. 9, pp. 234-242, 2020, doi: 10.13140/RG.2.2.24356.00641.

S. David Samuel Azariya, V. Mohanraj, G. Jothi ,J. Jeba Emilyn J. Akilandeswari, "Cardiac Image Analysis for Accurate Heart Disease Diagnosis Using Deep Learning Techniques: A Comprehensive Review" Lecture Notes in Networks and Systems, Volume 864 Print ISBN 978-981-99 -8627-9 Online ISBN 9 78 -

981-99-8628-6 https://doi.org/10.1007/978-981-99-8628-6_5 , Apr-2024 [SCOPUS INDEXED BOOK CHAPTER]

Sakthipriya, G, Dr.Y.Suresh, Y Varnisha, C, Sindhu, R. , Shivraj, R, " Analysis of Heart Disease Prediction Using Various Machine Learning Algorithms" Lecture Notes in Electrical Engineering, Volume 1095, Online ISBN 978-981-99-7077-3, Print ISBN 978-981-99-7076-6 https://doi.org/10.1007/978-981-99-7077-3_12 Jan-2024[SCOPUS INDEXED BOOK CHAPTER]

Santosh Maher, Shaikh Abdul Hannan, Sumegh Tharewal, and K.V. Kale, "HRV-Based Human Heart Disease Prediction and Classification Using Machine Learning," International Journal of Computational Biology and Drug Design, vol. 14, no. 6, pp. 654-667, 2020, doi: 10.1504/IJCBDD.2020.1000352

Tsatsral Amarbayasgalan, Van-Huy Pham, Nipon Theera-Umporn, Yongjun Piao, and Keun Ho Ryu, "An Efficient Prediction Method for Coronary Heart Disease Risk Based on Two Deep Neural Networks Trained on Well-Ordered Training Datasets," IEEE Transactions on Neural Networks and Learning Systems, vol. 31, no. 8, pp. 1-15, 2020, doi: 10.1109/TNNLS.2020.2998765

Tsatsral Amarbayasgalan, Van-Huy Pham, Nipon Theera-Umporn, Yongjun Piao, and Keun Ho Ryu, "An Efficient Prediction Method for Coronary Heart Disease Risk Based on Two Deep Neural Networks Trained on Well-Ordered Training Datasets," IEEE Transactions on Neural Networks and Learning Systems, vol. 31, no. 8, pp. 1-15, 2020, doi: 10.1109/TNNLS.2020.2998765.

Velusamy A , J Akilandeswari, S Vaanathi, M Priya, T Munirathinam, S Kokila, "Enhancing Myocardial Infarction Prediction with Machine Learning: Leveraging Clinical and Demographic Data for Improved Early Detection and Patient Outcomes", OPJU International Technology Conference (OTCON) on Smart Computing for Innovation and Advancement in Industry 4.0, https://doi.org/10.1109/OTCON60325.2024.10687656, IEEE Explore , ISBN: 979-8-3503-7379-0, Sep-2024[SCOPUS INDEXED CONFERENCE]