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A Naive Bayes Approach for Improving Heart Disease Detection on Healthcare Monitoring through IoT and WSN

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Abstract: Cardiovascular disease has become a prominent health concern among the medical community. This study proposes a unique approach to identify and forecast cardiac illness by using wireless sensor networks (WSN) and the Internet of Things (IoT). The suggested methodology employs the Naive Bayes algorithm for the analysis and categorization of health data. The timely identification of heart conditions enhances the probability of successful treatment and management under the guidance of a medical professional. Due to insufficient accuracy in classifying patient information, the existing healthcare monitoring system that relies on IoT devices and classification algorithms addresses a substantial challenge that could result in incorrect diagnoses and inappropriate treatment choices. The primary goal of this approach is to combine IoT with WSN to develop a real-time, dependable monitoring system that will enhance early identification and intervention for people at risk for heart disease. The proposed Naive Bayes classifier observes accuracy classes such as ROC, Recall, TP rate, F-measure, and FP rate. The obtained accuracy rate is compared with the existing approaches Backtracking Search-Based Deep Neural Network (BS-DNN) [17] and Convolutional Neural Network (CNN) [18]. The comparison result proves that the proposed Naïve Bayes has attained a classification accuracy of 97 %, far better than the others.

Keywords: *Machine Learning, Classification, Heart disease, WSN, IoT.*

1. Introduction

Heart attacks, strokes, and angina are all examples of cardiovascular disorders. Machine learning is crucial in proactively detecting cardiac disease, allowing healthcare providers to gather crucial information for precise evaluation and treatment preparation. It's important to remember that heart disease is fundamentally a sign of coronary artery disease. A significant challenge emerges in providing consistent management across various peopleIt provides comprehensive medical equipment, healthcare monitoring, recuperation assistance, and an overall better quality of life for the aged and those undergoing therapeutic evaluations. [1]. The Internet of Things (IoT) is a game-changing innovation that has liberated us from geographical and temporal constraints on transmitting massive volumes of data. The widespread use of IoT is revolutionizing remote monitoring by making it much more efficient, intelligent, and intuitive. Benefits of wireless sensor networks (WSNs) include comprehensive area coverage, inexpensive installation costs, low power consumption, autonomous operation, and immediate access to data. Connecting WSNs to the appropriate networks and meeting the Quality of Service (quality of service) criteria of a wide range of use cases calls for a wide range of communication protocols. Many researchers have spent the last few years studying WSNs in healthcare networks, which integrate wireless technology, medical data, and sensor data. [2,3]. IoT with WSN has been used in various industries, including factory automation and urban monitoring, to create complex and accurate systems [4,5].

There is an increasing demand for specialist medical care and solutions for careful health monitoring due to the rise in the world's population. The IoT has enormous promise to meet these needs and provide specialized and efficient healthcare solutions for this vulnerable group. By enabling the quick and ongoing gathering of vital health data on the elderly, the IoT offers an amazing answer. The quality of care can be improved by conveniently sharing this information with medical experts working in various locations [6]. The incorporation of IoT technology has the potential to improve time management and cost-effectively deliver exact results because the significant range of the aging population deals with common health concerns that necessitate periodic medical examinations [7-9].

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Heart disease is now becoming the leading cause of mortality compared to other diseases. It is quite difficult for medical professionals to diagnose accurately and timely [10]. Therefore, incorporating computational expertise is essential in this field to support medical professionals in providing accurate and rapid diagnoses. Based on Internet of Things (IoT) technology with WSN, remote patient monitoring is now being developed as a promising solution for addressing global health inequalities [11,12]. By implementing machine learning algorithms, it is possible to find patterns hidden within a database's historical records that were previously undiscovered. Accurately detecting diseases is a big problem for machine learning algorithms (ML) [13,14]. Even though several ML algorithms are currently in use in the healthcare sector, further study is still needed to determine how well these classification methods are effective in achieving accuracy [15].

This document provides a full understanding of its structure. The first section provides an overview of the topic. Section 2 provides a comprehensive analysis of a notable literature review conducted on previous investigations. The details of the suggested approach are further forth in Section 3. Section 4 encompasses the presentation and subsequent discussion of the obtained findings. The concluding section, Section 5, encapsulates the last remarks and findings of the study.

2. Related Works:

Malik Bader Alazzam et al. [16] proposed utilizing sensor integration, data exchange, and processing strategies through IoT technology. The collected data is analyzed using machine learning techniques to draw important insights for precise predictive analytics and individualized treatment. Improved patient monitoring, accurate health status projections, individualized suggestions, and effective resource use are all supported by previous study findings. Rasha M. Abd El-Aziz et al. [17] provide a combined approach using feature selection, machine learning, and data preparation techniques. The main objective of the proposed study is to extract pertinent information from the dataset. The results indicate that their methodology allows accurate forecasting of individuals' health conditions, timely detection of deviations from the norm, and personalized recommendations for healthcare interventions. The effective deployment of the healthcare monitoring technique using the Internet of Things (IoT) and a Backtracking Search-Based Deep Neural Network (BS-DNN) is facilitated by the use of cloud computing. This enables the smooth storage, processing, and scaling of data.

Zhao et al.'s research [18] used CNN models, machine learning, and temporal analysis to study the heart breakdown rates as pulses varied. Three feature selection strategies were applied to obtain the key features. Levy et al. [19] proposed cardiovascular risk percentage over a year in people with severe DCM using machine learning techniques. The ML model employs information gain methodology for choosing significant findings about heart issues from 32 healthcare-related information. This study focused mainly on those with heart disease who were also taking prescription drugs.

In their study, Kumar et al. [20] developed an IoT-based, user-friendly robotic garbage sorting apparatus. Their breakthrough is the coordinated use of an up-flow anaerobic sludge blanket and leach bed reactor. In [21], convolutional neural networks recognize Gurumukhi month names. A complete framework for appropriately distributing the computational load across fog nodes and allowing them to satisfy the requirements of real-time smart application demands is proposed [22] [23].

Li et al. [23] described an AI-driven system for studying huge healthcare datasets in their work. It is now possible to use IoT-compatible sensor devices for tasks linked to healthcare due to the recent acceptance of machine learning techniques in numerous IoT applications. This includes using machine learning techniques to address problems like routing, security, resource allocation, and traffic management. : Due to the self-organizing and random nature of sensor nodes, securing Wireless Sensor Networks (WSN) has become a more difficult task in recent years. Due to its advantages of self-organizing nature, low power consumption, and reduced cost consumption, Wireless Sensor Networks (WSNs) have grown more popular [31,32]. The Internet of Things (IoT), an emerging technology, makes it easy and advantageous to share data with additional devices across wireless networks. [33,34] However, due of their continual development and technological advancements, IoT systems are more vulnerable to cyberattacks, which could result in strong assaults [35].

3. Proposed Architecture

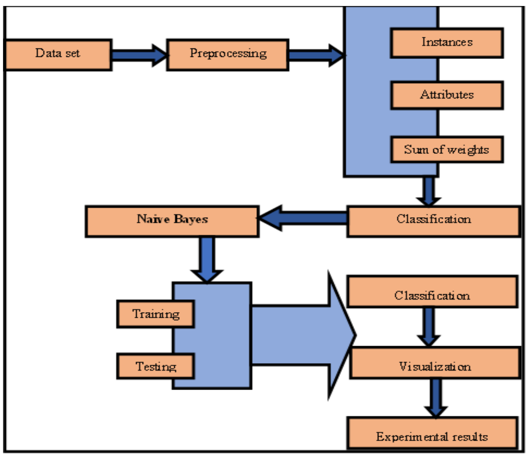

Fig. 1: Proposed architecture model

3.1.1 Data preprocessing

Data preparation involves significant difficulties, especially in processing healthcare datasets. Medical datasets will contain more duplicate records and irrelevant, erratic, and noisy information, making the entire process complex. The two significant stages in data processing are data creation and filtering. Particularly, effective preprocessing helps shorten the total execution time. Data processing involves multiple stages such as filtering, feature extraction, standardization, transformation, feature selection, and Instant determination. The obtained last training set will be the outcome of data preprocessing.

3.1.2 Data Mining Tools

Data mining tools are vital in software programs that extract valuable data from extensive databases, facilitating pattern recognition and intelligent decision-making in various industries. These technologies use advanced algorithms to find patterns and hidden information in data. WEKA is a flexible open-source data mining application renowned for its friendly user interface, wide selection of machine learning algorithms, and thorough assistance for the data mining procedure. Its capacity to manage a variety of datasets, simplicity of algorithm experimentation, and ongoing community development make it beneficial to researchers and data scientists. Weka is a great option for those trying to get useful information from their data due to its versatility and extensive feature set. WEKA's C4.5, commonly known as J48, is the most reliable algorithm.

3.1.3 Classifications

Data is categorized into specific categories or labels based on its qualities using the core classification approach in data mining. It entails creating prediction models that can categorize brand-new occurrences of data into one of these types. Since it allows for automatic decision-making and pattern identification, this method is crucial in many applications, including detecting spam emails, the diagnosis of diseases, and sentiment analysis. Organizations frequently use classification algorithms like support vector machines, neural networks, and decision trees to complete this task to assist them in making educated decisions and discovering valuable details from their data. Data analysis is made easier by supervised learning, commonly referred to as pattern recognition, which organizes data into predetermined categories. Decision-or-classification-related challenges are the most prevalent in science, business, and industry. Each system develops a strategy and can progress toward the objective.

3.1.4 Classification algorithms

Classification is the most important technique used for dataset analysis in data mining, including various approaches. Initial data allocation to classes depends on the class instance; the classification error can be reduced by making this decision. based on which distinct models are made to determine the essential information classes using the provided datasets precisely. The process of classification is comprised of two distinct steps. During the first phase, classification techniques are used to apply training datasets. To obtain accuracy and trained execution, the second phase examines an experimental dataset specified previously. Classification differentiates the dataset into clear labels and unclear labels.

3.1.5 Machine learning

Machine Learning (ML) is the most popular and significant Artificial Intelligence technology. It can acquire knowledge from data and make predictions without being explicitly programmed. Enough datasets are given to train models to recognize patterns, correlations, and trends throughout this process, which is one of the machine learning process's essential technical features. These models can range from straightforward linear regressions to sophisticated neural networks, and the key to their efficiency is their propensity to generalize from training data to forecast the outcome of new, unobserved data. Automated, repetitive processes are avoided by machine learning methods, which also reduce energy consumption and time. The impact of machine learning (ML) has increased recently across many industries, including marketing, sales, health care, delivery, and financial services.

Naive Bayes

A typical machine learning approach for performing classification tasks is naive Bayes. It is a popular option because of its usefulness and simplicity, particularly for text categorization and spam email screening. The approach utilizes the feature values to assess the chance that an instance is associated with a certain class, and then selects the class with the highest likelihood of occurrence. Naïve Bayes frequently produces competitive and exceptionally fast performance, especially when working with high-dimensional data. Naive Bayes implies Bayesian techniques, which performs well in various uncertain real-time situations dealing with inadequate presumptions and simplified model.

4. Result & Discussion

=== Evaluation of training set ===

=== Summary ===

Table 1 Evaluation of training set

Correctly Classified Instances	285	96.9388 %
Incorrectly Classified Instances	9	3.0612 %
Kappa statistic	0.9326	
Mean absolute error	0.0217	
Root mean squared error	0.0992	
Relative absolute error	11.5971 %	
Root relative squared error	32.6609 %	
Total Number of Instances	294	

Table 1 shows the experiment conducted on the classification task, which includes 294 cases, among which 96.94% are correctly classified and 3.06% are wrongly classified. A Kappa score of 0.9326, which shows significant agreement above and above what would be predicted by chance alone, further supports this excellent accuracy. The mean absolute error of the model is 0.0217, while the root mean squared error is 0.0992, demonstrating the model's high predictive accuracy. Although the relative absolute error is 11.60% and the root relative squared error is 32.66%, these metrics are appropriate given the data's complexity and the issue's nature. Overall, this model does amazingly well at precisely and quickly categorizing occurrences.

Table 2 accuracy details by class

TP Rate	F P Rate	Precision	Recall	F-Measure	ROC	Area Class
0.995	0.075	0.959	0.995	0.977	0.987	<50
0.925	0.005	0.99	0.925	0.956	0.986	>50_1
0	0	0	0	0	0	>50_2
0	0	0	0	0	0	>50_3
0	0	0	0	0	0	>50_4
0.969	0.05	0.97	0.969	0.969	0.986	

Table 2 shows the accuracy details obtained by the proposed naive Bayes system. The evaluation metrics and their obtained values are mentioned in the above table.

Training Results

Table 3 Training Results

Accuracy (Validation)	97%
Total cost (Validation)	209
Prediction speed	~10000 obs/sec
Training time	80.584 sec

Table 3 shows the obtained training results with the proposed naive Bayes system. About 97% accuracy is obtained with a total cost of 209, a prediction speed of 10000 obs/sec, and a total training time of 80.584 sec.

Table 4 classification parameter results

S.No	**Features**
1	Age
2	Sex
3	ChestPainTypes
4	RestingBP
5	Cholesterol
6	FastingBS
7	RestingECG
8	MaxHR
9	Exercise Angina
10	Oldpeak
11	heart disease

In the dataset, several features are considered as classification parameters, which are listed in Table 4.

Predicted Class

Table 5 Dataset Features

	Down	**Flat**	**Up**
Down	0	1	1
Flat	1	0	1
UP	**1**	1	0

Table 5 shows the predicted class from the dataset using the proposed system. Optimizer options apply only to optimizable models.

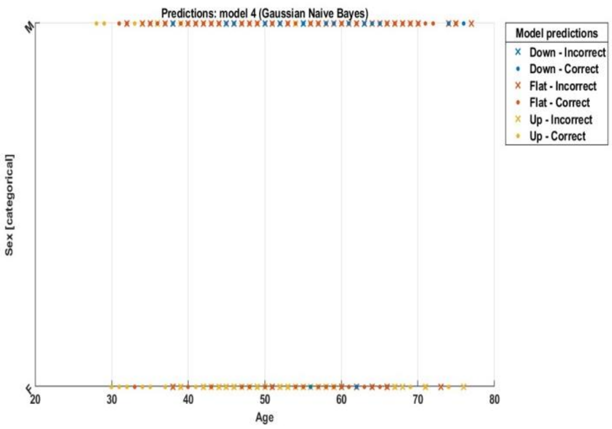

Fig. 2 Scatter plot age and sex

Figure 2 illustrates the scatter plot on age and sex from the dataset. The model will predict both age and sex. The x-axis represents the plotted point on age, and the y-axis represents the plotted point on sex.

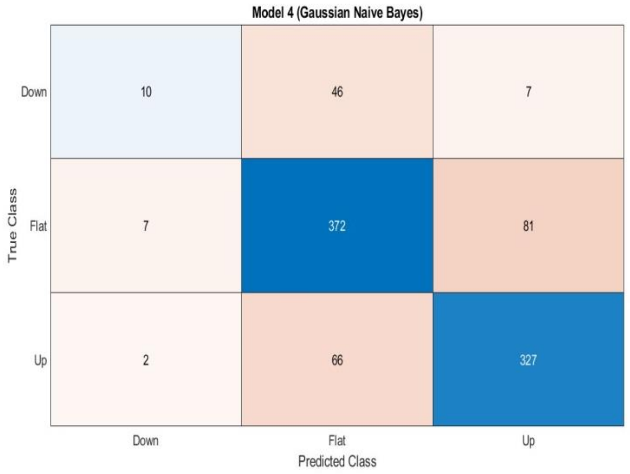

Fig. 3 Number of observations

Figure 3 represents the total observation done using the proposed Naive Bayes classifier. In the observation, three classes are classified UP, Down, and Flat. The horizontal axis denotes the class that is predicted, while the vertical axis indicates the actual class.

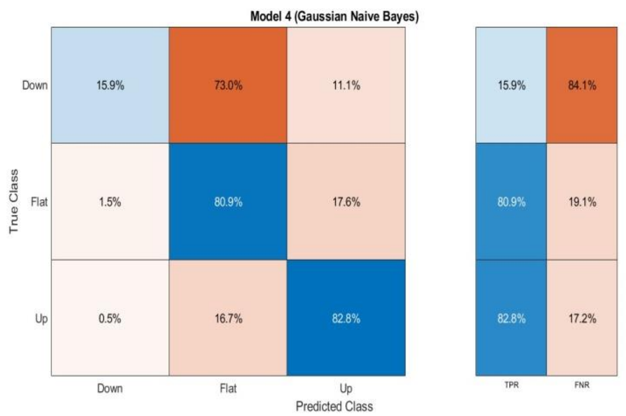

Fig. 4 True Positive Rates (TPR), False Negative Rates (FNR)

Figure 4 represents the observation on TPR and FNR using the proposed Naive Bayes classifier. The horizontal axis denotes the class that is predicted, while the vertical axis indicates the actual class.

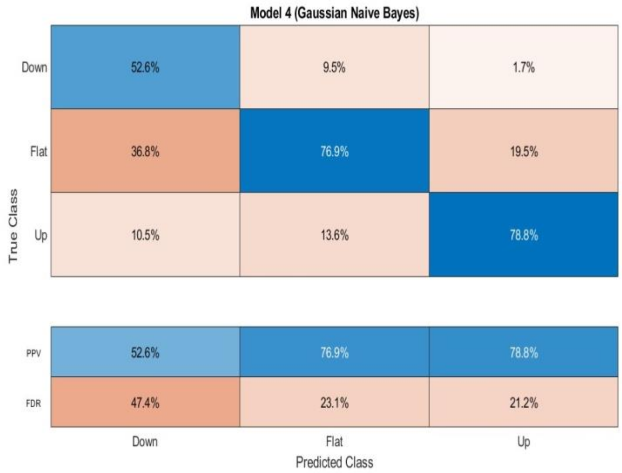

Fig. 5 Positive Predictive Values (PPV), False Discovery Rates (FDR)

Figure 5 represents the observation on PPV and FDR using the proposed Naive Bayes classifier. The horizontal axis denotes the class that is predicted, while the vertical axis indicates the actual class.

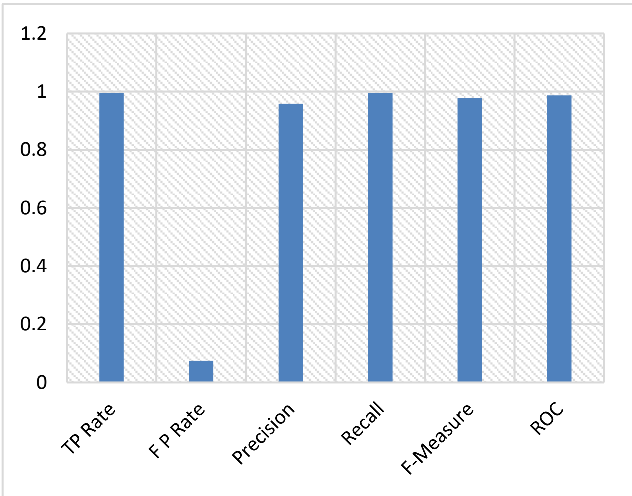

Fig. 6.1 TP, FP Rate precision, recall, F-Measure, ROC performance area class <50

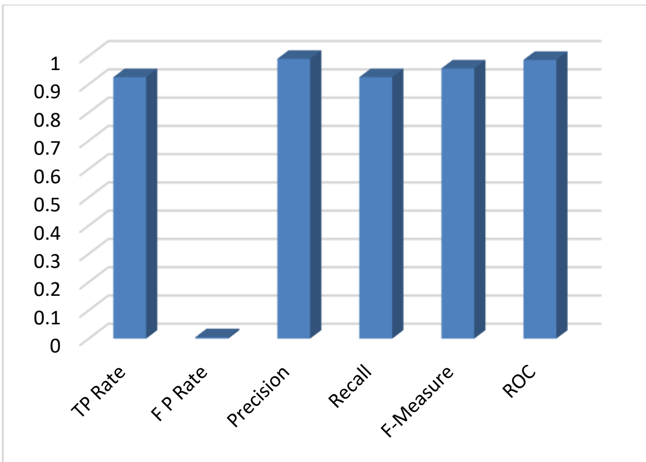

Fig. 6.2 TP, FP Rate precision, recall, F-Measure, ROC performance area class >50_1

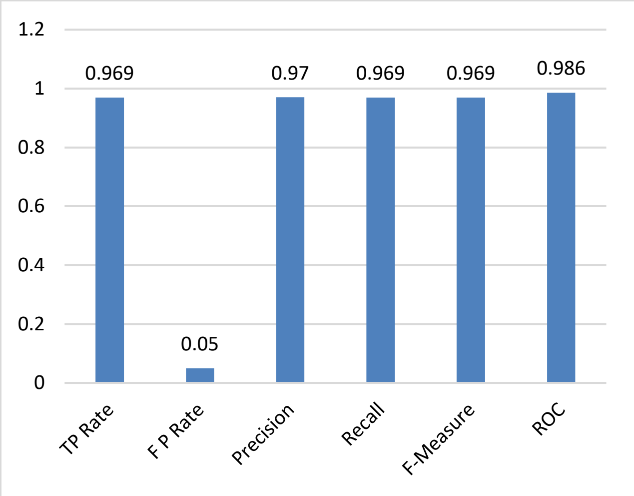

Fig. 6.3 TP, FP Rate precision, recall, F-Measure, ROC performance area class >50_4

Figure 6.1, Figure 6.2, and Figure 6.3 is the graphical representation of accuracy details by class mentioned in Table 2. The evaluation parameters taken into consideration are ROC, Recall, TP rate, F-Measure, and FP rate.

Table 6 Comparison result

Classifiers	**Achieved Accuracy level in %**
Proposed Naïve Bayes	97
BS -DNN	90
CNN	88

Table 6 provides the comparison study done to assess the performance of the proposed Naïve Bayes with existing Backtracking Search-Based Deep Neural Network (BS-DNN) [17] and Convolutional Neural Network (CNN) [18]. The accuracy of the proposed Naïve Bayes was 97%, compared to BS-DNN's 90% and CNN's 88%. The proposed Naïve Bayes achieves a higher level of classification accuracy than the others.

5. Conclusion

This work demonstrates the Naive Bayes algorithm for heart disease identification in the context of IoT-based healthcare monitoring systems. The existing approaches are ineffective in determining the disease prediction's accuracy. The proposed approach initially undergoes data preprocessing to remove the unwanted information from the dataset. Next, the proposed Naive Bayes classifier is introduced to classify the labels under three classes: down, up, and flat. The proposed Naïve Bayes classifier's accuracy level is determined using the accuracy parameters: ROC, Recall, TP rate, F-Measure, and FP rate. The comparison findings with the current methodologies also demonstrate the efficacy of the suggested system in terms of its accuracy rate. Hence, this work emphasizes the bright prospects for IoT and WSN in healthcare applications and emphasizes how they have the potential to transform the field of medical monitoring completely.

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