Prediction of Heart Disease Using Modified Hybrid Classifier

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This paper proposes a Machine Learning or ML-based strategy to accurately identify a possible heart disease patient. Unlike traditional diagnostic systems which are time-consuming and have human error involved to take care of the patient and diagnose the patients. The proposed system identifies whether the patient will face these kinds of diseases in near future or not. The system is developed based on machine learning techniques such as Naive Bayes, XGBoost gradient classifier, support vector machine, and decision tree. Some external factors were also considered which may lead to heart disease in the future. Furthermore, an integrated web application has been developed that alert and gives a user-friendly interface for recognition and prediction. Thirteen diagnostic factors and five environmental factors are analyzed. The proposed diagnosis system attained good precision as compared to previous methods recommended earlier. In addition, the system can easily be implemented in the public domain to spread awareness regarding heart disease, and it also talks about the possibility of heart disease in near future.

Povzetek: Predstavljeni sistem zazna morebitno srčno bolezen iz trinajstih diagnostičnih in petih okoljskih dejavnikov z uporabo algoritmov strojnega učenja.

1 Introduction

Cardiovascular diseases are popularly known as heart disease leading to a heart attack. In 2018 heart attacks killed nearly 17.9 million humans all over the world. Heart disease is found in 3 out of 5 patients in the critical care unit. The complexity of this disease lies in the fact that it suddenly fails the functioning of human and then SOP (Standard Operating Plan) is required; if not provided on time, patients' life is in danger. A proper healthcare system takes time to detect the cause and effectively start the diagnosis whereas our proposed system efficiently and accurately tells the client whether a patient has heart disease or not. The heart has an essential and critical role in the physical body as it is in control of the flow of blood in different parts of the body which helps in adequate oxygen supply and nutritious elements to be supplied to the required part. Any life is dependent totally on a proper flow of blood, in human life heart is the pumping room of blood. Any disturbance in the flow or the function of the heart may lead to death within seconds [1]. According to the World Health Organization, 17,000,000 people die every year among the 3,000,000 who die before the age of 60 from heart disease. In 2019, the percentage of sudden deaths from heart disease ranged from 4% in high-income countries to 42% in low-income countries [2].

When the heart receives limited blood for a longer period of time it is called ischemic heart disease. Search conditions develop over a course of time which can be periodically monitored and cured with the help of expert supervision. There is a time when ischemic heart patients have a heart attack and after that, the chance of survival also reduces as the disease has been developing over a longer period of time and the heart is habituated or accustomed to limited blood flow. For such things, early predictions or alertness help in the long run.

Diagnosis of heart disease is usually done by reading the patient's medical history, the medical examination report, and the evaluation of symptoms associated with a medical doctor. Although the research found in this diagnostic method is less accurate in diagnosing a heart disease patient. In addition, it is expensive, and it is a computerized challenge to analyze [3]. We have proposed a machine-based diagnostic method. In this study, the machine learning prediction model includes naive bayes, support vector machine (SVM), tree decision, and XGBoost gradient classifier. The standard state of these models has been maintained for analysis purposes. Stalog, Hungarian, Switzerland, Long Beach VA, and Cleveland datasets combinedly were used in this article. We have designed a web-based application that accesses the model for general public use.

This article addressed the problem of predicting the possibility of a heart disease using machine learning (ML) techniques. Here standard feature extraction and profound algorithm classifiers appropriate features were extracted and analyze with expert guidance from medical's experts which gave a good result in the analysis and accuracy of the proposed algorithm. Then it predicts the future possibility of heart disease by understanding the environmental factors and common habits which may lead to heart disease. Finally, all the modules are combined into a single Python-based framework known as a flask for giving the model a front-end part. This web-based application represents heart disease possibilities with simplicity so that any non-technical or layman can easily detect heart disease.

The organization of the following sections is explained below. This article aims to provide a literature review on relevant heart disease factors and their identification techniques in section 2. Section 3 introduces the proposed system model. Section 4 introduces the web-based design of the proposed model. Section 5 includes results and discussion where performance is analyzed and training and testing results are shown.

2 Related work

The researchers in this case analyze several automatic learning algorithm-based diagnosis strategies to find heart illness. The analysis provides a few machine learning-based methods that make it easier to comprehend the suggested approach. Detrano et al. [4] method for classifying heart illness using machine learning approaches produced a precise end result with an accuracy of 77.00 percent. The dataset was utilized to extract features from the system's multi-layer kit architecture. Another researcher, Gudadhe et al. [5], developed a diagnosis method for heart dis-ease labeling utilizing a multi-layer operational design and SVM classifier and achieved a precision of 80.41 percent. The categorization algorithm for the cardiac disease was created by Kahramanli et al. [6] using a neural network and fuzzy logic. The categorization algorithm achieved a precision of 87.40%. An ANN troupe-based method of heart disease detection was developed by Li et al. [7]. In addition to using a numerical measurement method, it achieved 89.01 percent precision. A machine learning-based approach for identifying heart disease was developed by McKinley et al. [8]. The ANN-DBP system, in conjunction with the FS algorithm, proved worthwhile. A professional health diagnosis approach for heart dis-ease identification was advised by Palaniappan et al. [9]. The prognostic ML models Decision Tree (DT), Navies Bayes (NB), and Neural Networks were utilized to improve the system. Decision Tree Algorithms acquired a precision of 80.40 percent, ANN ac-curacy-ness of 88.12 percent, and Navies Bayes attained a precision of 86.12 percent. Olaniyi et al. [10] developed a 3-layer algorithm for heart disease prediction based on neural network technology and achieved 88.89 percent accuracy. A classification scheme for heart disease employing restraint and stringent set procedures was suggested by Liu et al. [11]. The approach has a 92 percent accuracy rate. For the purpose of identifying cardiac illness, Samuel et al. [12] developed an integrated medical aid system based on Fuzzy AHP and an artificial neural network. The performance of the suggested approach in terms of precision achieved is 91%. Cross-machine learning approaches were employed in one of the research publications by Singh et al. [13] designed as a heart disease forecast tool. They also suggested a novel technique for comprehensive characteristic selection from the data for effective ML classifier training and testing. They were noted as having 88.07 percent accuracy. Sequential Backward Selection Technique for Features Selection, a selection and classification algorithm, has been proposed in [14]. The suggested strategy achieved excellent levels of accuracy. Geweid et al.'s analysis of sophisticated Support Vector Machine-based dichotomy optimization algorithms for heart disease identification [15]. Prior attempts to diagnose heart disease had certain limitations, and the results have been compiled to help people better appreciate the significance of our suggested method. Among all the available techniques, many ways are utilized to spot coronary heart disease early on. Reduced accuracy and lengthy computation times in those earlier solutions are major problems, and it's possible that these are related to the use of datasets with the wrong functions. The prediction must be enhanced for increased detection accuracy, and it also needs to develop effective and accurate early detection for better treatment and healing. Ahammad et al. [16] proposed an approach for designing a healthcare social media platform for services for provisioning, consuming, enabling patients to find an alternate source of healthcare advice, and then it builds a collaborative health community for all kinds of people. Gadiparthi et al. [17] proposed a model for predicting ill effects. Here it predicts the effects of human exposure to social networks in the near future. Milioris et al. [18] investigated and implemented a technique to assess health professionals' views on the adoption and value of health information systems and to assess their usage. Jasim et al. [19] implemented CNN based model for building a system to recognize diseases that are happened in citrus.

Considering the significant research gap and difficulty in improving forecast accuracy, new methods are being used in our paper to precisely locate coronary heart disease to address these problems.

3 Proposed system model

The proposed system model has used a Hybrid classifier that refers to the system being a composite mapping of four algorithms (naive bayes, decision tree, support vector machine, and XGBoost gradient classifiers). The mapping referred to the design of the system in an additive form such that the accuracy of the system gets increased and the error rate reduces because too many systems to run against.

3.1 Data set

Every dataset used can be found under the Index of heart disease datasets from UCI Machine Learning Repository at the following link: https://archive.ics.uci.edu/ml/machine-learningdatabases/heart-disease/. Stalog, Hungarian, Switzerland, Long Beach VA, and Cleveland datasets combinedly used in this article, featuring the following variables with their description. The size of the dataset is 1023. For training purposes, 648 data are used and for testing purposes, 412 data have been used. In all the classifiers same testing and training ratio has been maintained to get the optimal result. The dataset consists of 13 features dataset where one is the output label output level has 2 possibilities one being the presence of heart disease second being the absence of her disease. Table 1 gives the description of 13 features of the dataset with the feature code. Table 2 shows various external factors and its description which may result in future heart disease.

Table 1: Features of data set with their description.

Sl. No.	Feature name	Feature code	Description
1	Age	AGE	Age in Years Avg=54.38
2	Sex	SEX	Male=1, Female=0 Ratio=70:30 (Male to Female)
3	Chest Pain	CPT	Atypical angina=1 Typical angina=2 Asymptomatic=3 Non-anginal pain=4
4	Resting Blood pressure	RBP	In Mm hg
5	Serum Cholesterol	SCH	In Mg/dl
6	Fasting blood sugar>120mg/dl	FBS	True =1 False =0
7	Resting electrocardiogram	RES	Normal=0 ST T=1 Hypertrophy =2
8	Maximum heart rate	MHR	Numeric
9	Exercise induced angina	EIA	Yes =1 No=0
10	Old peak=ST depression induced by exercise relative to rest	OPK	In Numeric
11	The slope of peak Exercise ST Segment	PES	Up sloping=1 Flat =2 Down sloping =3
12	No. of major vessels Colored by fluoroscopy	VCA	(0-3)
13	Thallium Scan	THA	Normal=3 Fixed Defect=6 Reversible Defect=7
14	Label	LB	Patient has heart diseases=1 Heathy Person =0

Table 2: External factors with their description.

Factors	Feature code	Description
Body Mass Index	BMI	True=has higher BMI False=BMI normal
History of diseases	Phist	Yes =factor present No =Factor not present
Family history of diseases	Fhist	Yes =factor present No =Factor not present
Alcohol	Alchol	Yes =factor present No =Factor not present

Four suitable and efficient classifier techniques are described in a gist in Table 3. In Table 4, a comparison of these four models with the proposed model is also shown.

Table 3: Classifier algorithms with their description.

Classifiers	Description
Navies Bayes algorithm	This is used for the classification concerned problem. The training data set is used by the algorithm to compute the value of the conditional probability of a vector for a given class. The conditional probability value is evaluated for each vector, and then the new vector class is evaluated based on its conditional probability.
Support Vector Machine algorithm	This is a supervised learning model with associated learning algorithms that analyze data for classification and regression analysis. The SVM algorithm is mostly used for classification problems because of its excellent performance in various applications.
Decision Tree algorithm	Shape is the just like a tree consisting of a leaf or addition node. A decision tree has internal external nodes linked to each other. The decision-making part of the internal node takes the decisions and informs the child node to visit the next note.
eXtreme Gradient Boosting algorithm	XGBClassifier of gradient boosting algorithm provides a wrapper class to allow models to be treated like a classifier or regressor.

Table 4: Classifier algorithms with their limitation, advantage and accuracy.

Classifiers	Limitation	Advantage	Accuracy in percentage
Heart disease diagnosis using a single machine learning classifier	Accuracies are very low and system errors can occur very easily	Computation is less complex	70 to 80%
Decision tree + SVM	More exaggeration time is required to generate the result	Accuracy is comparatively high	82.01%
SVM + kNN + k-Means	Computationally complex and performance time is very High	accuracy is high	87.4%

Classifiers	Limitation	Advantage	Accuracy in percentage
System based on Navies bayes + Decision tree + ANN	Computationally complex and ANN performance is low	Navies bayes and decision tree achieved high performance in terms of accuracy	84.33%
Random forest+xgboost + Decision tree	Random forest showed less accuracy in comparison to other classifiers	Xgbosst showed high accuracy	88.21%
Navies Bayes + Decision tree + Support vector machine + XGboost	More execution time is required to generate results	Performance is high and accurate. It suggests high performance in extreme situations	98.73%

Heatmap shown in Figure-1 clearly reflects about the variable weightage which helps in understanding the relevance of each variable.

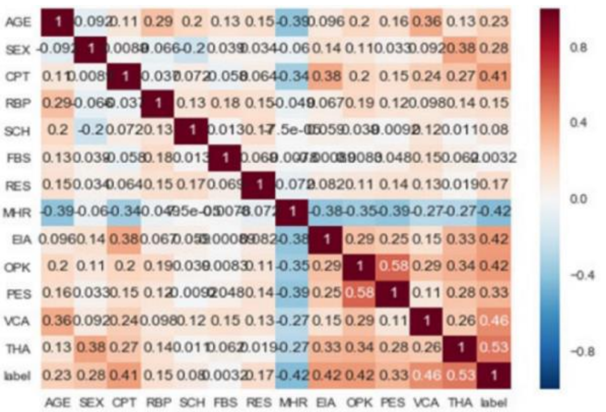

Figure 1: Heatmap of dataset reflecting weightage of each variable.

3.2 The modified classifier used in the model

The modified hybrid classifier is a mechanism to use multiple classifiers with different strategies to get desired output with high accuracy.

3.2.1 Navies bayes

This classifier uses standard arguments in a modified manner to get desired outcomes. Here probability (P) is calculated based on the likelihood of heart disease and class prior probability.

$$\mathrm{P(heart\ disease)} = \frac{\mathrm{P(Likelihood\ of\ heart\ disease)} * \mathrm{Class\ prior\ probability}}{\mathrm{Predictor\ prior\ probability}}$$

3.2.2 Decision tree

This classifier is an application for choosing several different extracted features in a modified manner to get desired outcomes.

A function that calculates the degree of randomness, also called entropy is defined as

$$f(s) = -P_+ \times \log(P_+) - P_- \times \log(P_-) \text{ where}$$

P_+ is the probability of the patient having heart disease.

P_- is the probability of the patient not having heart disease.

3.2.3 Support vector machine

This classifier partition training is set into two classes. It maximizes the distance between two parallel hyperplanes of the two classes and minimizes the sum of classification errors. Here f is the optimal function that minimizes total risk.

$$\text{Min f} = \frac{1}{2}\|w\|^2 + c\sum_{i=1}^{m}\rho_i \text{ where}$$

$\|w\|$ is the distance between two hyperplanes.

ρ is the deviation of misclassified objects.

Here **the** first term of the objective function is structural risk and the second term is an empirical risk.

3.2.4 XGBoost

This classifier uses fast learning through parallel and distributed computing and offers efficient memory usage. It uses begging and boosting. Here boosting technique makes use of trees with fewer splits.

$$f_{m-1} + h_m(x) \rightarrow f_m(x)$$

'm' denotes the iterations, until residuals have been minimized as much as possible.

'f' is defined to predict the target where f_m is the current model and f_{m-1} is the previous model.

'h' denotes the fit to the residuals from the previous step.

3.2.5 Modified hybrid classifier

Here we have taken 4 independent classifiers based on the accuracy of our dataset. We have experimented and found high accuracy using Naive Bayes, Decision tree, SVM, XGBoost. After this, we propose that each new data will go through all the classifiers and result in individual results.

These results then will be cross-validated with each other to check for any ambiguity. In case of ambiguity, we would go with XGBoost (as it resulted in the highest accuracy on our dataset used). If no ambiguity arises in the result, we will go for result analysis. If the result is positive which means the patient is having heart disease, we display the message accordingly. If it does not have heart disease the possibility of future possibilities and display a message according to the external factor's possibilities.

Strategies used in the modified hybrid classifier are shown below.

Step-1. We would first take the 13 features from the user interface and run them among all 4 classifiers.
Step-2. In case the same value is found (all of them predicting the same disease analysis), we would display the message accordingly.
Step-3. In case of ambiguity (different value from the classifiers), we consider the estimated value given by XGBoost as it resulted in the highest accuracy on our dataset used and display the message of XGBoost on the screen.
Step-4. In case we see that person is not having a heart disease we check with 5 future possibilities variables and display a warning message accordingly.

3.3 Algorithm for the proposed model

Step-1: It starts with the training of the dataset, in which 624 data are trained to each algorithm classifier.

a. There are 4 algorithm classifiers in the model namely Decision tree, Navies Bayes, Support vector machine, and XGboost.
b. A decision tree is a graphical representation for getting all possible solutions to a decision-making situation on a given condition. It follows the supervised learning technique, where internal nodes represent the feature of a data set and branches represent the decision rules and each leaf node represents the possible outcome.
c. Navies Bayesis a probabilistic classifier that predicts the possibilities given by a probability of an object. It applies Bayes law which is based on the probability of a hypothesis with prior knowledge.
d. In the Support vector machine, we plot each data item into a point in the 'n' dimension space where 'n' represents a number of features available in the data set. Then classification is performed on the hyperplane that differentiates the two classes properly.
e. XGboost or extreme gradient boost is an advanced version of gradient boosting classifiers. The major difference lies in the fact XGboost is a regularized model formalized to control overfitting which gives better performance.

Step-2: The extracted feature is computed after training of data set for every algorithm classifier upon which each variable can be used for the model.
Step-3: All the extracted features are sent to 4 different ML algorithms and a resultant output is obtained without any ambiguity.
Step-4: If there is any ambiguity between the four different algorithms the system alerts its reserved feature of taking the most accurate method among all.
Step-5: The resulting output shall be checked with 420 data for testing purposes and the reliability of the model proposed
Step-6: The resulting output is converted into a model which segregates the prediction of heart disease and future possibilities of heart disease.
Step-7: When a user enters new data, it follows a certain pattern to label it into categories.
Step-8: Features are extracted from the new data. Then it is passed to the proposed model.
Step-9: Then a prediction is made about the possibility of having heart disease or not. If a person does not have heart disease at present, then future possibilities are also looked upon.
Step-10: The user gets a message about the present condition and consultations for the future.

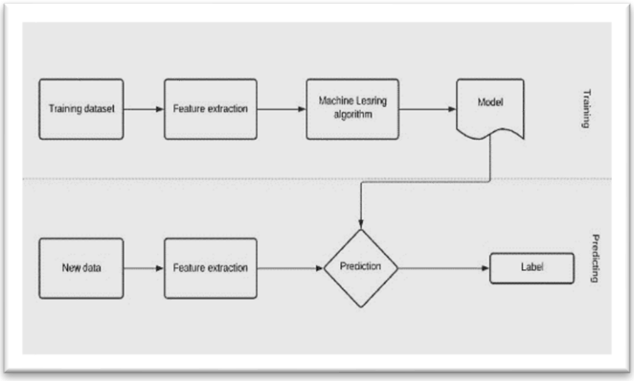

Figure 2(a): Flow diagram of the proposed algorithm.

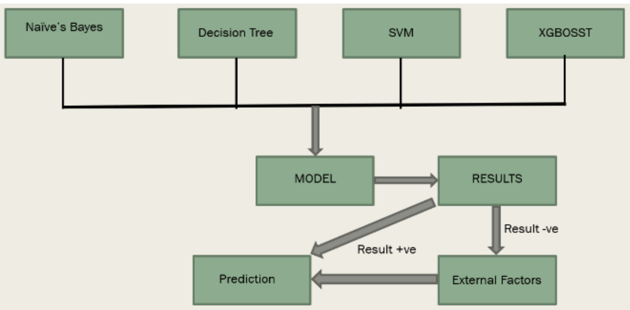

Figure 2(b): Flow diagram of the proposed algorithm with new input arrival

Figure 2(a) explains flow diagram and 2(b) explains the manner of prediction done on each new input arrival. Each new input is taken to individual classifiers namely Naive Bayes, Decision tree, SVM, XGBoost. Then each of the classifier's results, with individual output are predicted which are verified for any ambiguous data or any system error then it is converted into a model.

In the model verification and validation, results are calculated and then the results are categorized into positive and negative. If a patient has a negative result, it redirects to take external factors and then make a prediction according to it, whereas in positive results a warning message is shown and consultation with a specialist is advised.

4 System U/I design

We have designed a webpage using flask for the implementation of the proposed model in Fig 3 (a-e) and its subparts. Here four figures depict the input and result pattern of the heart disease patient.

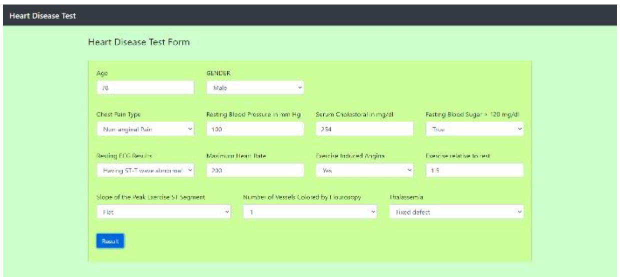

Figure 3(a): Input of heart disease symptoms.

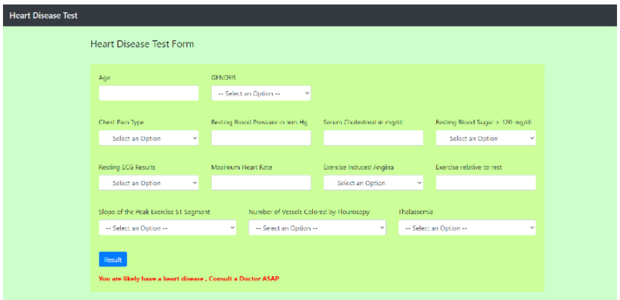

Figure 3(b): Positive result of heart disease symptoms.

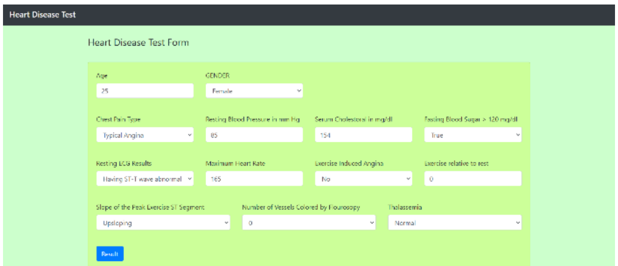

Figure. 3(c): Input of Non-heart disease symptoms.

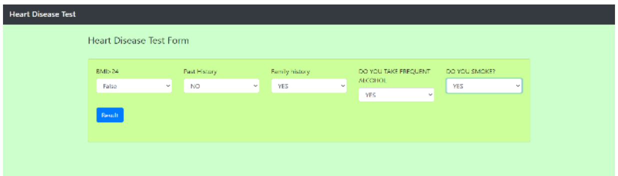

Figure 3(d): Input of external factors of Non-heart disease symptoms.

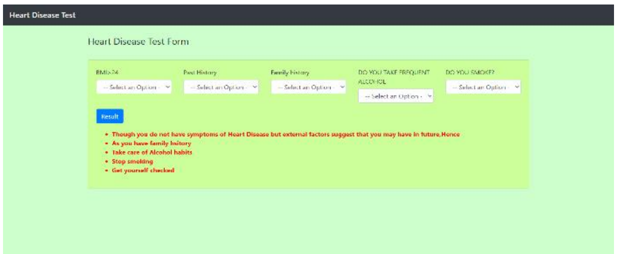

Figure 3(e): Result of negative heart disease but having external factors positive.

5 Result and discussion

Table 5 clearly shows that all 4 methods used have resulted very accurately in training and testing areas. The training and testing are done on the ratio of 60 and 40 on the same dataset. Some data are kept reserved for model evaluation and application testing at a later stage to evaluate a proper idea of the system errors. While testing at the latest stage, no error was found either at the system end or at the web end. The resultant accuracy was calculated using a table-6 with the proposed algorithm (Modified hybrid classifier) of the system proposed is 98.73% which is comparatively far better in the context of previous research.

Table 5: Training and testing results.

Classifiers	**Training accuracy (%)**	**Testing accuracy (%)**
Naive Bayes	85	78
Decision tree	100	96
Support vector machine	100	84
eXtreme Gradient Boosting	100	97
Modified hybrid classifier(Proposed)	100	98.73

Table 6: Confusion matrix of modified hybrid classifier.

	Positive	**Negative**
Positive	760	8
Negative	7	300

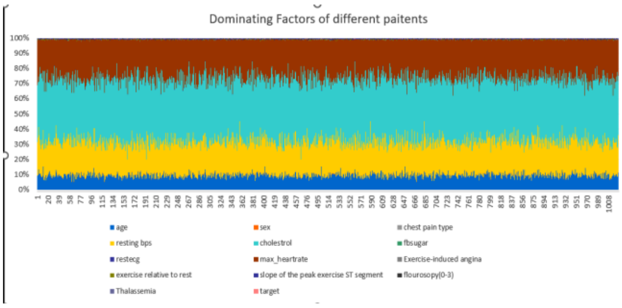

Figure 4: Representation of performance parameter.

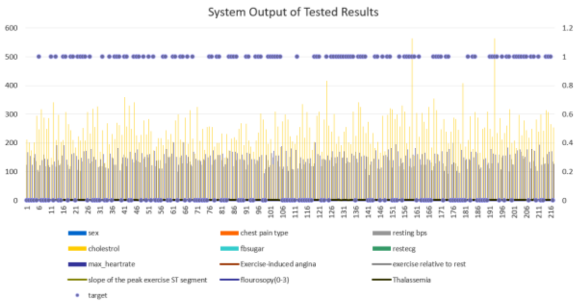

Figure 5: Output of tested results for various parameters.

This graph (shown in Figure 5) refers to the various features entered in the line graph form and the blue dot represents patients' results, the blue dot at 0 means heart diseases not found blue dot at 1 means heart diseases detected. (Note that this is the sample testing done on 216 data for a better understanding of system results and to get an overall view).

The graph (Fig-6) shows us various algorithms which are present in the industry and their accuracy against the proposed method. The Blue dotted lines suggest the industry standards line of accuracy.

The purpose of this experiment was to analyze and predict the possibility of heart disease with high precision which benefits directly to human society. Results shown in the process of prediction suggest high accuracy and fewer system failures. The on-ground implementation of the project has been successfully deployed with accurate precision. At no point in time, no conclusive system error has occurred neither at the system end or at the web application end.

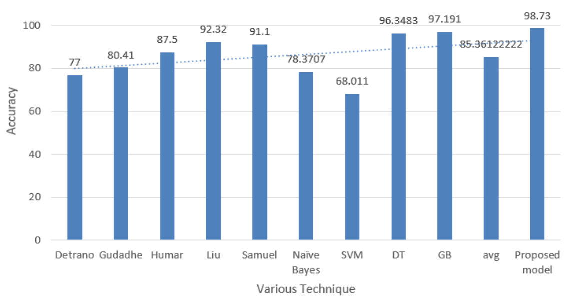

Figure 6: Comparative analysis of algorithms.

6 Conclusion and future scope

Our proposed system achieved an accuracy of 98.73% where the model accepts 13 clinical data and 5 environmental data, and it is trained using backpropagation algorithms to read it and analyze the presence or absence of heart disease in a patient. We also presented a user-friendly web application which helps a patient easily access his/her present condition and act accordingly.

Integrated multiple disease prediction-based models could be designed so that a user can analyze any condition according to their choice. A market review could also be done in order to launch the prototype for medical and general public use. All these may help society to come closer in the fight against modern-day diseases and their detection.

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Author's Contributions

All the authors have contributed equally to this paper.

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