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Prediction of Heart Disease Using a Collection of Machine and Deep Learning Algorithms

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Abstract*: Heart diseases are increasing daily at a rapid rate and it is alarming and vital to predict heart diseases early. The diagnosis of heart diseases is a challenging task i.e. it must be done accurately and proficiently. The aim of this study is to determine which patient is more likely to have heart disease based on a number of medical features. We organized a heart disease prediction model to identify whether the person is likely to be diagnosed with a heart disease or not using the medical features of the person. We used many different algorithms of machine learning such as Gaussian Mixture, Nearest Centroid, MultinomialNB, Logistic RegressionCV, Linear SVC, Linear Discriminant Analysis, SGD Classifier, Extra Tree Classifier, Calibrated ClassifierCV, Quadratic Discriminant Analysis, GaussianNB, Random Forest Classifier, ComplementNB, MLP Classifier, BernoulliNB, Bagging Classifier, LGBM Classifier, Ada Boost Classifier, K Neighbors Classifier, Logistic Regression, Gradient Boosting Classifier, Decision Tree Classifier, and Deep Learning to predict and classify the patient with heart disease. A quite helpful approach was used to regulate how the model can be used to improve the accuracy of prediction of heart diseases in any person. The strength of the proposed model was very satisfying and was able to predict evidence of having a heart disease in a particular person by using Deep Learning and Random Forest Classifier which showed a good accuracy in comparison to the other used classifiers. The proposed heart disease prediction model will enhances medical care and reduces the cost. This study gives us significant knowledge that can help us predict the person with heart disease. The dataset was collected from Kaggle depository and the model is implemented using python.*

Keywords: Heart Disease, Machine Learning, Deep Learning, Prediction

1. Introduction

Machine Learning (ML) is an application of Artificial Intelligence (AI) that provides systems with the ability to automatically learn and improve from experience without being explicitly programmed [1-10]. Machine learning focuses on developing computer models that can access and use data in learning by itself [11-20]. Learning begins with observations or data, such as examples, first-hand experience, or instructions, to search for data patterns and make better decisions in the future based on the examples we provide [21-30]. The primary goal is to make computers learn and act like humans do, and to improve their learning over time in an independent way, by providing them with data and information in the form of real-world observations and interactions [31-40].

Deep learning is a type of machine learning and artificial intelligence (AI) [41-50] that mimics the way humans acquire certain types of knowledge. Deep learning is an important component of data science, which includes statistics and predictive modeling [51-60]. It is extremely useful for data scientists charged with collecting, analyzing and interpreting large amounts of data; deep learning makes this process faster and easier [61-70].

Cardiovascular Diseases (CVD) are very common these days; they describe a variety of circumstances that could affect ones heart. According to the CDC, heart disease is one of the leading causes of death for people of most races in the US (African Americans, American Indians and Alaska Natives, and white people). About half of all Americans (47%) have at least 1 of 3 key risk factors for heart disease: high blood pressure, high cholesterol, and smoking. Other key indicator include diabetic status, obesity (high BMI), not getting enough physical activity or drinking too much alcohol as in Table 1. Detecting and preventing the factors that have the greatest impact on heart disease is very important in healthcare. Computational developments, in turn, allow the application of Deep Learning and machine learning methods to detect "patterns" from the data that can predict a patient's condition [71-80].

The dataset is collected from Kaggle depository with patient’s medical history and attributes. By using this dataset, we can predict whether the patient have a heart disease or not. The dataset has 18 medical features/attributes/variables of a patient.

2. Related Work

A quiet significant amount of work related to the diagnosis of Cardiovascular Heart disease using Machine Learning techniques has motivated this study. An efficient Cardiovascular heart disease prediction has been made by using many techniques some of them include Logistic Regression, KNN, Random Forest Classifier etc. It can be seen in Results that each technique has its strength to register the defined objectives.

Muktevi Srivenkatesh carried out a study for the Prediction of Cardiovascular Disease by comparing the accuracies of applying rules to the individual results of Support Vector Machine, Random forest, Naive Bayes classifier and logistic regression on the dataset taken in a region to present an accurate model of predicting cardiovascular disease. The machine learning algorithms used in that study were able to predict cardiovascular disease in patients with accuracy between 58.71% and 77.06%. Logistic Regression achieved the highest Accuracy (77.06 %) when compared to different Machine-learning Algorithms [81].

The authors in [82] presented various attributes related to heart disease, and the model on basis of supervised learning algorithms as Naïve Bayes, decision tree, K-nearest neighbor, and random forest algorithm. They used the dataset from the Cleveland database of UCI repository of heart disease patients. The dataset comprises 303 instances and 76 attributes. Of these 76 attributes, only 14 attributes were considered for testing, important to substantiate the performance of different algorithms. The results portray that the highest accuracy score was achieved with K-nearest neighbor was 90.79%.

In the study of [83] different machine learning algorithms and deep learning were applied to compare the results and analysis of the UCI Machine Learning Heart Disease dataset. The dataset consists of 14 main attributes used for performing the analysis. Various promising results are achieved and are validated using accuracy and confusion matrix. The dataset consists of some irrelevant features which are handled using Isolation Forest, and data are also normalized for getting better results. Using deep learning approach, 94.2% accuracy was obtained.

In the study [84] they used nine classifiers of machine learning such as AB, LR, ET, MNB, CART, SVM, LDA, RF, and XGB. Furthermore, they checked their accuracy on the standard heart disease dataset by performing certain preprocessing, standardization of dataset, and hyperparameter tuning. Additionally, to train and validate the machine learning algorithms, they deployed the standard K-fold cross-validation technique. Finally, the experimental result indicated that the accuracy of the prediction classifiers with hyperparameter tuning improved and achieved notable results with data standardization and the hyperparameter tuning of the machine learning classifiers.

In the study of [85] they proposed machine learning techniques to predict cardiovascular disease using features. BMI is one of the highlighting features they used for prediction. BMI was important in predicting cardiovascular disease. The main focus of the study was the effect of BMI on the prediction of cardiovascular disease. The model has proposed with different features as well as regression and classification techniques. They concluded that BMI was a significant factor while predicting cardiovascular disease.

In the study of [86] they employed evolutionary algorithms like Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) for the feature selection to improve the accuracy of machine learning algorithms further. GA and PSO combined with Naïve Bayes (NB), Support Vector Machine (SVM), and J48 have been applied for feature selection. After selecting the significant features, the effectiveness of the feature selection algorithm is evaluated by applying machine learning approaches on the complete dataset and reduced dataset. Five different machine learning approaches, viz., NB, SVM, Decision Tree (DT), Logistic Regression (LR), and Random Forest (RF) algorithm, have been used to predict heart disease and thus measure the effectiveness of the feature selection approaches. The results indicated that the GA has been the most effective algorithm for feature selection as it enhances the prediction accuracy most.

After reviewing the previous studies, it seems that the dataset used is the one in UCI Machine Learning Heart Disease dataset which is different from the dataset which is in the Kaggle depository [87]. We will use similar machine learning algorithms and a new deep learning algorithm for training, validating and testing these algorithms.

3. Dataset

An Organized Dataset of individuals had been selected keeping in mind their history of heart problems and in accordance with other medical conditions]. Heart disease are the diverse conditions by which the heart is affected. According to World Health Organization, the greatest number of deaths in middle aged people are due to cardiovascular diseases. The collected dataset consisted of medical history of 319795 different patient with different age groups. This dataset provide us with all needed data i.e. the medical features such as Age, BMI, Smoking, Alcohol Drinking, Stroke, Physical Health, Mental Health, Diff Walking etc. of the patient that helps us in detecting the patient that is diagnosed with any heart disease or not(as seen in Table 1). This dataset contains 18 medical features of 304 patients that helps us detecting if the patient is at risk of getting a heart disease or not and it helps us classify patients that are at risk of having a heart disease and that who are not at risk. The dataset was split into three parts: Training, Validating and Testing. This dataset contains 319795 rows and 18 columns, where each row corresponds to a single record [82]. All attributes are listed in Table 1.

Table1: Shows the features of the dataset

Feature	Description	Type of Feature
Heart Disease	Respondents that have ever reported having coronary heart disease (CHD) or myocardial infarction (MI).	Yes/No, Goal
BMI	Body Mass Index (BMI).	Yes/No
Smoking	Have you smoked at least 100 cigarettes in your entire life?	Yes/No
Alcohol Drinking	Heavy drinkers (adult men having more than 14 drinks per week and adult women having more than 7 drinks per week	Yes/No
Stroke	(Ever told) (You had) a stroke?	Yes/No
Physical Health	Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good? (0-30 days).	Numeric (0-30 days)
Mental Health	Thinking about your mental health, for how many days during the past 30 days was your mental health not good? (0-30 days).	Numeric (0-30 days)
Diff Walking	Do you have serious difficulty walking or climbing stairs?	Yes/No
Sex	Are you male or female?	Male/Female
Age Category	Age category.	Category (14 groups)
Race	Imputed race/ethnicity value.	Category
Diabetic	(Ever told) (You had) diabetes?	Yes/No
Physical Activity	Adults who reported doing physical activity or exercise during the past 30 days other than their regular job.	Yes/No
Gen Health	Would you say that in general your health is...	Category
Sleep Time	On average, how many hours of sleep do you get in a 24-hour period?	Numeric
Asthma	(Ever told) (You had) asthma?	Yes/No
Kidney Disease	Not including kidney stones, bladder infection or incontinence, were you ever told you had kidney disease?	Yes/No
Skin Cancer	(Ever told) (You had) skin cancer?	Yes/No

4. Methodology

This paper shows the analysis of various machine learning algorithms, the algorithms that are used in this paper are Gaussian Mixture, Nearest Centroid, MultinomialNB, Logistic RegressionCV, Linear SVC, Linear Discriminant Analysis, SGD Classifier, Extra Tree Classifier, Calibrated ClassifierCV, Quadratic Discriminant Analysis, GaussianNB, Random Forest Classifier, ComplementNB, MLP Classifier, BernoulliNB, Bagging Classifier, LGBM Classifier, Ada Boost Classifier, K Neighbors Classifier, Logistic Regression, Gradient Boosting Classifier, Decision Tree Classifier, and Deep Learning which can be helpful for practitioners or medical analysts for accurately diagnose Heart Disease. This study includes examining the journals, published papers and the dataset of cardiovascular disease. The methodology is a process, which includes steps that transform given dataset into recognized data for

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the knowledge of the users. The proposed methodology (as in Figure 1) includes the following steps: the first step is referred to as the collection of the data then in second step, it extracts significant values then the 3rd is the preprocessing step where we explore the data. Data preprocessing deals with the missing values, cleaning of data and normalization depending on algorithms used [81]. After pre-processing of data, each classifier is used to classify the pre-processed data. Finally, the proposed model is undertaken, where we evaluated our model on the basis of accuracy and performance using various performance metrics. Here in this model, an effective Heart Disease Prediction System has been developed using different classifiers. This model uses 18 medical features such as Age, BMI, Smoking, Alcohol Drinking, Stroke, Physical Health, Mental Health, DiffWalking etc. for prediction [82].

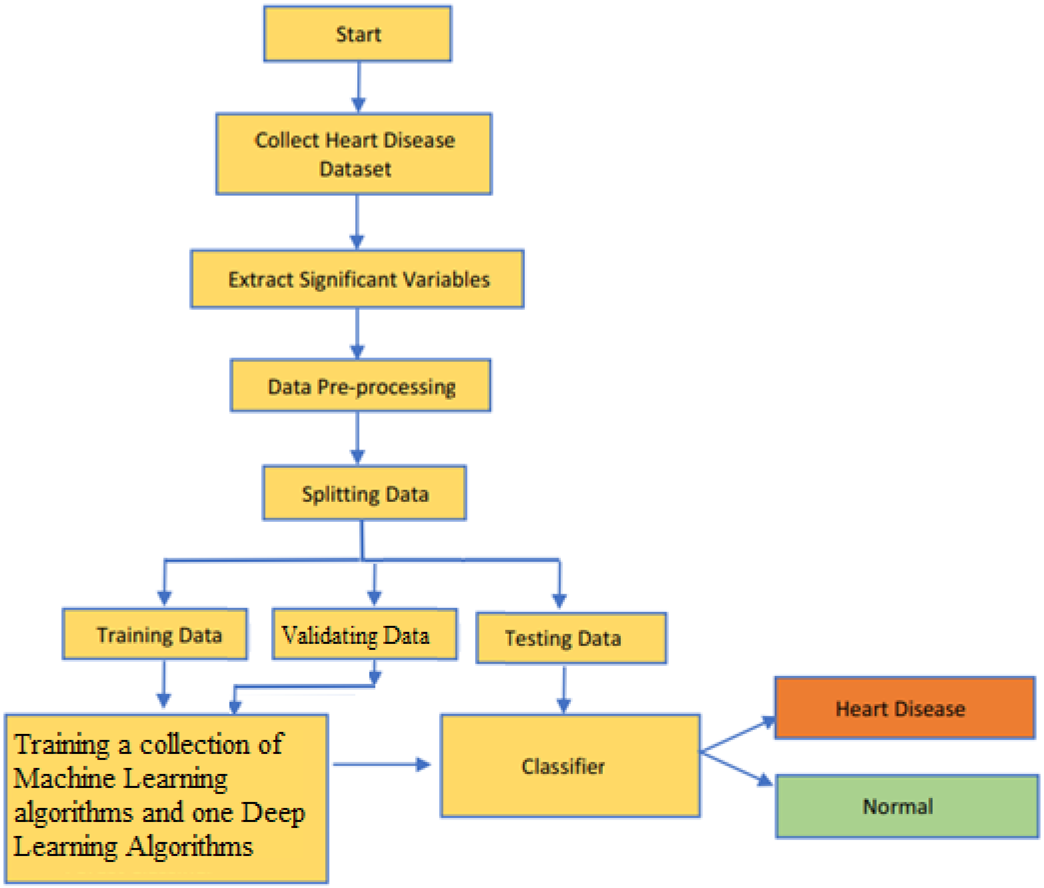

Figure 1: Proposed model

4.1 Data Cleaning

The Dataset has around 319795 entries with 18 columns. No null values and we have 14 numeric features, and 4 categorical features. We can convert the string attributes that has only two possibilities of unique values, but first let's make sure that there is no abnormal values.

We have some attributes that have more than two unique values; we will use OneHotEncoder in the preprocessing step later.

4.2 Exploratory Analysis

4.2.1 Visualization of Categorical Features

Figure 2 shows the distribution of cases with Yes/No heart disease according to Sex. Number 1 refers to men and 0 refers to women on the x-axis. From the figure, we notice that:

- Most cases of heart disease are men.
- Most cases that got no heart disease are women

Figure 3 shows the distribution of cases with Yes/No heart disease according to Smoker or not. From the figure we notice that:

- For smokers, they are the largest group that suffers from heart disease.

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- There are also cases of heart disease, although they don't smoke, this is related to other factors.

Figure 4 shows the distribution of cases with Yes/No heart disease according to Race where 1 refers to heart disease and 0 refers to normal state. From the figure, we can see that:

- White people are more susceptible to heart disease.

Figure 5 shows the distribution of cases with Yes/No heart disease according to AgeCategory. We can see from Figure 5 that:

- People who are 80 years or older are more likely to get Heart Diseases.

Figure 6 shows the distribution of cases with Yes/No heart disease according to KidneyDisease feature. We notice from the figure that:

- People with no Kidney Disease are more likely to get Heart Diseases.

Figure 7 shows the distribution of cases with Yes/No heart disease according to Skin Cancer feature. From the figure we can see that:

- People with no Skin Cancer are more likely to get Heart Diseases.

Figure 8 shows the distribution of cases with Yes/No heart disease based on previous exposer to Stroke. From the figure we can see that:

- People who were previously exposed to Stroke are less likely to get Heart Diseases.

Figure 9 shows the distribution of cases with Yes/No heart disease based on previous exposer to Diabetic. From the figure we can see that:

- People who were previously exposed to Diabetic are less likely to get Heart Diseases.

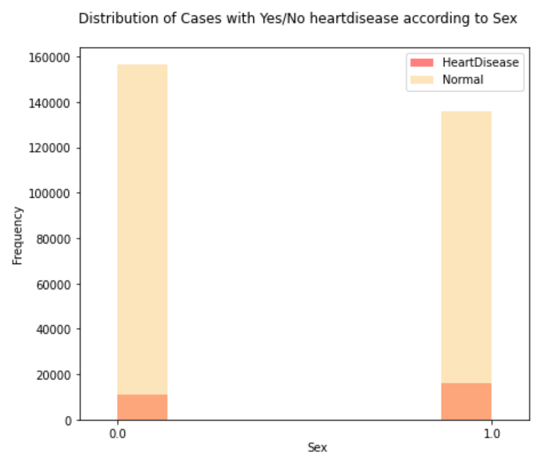

Figure 2: Distribution of cases with Yes/No heart disease according to Sex

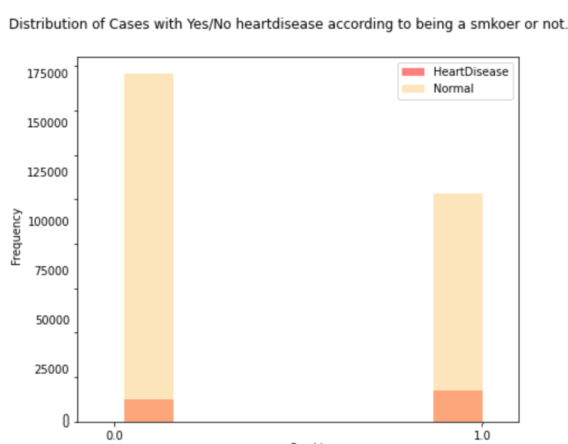

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Figure 3: Distribution of cases with Yes/No heart disease according to Smoker or not

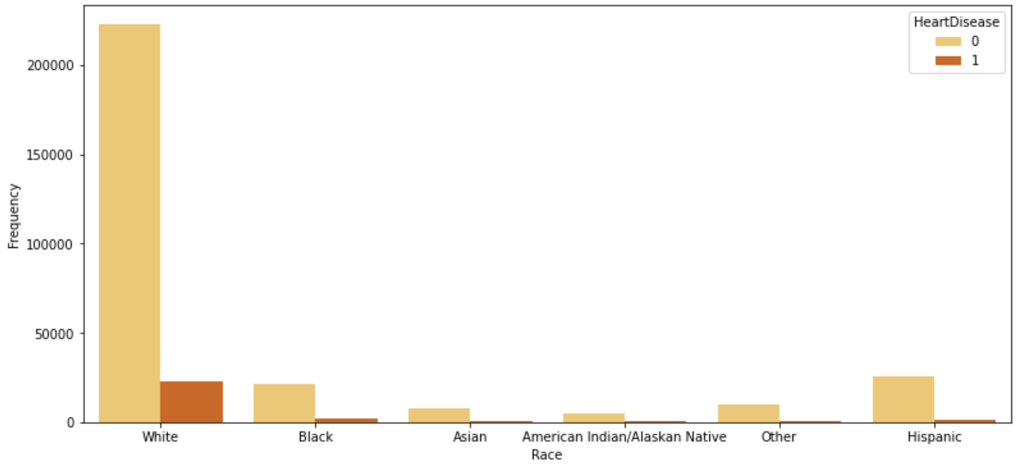

Figure 4: Distribution of cases with Yes/No heart disease according to Race

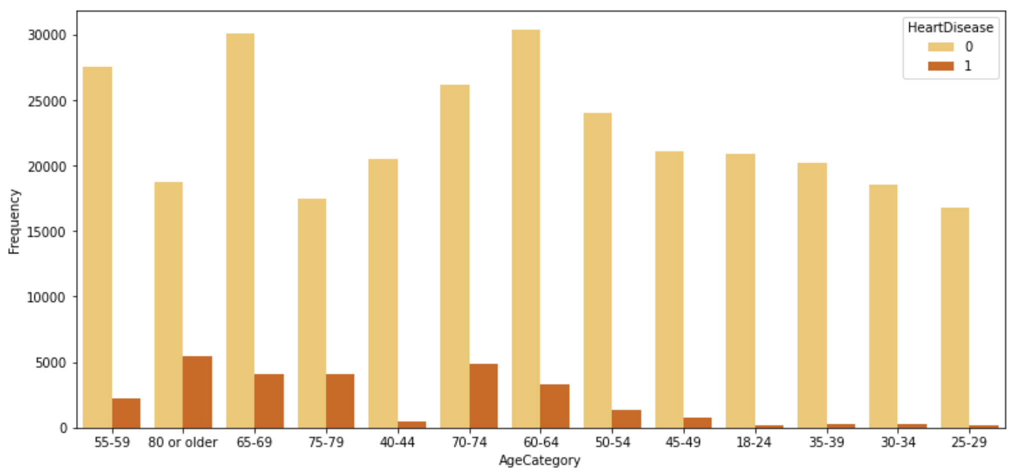

Figure 5: Distribution of cases with Yes/No heart disease according to AgeCategory

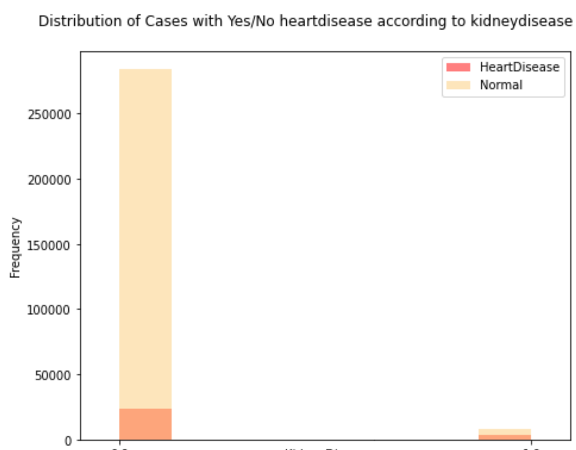

Figure 6: Distribution of cases with Yes/No heart disease according to KidneyDisease

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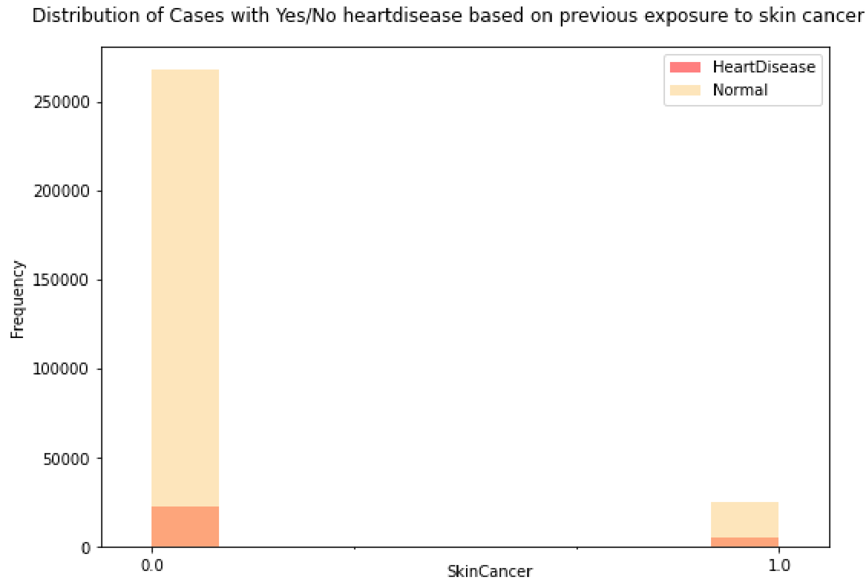

Figure 7: Distribution of cases with Yes/No heart disease according to SkinCancer

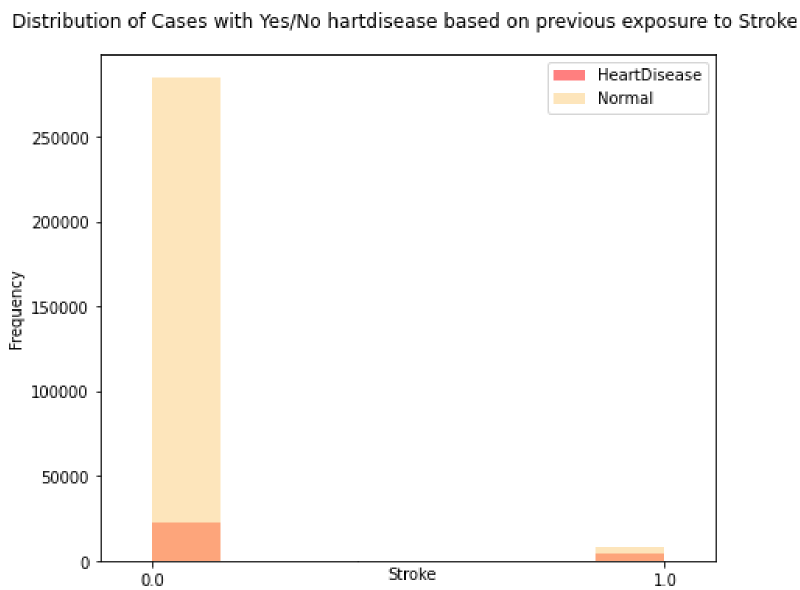

Figure 8: Distribution of cases with Yes/No heart disease based on previous exposer to Stroke

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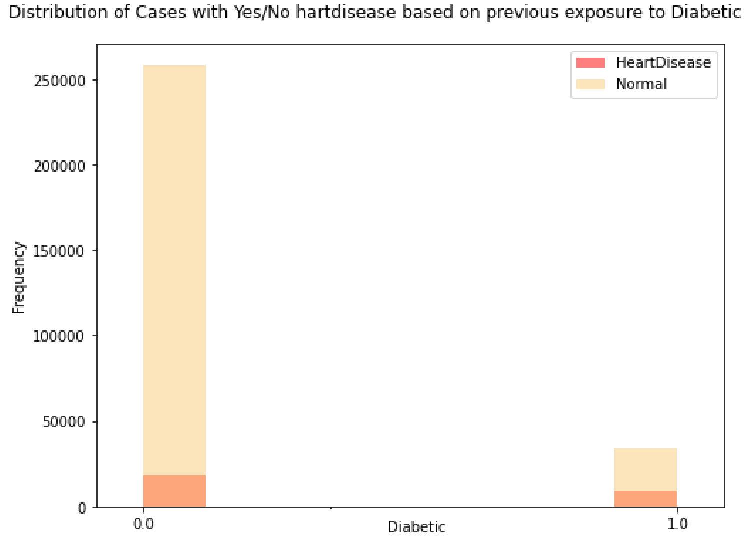

Figure 9: Distribution of cases with Yes/No heart disease based on previous exposer to Diabetic

4.2.2 Visualization of Numerical Features

We can see from Figure 10 that people who weigh less than 40 kg are more likely to get heart disease. Figure 11 shows the distribution of cases with Yes/No heart disease based on SleepTime values. Figure 12 shows the distribution of cases with Yes/No heart disease based on Physical Health state for the last 30 days. Figure 13 shows the distribution of cases with Yes/No heart disease based on Mental Health state for the last 30 days.

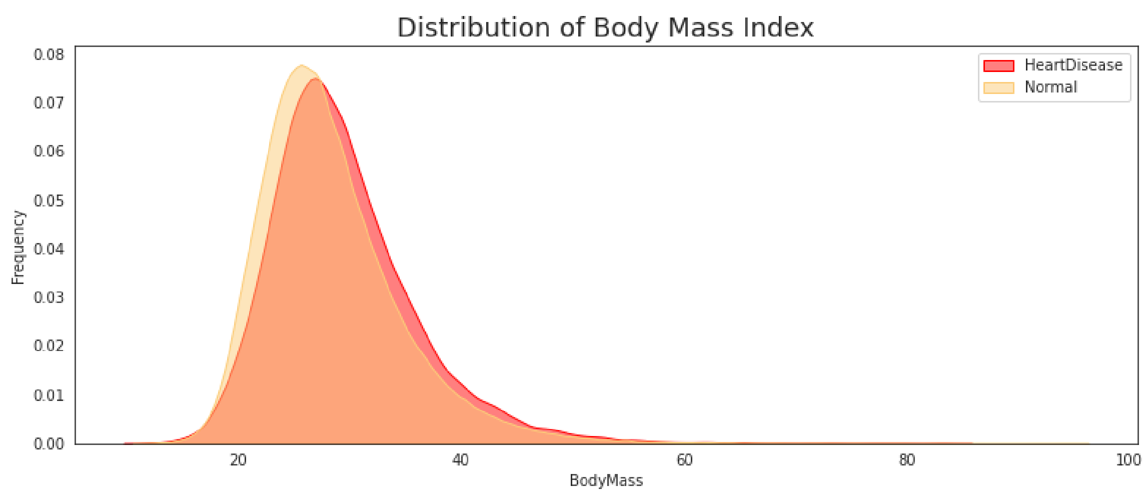

Figure 10: Distribution of cases with Yes/No heart disease based on Body Mass Index

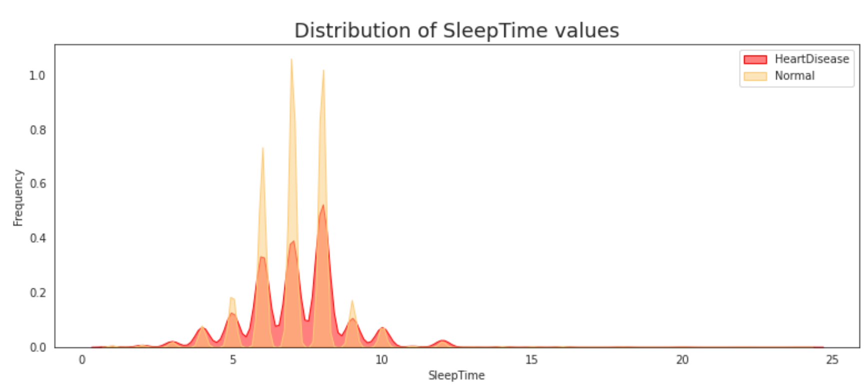

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Figure 11: Distribution of cases with Yes/No heart disease based on SleepTime values

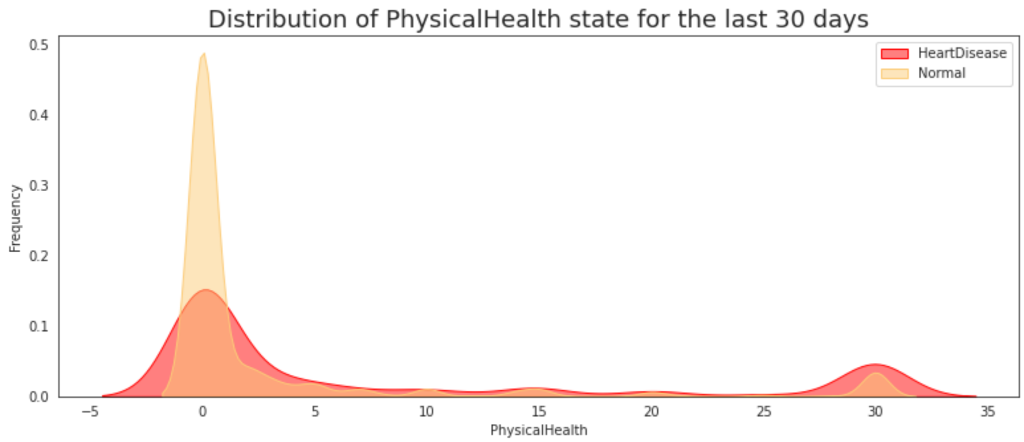

Figure 12: Distribution of cases with Yes/No heart disease based on Physical Health state for the last 30 days

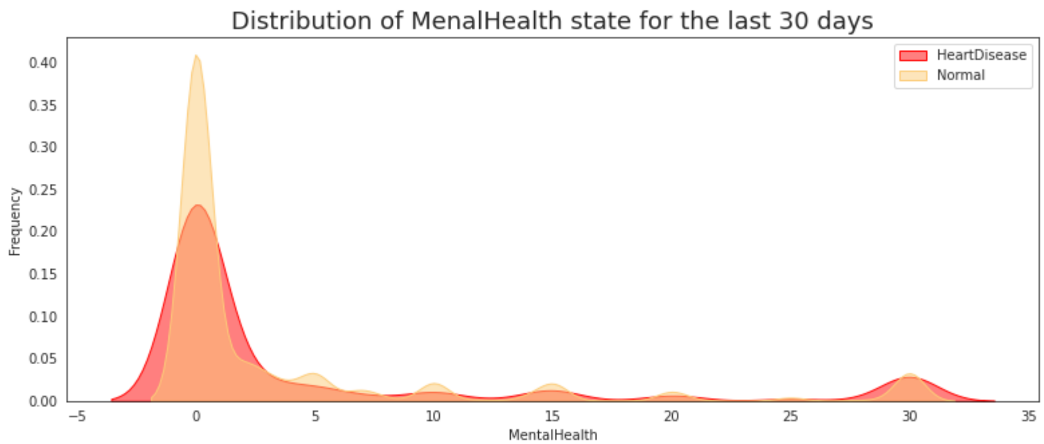

Figure 13: Distribution of cases with Yes/No heart disease based on Mental Health state for the last 30 days

4.3 Data Preprocessing

4.3.1 Standardization

We used StandardScale function to standardize the following features: MentalHealth, BMI, PhysicalHealth, and SleepTime.

4.3.2 Encoding

We used One Hot Encoding technique for the following features: AgeCategory, Race, GenHealth.

4.4 Balancing the Dataset

The ration of the target category (HeartDisease) is 91% (Not Heart Disease) to 9% (Yes Heart Disease). Thus, the dataset is not balanced.

There are two popular methods for balancing the dataset: over sampling, and under sampling. Under sampling method is used by downsizing the higher attribute to be the same with the lower attribute values; while the over sampling is used when we want to increase the lower attribute to be equivalent to the higher attribute values.

In this study, we used both under sampling and over sampling and compared the results of both techniques.

4.5 Splitting Dataset

We have divided the dataset after preparation into three datasets: Training, Validating and Testing. The ratio of splitting is 60x20x20.

4.6 First Experiment

The first experiment was done using under sampling for dataset balancing. We trained the dataset using the collection of machine learning algorithms and one deep learning algorithm created from scratch. The results were recorded using accuracy, precision, recall, f1-score and time needed for the training. The result of each algorithm can be seen in Table 2.

Table 2: Results of all algorithms using under sampling technique

Model Name	Accuracy	Precision	Recall	F1_score	Time in Second
GaussianMixture	0.49817	0.00000	0.00000	0.00000	0.49
Perceptron	0.70283	0.70956	0.69045	0.69987	0.17
NearestCentroid	0.72886	0.74784	0.69354	0.71967	0.12
MultinomialNB	0.74575	0.75284	0.73449	0.74355	0.10
LogisticRegressionCV	0.76320	0.75429	0.78326	0.76850	7.99
LinearSVC	0.76274	0.75328	0.78399	0.76833	1.48
LinearDiscriminantAnalysis	0.76283	0.75332	0.78417	0.76844	0.34
LabelPropagation	0.71178	0.71856	0.69973	0.70902	58.03
CalibratedClassifierCV	0.76265	0.75457	0.78107	0.76759	8.267
ExtraTreeClassifier	0.68100	0.68220	0.68207	0.68214	0.15
SGDClassifier	0.75297	0.73936	0.78417	0.76111	0.17
QuadraticDiscriminantAnalysis	0.73160	0.68905	0.84768	0.76018	0.58
GaussianNB	0.74941	0.70545	0.85951	0.77490	0.14
RandomForestClassifier	0.74429	0.74476	0.74429	0.74414	5.93
ComplementNB	0.75397	0.76469	0.73631	0.75023	0.09
MLPClassifier	0.76110	0.73594	0.81711	0.77440	57.11
BernoulliNB	0.75288	0.76699	0.72903	0.74753	0.15
BaggingClassifier	0.72119	0.73186	0.70136	0.71629	1.79
LGBMClassifier	0.76694	0.75004	0.80328	0.77575	0.68
AdaBoostClassifier	0.76639	0.76388	0.77361	0.76872	1.78
KNeighborsClassifier	0.73662	0.73612	0.74067	0.73839	7.83
LogisticRegression	0.76813	0.76159	0.78308	0.77218	0.82
GradientBoostingClassifier	0.76594	0.75328	0.79345	0.77284	4.61
Deep Learning	**0.78767**	**0.76828**	**0.82602**	0.**79611**	81.00

4.6 Second Experiment

The second experiment was done using over sampling for dataset balancing. We trained the dataset using the same collection of machine learning algorithms and the same deep learning algorithm which was created from scratch. The results were recorded using the measures: accuracy, precision, recall, f1-score and time needed for the training. The result of each algorithm can be seen in Table 3.

Table 3: Results of all algorithms using over sampling technique

Model Name	Accuracy	Precision	Recall	F1_score	Time in Second
GaussianMixture	0.69104	0.63896	0.87809	0.73968	11.73
Perceptron	0.65682	0.62802	0.76891	0.69136	2.11
NearestCentroid	0.71694	0.73282	0.68263	0.70684	0.78
MultinomialNB	0.74546	0.74256	0.75126	0.74689	0.71
LogisticRegressionCV	0.76199	0.74393	0.79884	0.77041	77.16
LinearSVC	0.76219	0.74112	0.80573	0.77207	31.91
LinearDiscriminantAnalysis	0.76190	0.73995	0.80748	0.77224	3.31
SGDClassifier	0.75909	0.73703	0.80544	0.76972	1.31
ExtraTreeClassifier	0.85222	0.84620	0.86082	0.85345	2.89

CalibratedClassifierCV	0.76067	0.74526	0.79191	0.76788	155.57
QuadraticDiscriminantAnalysis	0.73278	0.70673	0.79556	0.74852	2.03
GaussianNB	0.72732	0.67401	0.88027	0.76345	0.91
RandomForestClassifier	0.90213	0.90221	0.90213	0.90212	85.51
ComplementNB	0.74279	0.74105	0.74622	0.74362	0.71
MLPClassifier	0.80250	0.77353	0.85533	0.81238	461.56
BernoulliNB	0.74156	0.74937	0.72573	0.73736	1.02
BaggingClassifier	0.89634	0.90433	0.88641	0.89528	34.48
LGBMClassifier	0.88054	0.88834	0.87043	0.87930	10.20
AdaBoostClassifier	0.80485	0.78739	0.83511	0.81055	22.25
KNeighborsClassifier	0.83242	0.79876	0.88865	0.84131	954.00
LogisticRegression	0.76017	0.74268	0.79602	0.76843	6.00
GradientBoostingClassifier	0.82845	0.81048	0.85728	0.83323	72.00
DecisionTreeClassifier	0.87066	0.86697	0.87561	0.87127	4.70
Deep Learning	**0.92353**	**0.90837**	**0.94204**	**0.92490**	600.00

5. Results & Discussions

From these results we can see that although most of the researchers are using different algorithms such as SVC, Decision tree, KNN, Random Forest Classifier and Logistic regression for the detection of patients diagnosed with Heart disease, yield the highest accuracy 88.5% with a different dataset than we are using in this study.

The algorithms that we used are more accurate, saves a lot of money i.e. its cost efficient and faster than the algorithms that the previous researchers used. Moreover, the maximum accuracy obtained using under sampling was Deep Learning: accuracy (78.77%), precision (76.83%), recall (82.60%), F1-score (79.61%) and time needed for training and validation (81 seconds). The reaming results of the other algorithms are as shown in Table 2.

On the other hand, the results of the same algorithms using over sampling came up with same algorithm (Deep Learning) but with higher accuracy. The maximum accuracy obtained using over sampling was: accuracy (92.35%), precision (90.84%), recall (94.20%), F1-score (92.49%) and time needed for training and validation (600 seconds).

The second best accuracy was for Random Forest Classifier: accuracy (90.21%), precision (90.22%), recall (90.21%), F1-score (90.21%) and time needed for training and validation (85.51 seconds). The reaming results of the other algorithms are as shown in Table 3.

So, in summary, our accuracy measures were better than previous studies. Our study also tells us that Deep learning and Random Forest Classifier in the prediction of the patient diagnosed with a heart Disease were the best. This proves that Deep learning and Random Forest Classifier are better in the diagnosis of a heart disease.

6. Conclusion

A cardiovascular disease detection model has been developed using a collection of ML classification modelling techniques and one deep learning model. This study predicts people with cardiovascular disease by extracting the patient medical history that leads to a fatal heart disease from a dataset that includes patients' medical history such as BMI, Smoking, Alcohol Drinking, Stroke, Physical Health, Mental Health, etc. This Heart Disease detection system assists a patient based on his/her clinical information of them been diagnosed with a previous heart disease. The algorithms used in building the given model are Deep Learning, Random Forest Classifier and many other classifiers. The top accuracy of our models was 92.23%. Use of more training data (as a result of dataset balancing) ensures the higher chances of the model to accurately predict whether the given person has a heart disease or not. By using these techniques, we can predict the patient fast and better and the cost can be reduced very much. There are a number of medical databases that we can work on as these machine learning techniques are better and they can predict better than a human being which helps the patient as well as the doctors. Therefore, in conclusion this study helps us predict the patients who are diagnosed with heart diseases by cleaning the dataset and applying deep learning an accuracy of an average of 92.23% on our deep learning model which is better than the previous models having an accuracy of 85%. In addition, it is concluded that accuracy of Deep learning is the highest between the collections of the algorithms that we have used.

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