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Article Title: Heart Disease Prediction using CNN Based on Deep Learning Algorithm

Heart Disease Prediction using CNN Based on Deep Learning Algorithm

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ABSTRACT

"Heart diseases" are a group of disorders related to the heart. Heart blood flow is hampered by coronary artery disease (CAD), the most frequent kind of heart disease in the United States. A heart attack may be brought on by a decrease in blood flow. Even though there are several heart conditions that may be avoided or managed, heart disease can also occasionally be "silent," going undiagnosed until a patient exhibits signs that point to a heart attack, heart failure, or an arrhythmia. This study suggests using a deep learning algorithm-based Convolutional Neural Network (CNN) to detect cardiac disease. Heart disease requires careful management due to its complex nature. This project provides accurate and practical deep learning techniques. The K-means clustering technique may be used to identify groups of data items within a dataset. The technique known as particle swarm optimization (PSO) is used to estimate solutions to very challenging or unsolvable numerical minimization and maximization problems. Long Short-Term Memory (LSTM) classifier, a deep learning technology, is employed to categorize the assaults under various scenarios. In addition to greatly enhancing the healthcare system, this project gives medical practitioners access to an invaluable diagnostic tool. Programs written in Python Jupyter are used to carry out this project. CNN has an accuracy of 97.7% and a Recall comparison of 94.17% respectively.

Keywords: CAD, CNN, PSO, LSTM, HFD.

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1 Introduction

According to the WHO's most recent study, 17.9 million people die annually. The fact that it will climb to 75 million by 2030 is not surprising. According to the American Heart Association, a heart attack occurs in the United States around every 40 seconds. Numerous cardiovascular diseases (CVD) use avoidable risks including smoking, eating disorders, physical inactivity, and excessive alcohol use in a variety of settings to kill people [1, 2]. CVD puts people at greater risk for heart attacks. As outlined below, prompt identification of the illness is necessary, as is advice on the administration of brief treatments. Ultimately, the synthesis of fatty reserves inside the ducts and the outflow of blood groups signal the end of CVD. It may also be connected to a tissue injury to the kidneys, heart, eyes, or skull [3, 4]. CNNs, a type of deep learning algorithm, are better at diagnosing diseases than the methods used today. This CNN-based model handles massive amounts of data processing. One advantage of CNN is that it manages all tasks, such as preprocessing, prediction, and feature extraction [5, 6].

In the area of deep learning, CNNs have become extremely effective tools, especially when it comes to image identification and classification tasks [7]. CNNs are useful for evaluating complicated data types such as medical pictures because they can automatically learn characteristics from raw data. The proposed model makes advantage of CNNs' capacity to efficiently predict the presence of cardiac disease in patients by combining clinical data such as patient demographics, medical history, and results of diagnostic tests with medical imaging data, such as X-rays or MRI scans [8, 9]. Many people pass away from symptoms that were either disregarded or never noticed before. It's time to anticipate cardiac disease before it manifests itself. Heart disease has several primary causes. Several factors might include elevated blood pressure, smoking, alcohol use, high blood sugar, inactivity, CVD, and hypertensive heart disease [10, 11]. The most common disease in the world, heart failure disease (HFD), has a complex pathophysiology. Changes in mechanical characteristics and modifications to heart electrical activity can occasionally result in a decrease in cardiac output. Early in the HFD, several neurohormonal regulation processes are triggered. While these compensatory mechanisms might temporarily counteract the consequences of a high-fat diet, they can also lead to lasting alterations in preload and afterload, pulmonary and peripheral edema, cardiac remodeling, and dyspnea during exercise [12, 13].

Patients with HFD are provided a wide range of treatment choices, including medication, lifestyle modifications, and implanted devices like defibrillators and pacemakers. Considering that hospitalization for acute HFD decompensation is the primary source of health care costs, following up with this population is a serious problem. Studies and data indicate that the most important issue that people, especially those on HFD, experience is heart disease. Like other

diseases, the first stage in therapy and care for heart disease is early discovery and diagnosis. Deep learning algorithms have the potential to improve illness recognition and treatment through increased accuracy and efficiency, which will eventually improve patient care and healthcare delivery [14, 15].
In this paper Data visualisation is employed to identify patterns and relationships within the dataset. The K-means cluster is used method to find groups of data items within a dataset. The accuracy and recall levels are predicted by the use of a CNN classification approach which is optimized with the help of PSO.

2 Recent Works

Tulasi Krishna Sajja et al [2020] have discussed the pressing need for efficient illness prediction models, with a focus on heart disease as it is one of the world's major causes of loss. In this regard, the research suggests using a CNN a Deep Learning technique to anticipate cardiac problems early on. In particular, the dataset has a remarkable 94% accuracy rate when used to predict CVD. This demonstrates how well the CNN-based prediction model predicts who is most likely to get heart disease. The study demonstrates CNN's advantage in early cardiac disease prediction in terms of accuracy and efficiency when compared to standard ML methods. CNNs and other deep learning models are prone to over fitting, a phenomenon in which the model becomes too familiar with the training set and fails to generalize to new data. When a model is over fitted, it may perform poorly on fresh data and lose dependability when used in practical settings.
Awais Mehmood et al [2020] have proposed heart disease is a grave worldwide fitness concern that mostly affects developing nations in Asia and Africa. Cardio Help is a data modeling tool that focuses on temporal data with the goal of early heart failure prediction. Results from experiments show that Cardio Help performs better than current techniques, with an amazing accuracy rate of 97%. Deep CNNs do not take into account the patient's past or the larger clinical context while analyzing raw data inputs, such as temporal sequences or medical pictures. For precise diagnosis and treatment planning, predictive models must incorporate domain expertise and clinical knowledge.
Yuanyuan Pana et al [2020] have discussed major obstacle in contemporary medical research is the identification of cardiac disease, which necessitates a thorough examination of patient medical histories and results from clinical tests. The results of the tests demonstrate that the EDCNN system, with its flexible architecture and hyper parameter customisation, offers an exceptional accuracy of up to 99.1%. The term "black box" is occasionally used to describe EDCNN and other deep learning models as it might be challenging to comprehend how they generate predictions. The model's lack of interpretability might make it difficult for medical

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professionals to comprehend and rely on its results, which could prevent it from being used in clinical settings.

Furqan Rustam et al [2022] have made a study on major cause of death worldwide, CVDs pose a serious threat to global health. The diversity of symptoms caused by age, gender, demography, and ethnicity exacerbate the difficulty of detecting CVDs. The CNN is utilized to increase the feature set of an ensemble model, which is then used to train linear models such as logistic regression, support vector machines, and stochastic gradient descent classifiers. Predictive performance is improved when these models are incorporated into an ensemble that uses soft voting. With an accuracy of 0.93 and scores of 0.92 for precision, recall, and F1 score, the results show how well the suggested model performs. The suggested technique shows notable improvements in CVD diagnostic accuracy and generalization across various datasets by utilizing ensemble models and addressing the shortcomings of current feature sets.

Annisa Darmawahyuni et al [2019] have proposed a Coronary heart disease is a major worldwide health burden that results in a large number of annual fatalities. Indonesia has a particularly high incidence of CHD. One major problem causing these deaths is misdiagnosis of coronary heart disease. In contrast to conventional techniques, the simulation presented in this research aims to diagnose CHD more accurately in order to detect if CHD is present (expressed as "1") or absent (represented as "0"), the DNN model is implemented using binary classification. The proposed DNN model's high levels of accuracy, sensitivity, and specificity point to its potential use as a useful diagnostic tool for coronary heart disease, supporting early intervention and preventative measures to lower the death rate associated with CHD. The interpretability of features produced from CNNs may be low, which makes it difficult to comprehend the underlying mechanisms influencing the ensemble classifier's predictions.

3 Proposed Work Explanation

This proposed work predicts cardiac disease using a CNN that is based on a deep learning algorithm. An analysis of the input dataset is the first step in the data pre-processing process, which uses an SDN dataset. Standard Scaler is used for pre-processing the datasets. Data pre-processing methods are used to deal with the unnecessary data in the dataset. The stage of the data visualization process is created after the data has been prepared. Data visualization is used to find features and relationships within the dataset.

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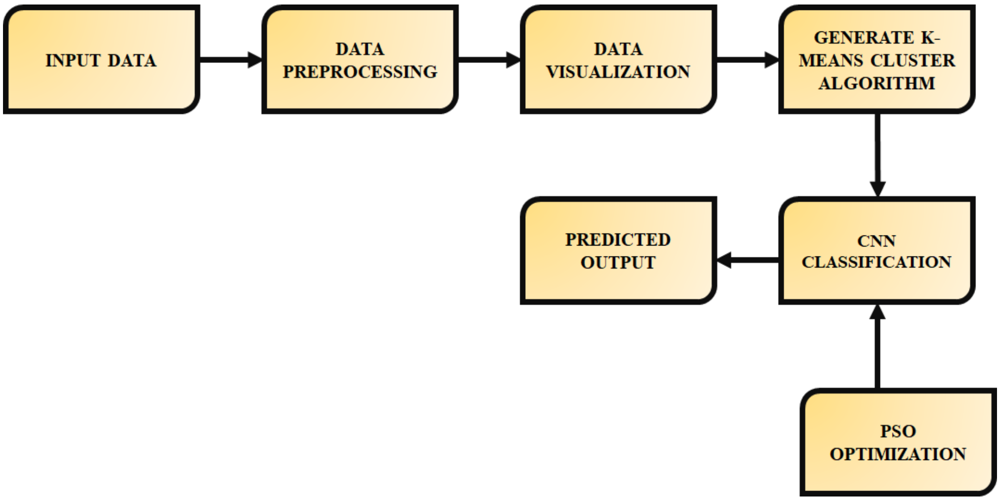

Figure 1: *Proposed block diagram*

This dataset is forwarded to the K-means cluster algorithm after visualization. To find clusters of data objects in a dataset, apply the K-means cluster method. The following deep learning method (CNN classifier) is acceptable for the data. The CNN classifier is used to categorize the assaults in order to identify problems in that area.

3.1 Data Preprocessing

To guarantee the accuracy and efficacy of the predictive model, there are many critical phases in the data preparation process for CNN-based heart disease prediction. This is a thorough rundown of the steps involved in data preparation: Data Collection: Compile pertinent datasets with heart disease-related information. Clinical data including patient demographics, medical history, symptoms, and test results from lab work, electrocardiogram (ECG) recordings, cardiac imaging and other pertinent medical data may be included in these datasets. Data Cleaning: Make sure the gathered data is free of any mistakes, missing values, or inconsistencies that might have a negative impact on model training. This process involves imputation approaches for handling missing data, duplication removal, and dataset correction for any inconsistencies. Data Labelling: Give the data the proper labels to show whether or not cardiac disease is present. This might entail using recognized diagnostic criteria or speaking with medical specialists in order to appropriately categorize the data.

3.2 Data Visualization

Data visualization is the branch of data analysis that focuses on how data is visually shown. It is a helpful tool for presenting conclusions derived from data and presents data in a visual manner. It could use data visualization to get a graphic representation of our data. Material

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provided in the form of pictures, maps, and graphs is easier for the human mind to digest and understand. It is challenging to examine all of our data in large data sets, much less manually process and understand it. Data visualization comes in quite handy here to portray vast and tiny data sets.

3.3 K-Means Cluster Algorithm

To divide an image into K clusters, the clustering technique K-Means segmentation is frequently used in image processing. However, because of the nature of the issue, using K-Means directly to forecast cardiac disease is less prevalent. Rather than segmentation, classification challenges are usually included in heart disease prediction. On the other hand, K-Means clustering techniques may be used in a different context if you are interested in applying them for heart disease studies. As an illustration:

1. Feature Clustering: To group related characteristics that were derived from patient data, you can use K-Means clustering. This might make it easier to spot trends or subgroups in the data that might point to various heart disease subtypes or risk factors.

2. Patient Segmentation: Based on health indicators like age, blood pressure, cholesterol levels, etc., K-Means clustering may be used to divide patients into several groups. The identification of high-risk populations or the customization of treatment plans may be aided by this segmentation.

3. Image analysis: You may be able to divide heart disease-related medical pictures into distinct zones of interest using K-Means segmentation, such as MRI or CT scans. This may help locate anomalies or regions of tissue damage linked to cardiac disease.

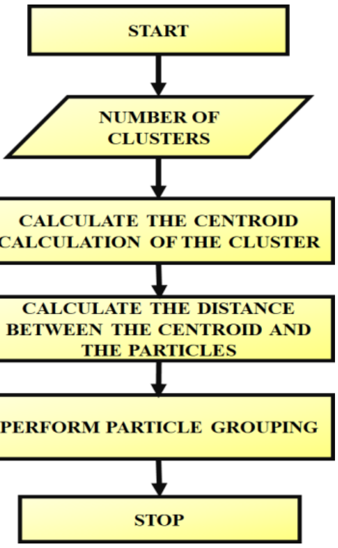

Figure 2: *K-Means Cluster Algorithm*

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It is noteworthy that although K-Means clustering can serve as a valuable instrument for exploratory data analysis and pattern identification, its applicability to all facets of heart disease prediction may be limited.

3.4 PSO Optimization

PSO is a stochastic optimization technique that draws inspiration from mobility and swarm intelligence. In PSO, problem resolution is based on the concept of social interaction. It uses a swarm of particles, or agents, to roam throughout the search area in pursuit of the best possible answer. In the solution space, each particle in the swarm searches for its positional coordinates, which are connected with the best solution that particle has found thus far. It refer to it as our personal best, or pbest. Detecting a function's maximum or minimum on a multidimensional vector space is the best use case for PSO.

Algorithm 1: Pseudo code for the PSO algorithm

Input: $Population_{size}$

Output: P_{g_best}

Population ← ∅;

P_{g_best} ← ∅;

for i=1 **to** $Population_{size}$ **do**

$P_{velocity}$ ← $RandomVelocity()$;

$P_{velocity}$ ← $RandomPosition(Population_{size})$;

P_{p_best} ← $P_{position;}$

if Cost (P_{p_best}) ≤Cost (P_{p_best}) **then**

P_{g_best} ← P_{p_best};

while-$StopCondition()$ **do**

$\boldsymbol{foreach}$ P∈Population **do**

$P_{velocity}$ ← $UpdateVelocity(P_{velocity,}P_{g\_best},P_{p\_best})$;

$P_{velocity}$ ← $UpdatePosition(P_{position,}P_{velocity})$;

if Cost ($P_{position}$) ≤Cost (P_{p_best}) **then**

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$P_{p\_best} \leftarrow P_{position}$;

if Cost (P_{p_best}) ≤Cost (P_{g_best}) **then**

$P_{g\_best} \leftarrow P_{p\_best}$;

return P_{g_best};

3.5 CNN Classification

One kind of deep learning algorithm that has been applied in several real-world scenarios is convolutional neural networks, or CNNs. CNNs may be trained to accurately predict the next word in a phrase, identify objects in a picture, and classify images. Rather of manually evaluating the MRI pictures, a CNN-based algorithm will assist medical practitioners in their therapeutic role to speed up the healing process. It bears similarities to the basic neural network. CNN has learnable parameters, such weights and biases, just as neural networks. Despite their resource and skill difficulty, CNNs offer comprehensive conclusions. Essentially, everything revolves around identifying subtleties and patterns that are so little and invisible to the human sight.

Basic Architecture of CNN

One class of algorithms for deep learning that can handle grid-like data layouts is CNNs. CNNs are a subtype of deep learning algorithms designed to process spatially or temporally-connected information. While CNNs and other neural networks are comparable, CNNs are more advanced due to their many convolutional layers. A crucial part of convolutional neural networks are convolutional layers. An example of a common CNN design is shown in Figure 3.

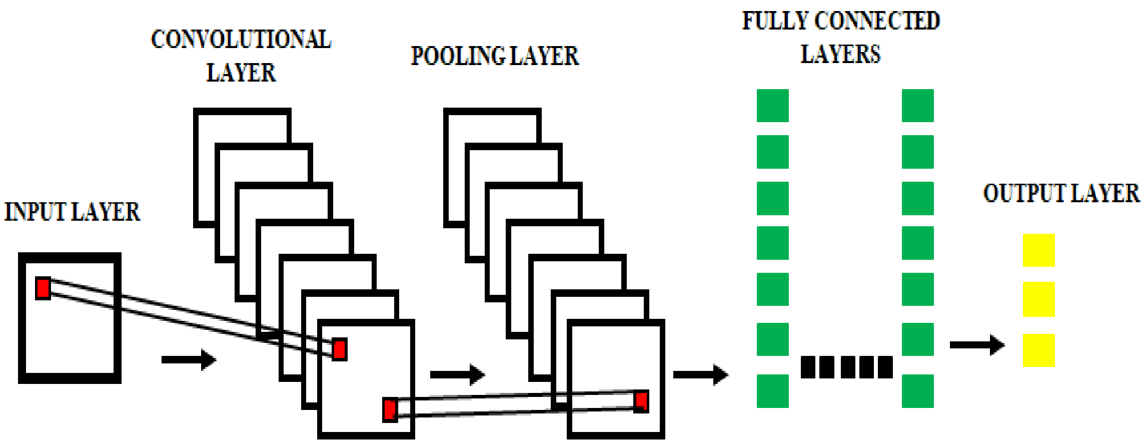

Figure 3: *Typical CNN Architecture*

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Convolutional Layer

Crucial part of CNNs are convolutional layers. The purpose of the convolution layer is to extract a feature from the input data, which is an image. For this reason, only a subset of the image is connected to the subsequent convolution layer; otherwise, the architecture would be challenging to compute. In CNN, the dot product of a particle and the receptive field constitutes the complete picture.

Pooling Layer

The pooling layer reduces the input picture dimension and controls over fitting. Mean, average, and maximum pooling are the three primary types of pooling. The primary objective of the pooling layer is to minimize the convolved feature map's size in order to reduce computation costs, whereas the average value is used in average pooling. Convolutional layers are usually followed by pooling layers to further minimize the amount of data before it is sent into an entirely connected layer.

Fully Connected layers

In a CNN, fully-connected layers are among the most fundamental kinds of layers. All of the neurons in a fully-connected layer are, as the name implies, totally linked to all of the other neurons in the layer above. Using the training data set, the final fully linked layer creates a categorized image. When the objective of a CNN is to provide predictions based on the attributes that the layers before it have acquired, fully linked layers are usually employed toward the conclusion of the network.

4 Results and Discussion

4.1 Input Dataset

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target
0	52	1	0	125	212	0	1	168	0	1.0	2	2	3	0
1	53	1	0	140	203	1	0	155	1	3.1	0	0	3	0
2	70	1	0	145	174	0	1	125	1	2.6	0	0	3	0
3	61	1	0	148	203	0	1	161	0	0.0	2	1	3	0
4	62	0	0	138	294	1	1	106	0	1.9	1	3	2	0
5	58	0	0	100	248	0	0	122	0	1.0	1	0	2	1
6	58	1	0	114	318	0	2	140	0	4.4	0	3	1	0
7	55	1	0	160	289	0	0	145	1	0.8	1	1	3	0
8	46	1	0	120	249	0	0	144	0	0.8	2	0	3	0
9	54	1	0	122	286	0	0	116	1	3.2	1	2	2	0
10	71	0	0	112	149	0	1	125	0	1.6	1	0	2	1

Figure 4: *Input dataset*

Figure 4 displays the Input Heart dataset.

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4.2 Target Distribution

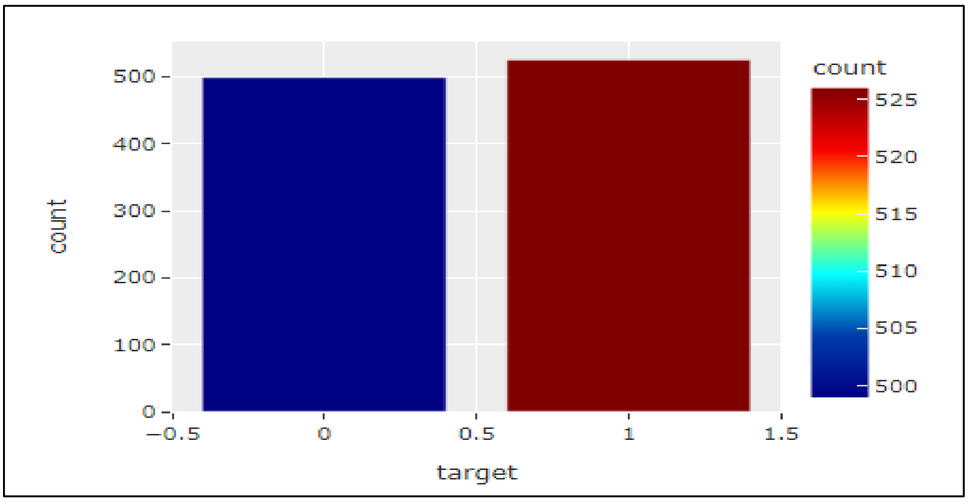

Figure 5: *Target Distribution*

Figure 5 displays the target deviation. A subset of data preparation, data preparation encompasses any kind of treating functional to unprocessed data in order to get it ready for further data processing operations. Preprocessing the data is crucial to enhancing its quality. During preprocessing, the computer receives the gathered heart datasets as input and is trained appropriately.

4.3 Data Visualization

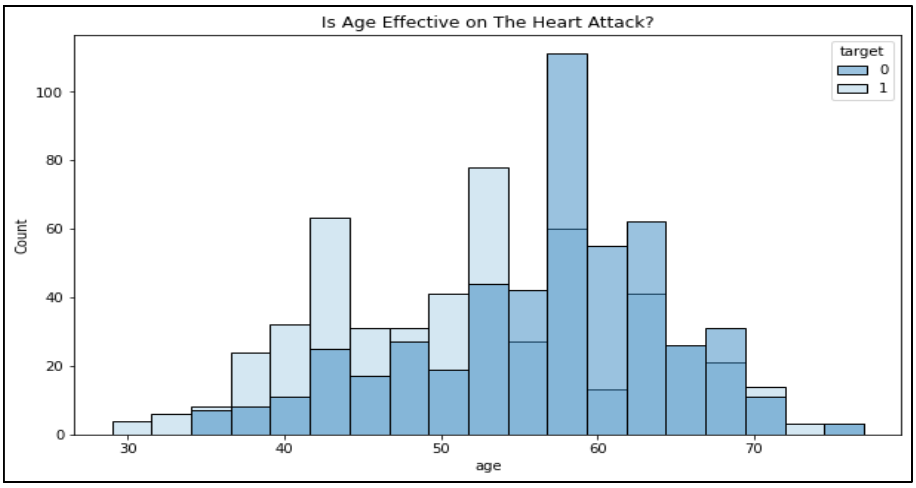

Figure 6: *Age Estimation*

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The age-based estimate of a heart attack is shown in Figure 6. Data visualization is the act of visually portraying our data to identify patterns and relationships. Making patterns, trends, and outliers in big data sets simpler to detect is the primary objective of data visualization.

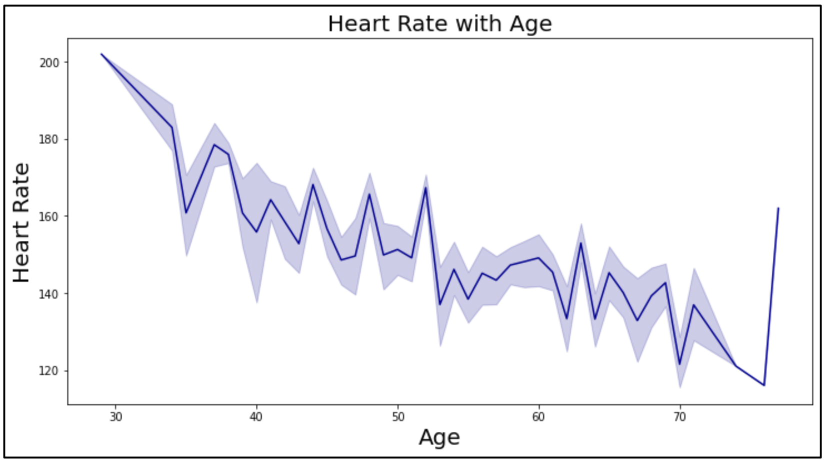

Figure 7: *Heart Rate Estimation*

Figure 7 shows how to estimate heart rate. Age-based heart rate estimate reflects the waveform above.
The above waveform is reflected by Heart Rate estimation based on age.

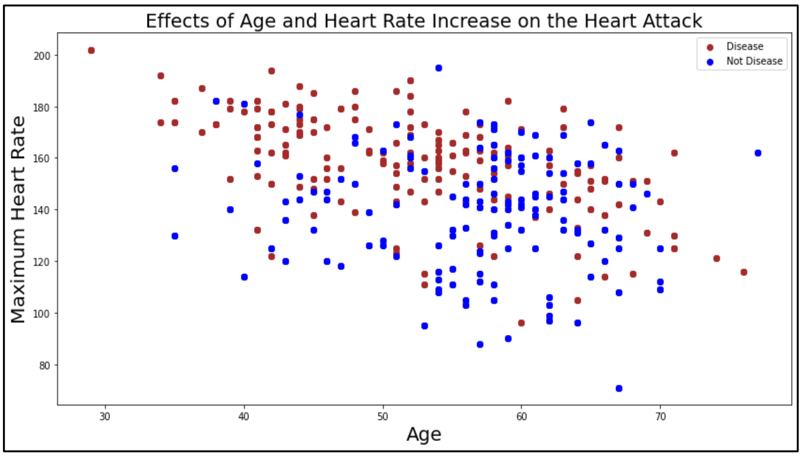

Figure 8: *Comparison of Attack and Non-Attack*

The consequences of a heart attack as a function of attack and non-attack are shown in Figure 8. The number of potential relationships between age and heart rate and illness are represented by brown color dots. The non-affected region between age and heart rate is indicated by the color blue. Based on age.

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4.4 K-Means Clustering

When determining the relevance of k-means clusters, it all boils down to how the clusters are described. A parallel coordinates plot allows us to see the locations of specific data points for each variable. By comparing the values of each variable across clusters, we may ascertain what each cluster represents. Figure 9 displays the data clustering process using the K-means algorithm.

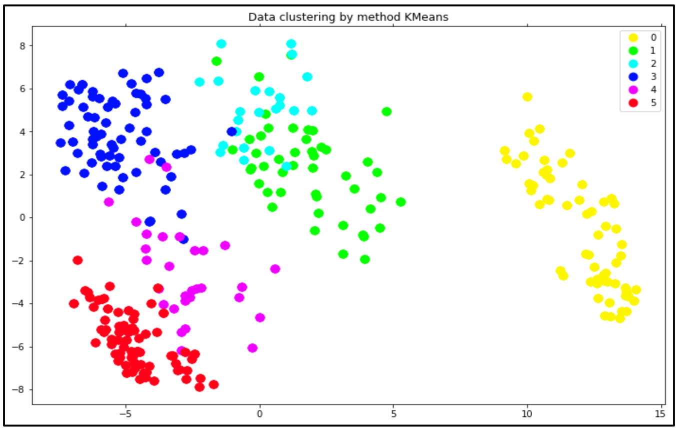

Figure 9: *Data clustering by method K-means*

CNN Classifier

The CNN-based classification procedure consists of training and testing phases. With terms like "oil spill" and "non-spill," the large number of images is divided into several groups. It's has three hidden layers. The test picture is sent into the pre-trained neural network, which uses it as a benchmark to classify the input image. Figure 9 shows the accuracy document for the CNN classifier.

```
....
Epoch 48/50
26/26 [==============================] - 1s 24ms/step - loss: 0.0071 - accuracy: 0.9976 - val_loss: 0.5532 - val_accuracy: 0.
9707
Epoch 49/50
26/26 [==============================] - 1s 22ms/step - loss: 0.0130 - accuracy: 0.9963 - val_loss: 0.5143 - val_accuracy: 0.
9707
Epoch 50/50
26/26 [==============================] - 1s 23ms/step - loss: 0.0059 - accuracy: 0.9976 - val_loss: 0.5066 - val_accuracy: 0.
9707
```

Figure 10: *Classifier-CNN*

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4.4.1 Performance Matrix for CNN

The values of recall (RE), F1 score, and precision (PR) are determined using the logistic regression classification method. Figure 11 shows the CNN performance matrix.

```
Accuracy: 97.07%
Recall: 94.17%
Precision: 100.00%
F1-Score: 97.00%
time to train: 31.18 s
time to predict: 5.00 s
total: 36.18 s
```

Figure 11: *Performance matrix for CNN*

4.4.2 Confusion Matrix for CNN

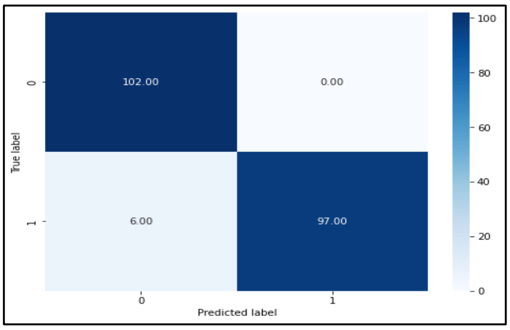

Figure 12: *Confusion Matrix for CNN*

The CNN confusion matrix is displayed in Figure 12. A confusion matrix, or 2x2 table that contrasts the model's predicted values with the test dataset's actual values, is a popular tool for assessing the accuracy of a logistic regression model.

4.4.3 ROC Curve for CNN

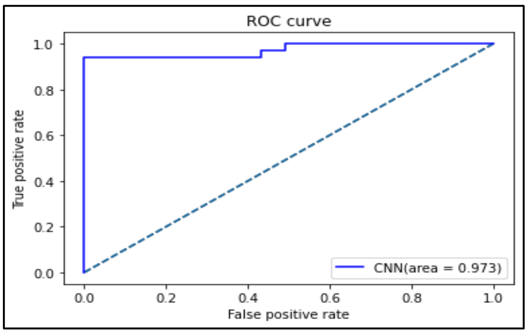

Figure 13: *ROC Curve for CNN*

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In figure 13, the CNN ROC curve is displayed. A graph that shows a classification model's performance over all classification levels is called a receiver functioning distinguishing curve, or ROC curve. It shows a curve representing two parameters: Real Positive Ratio. False positive rate.

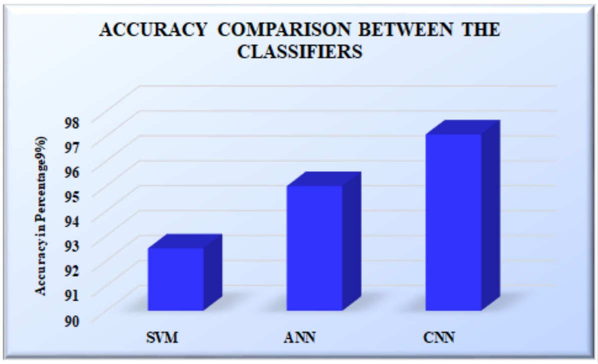

Figure 14: *Accuracy Comparison*

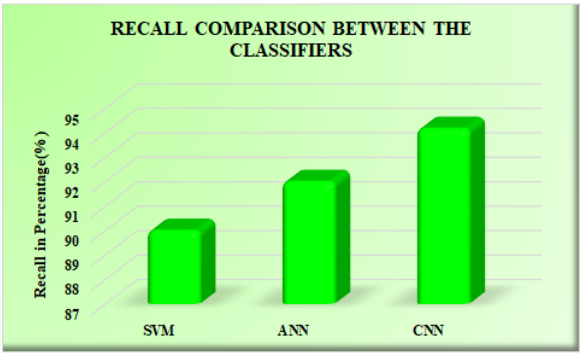

Figure 15: *Recall Comparison*

Fig. 14 presents the Accuracy Comparison of the Classification values, which are 92.5, 95%, and 97.7% for the SVM, ANN, and CNN Classifiers, respectively.

Fig. 15 presents the Recall Comparison of the Classification values, which are 90%, 92%, and 94.17% for the SVM, ANN, and CNN Classifiers, respectively.

5 Conclusion

In order to forecast cardiac illness, this research suggests using a CNN built on a deep learning algorithm. The F1 score, specificity, sensitivity, accuracy, and confusion matrix are the approaches that are compared. In this project, the CNN classification algorithms function admirably. Finally, assess how successful the categorization strategies were by analyzing the comparison. The findings suggest that another method for identifying potential future disruption-causing assaults is deep learning. CNN has an accuracy of 97.7% and a Recall comparison of 94.17% respectively.

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