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IJIEMR Transactions, online available on 04th May 2024. Link
https://www.ijiemr.org/downloads/Volume-13/ISSUE-5

10.48047/IJIEMR/V13/ISSUE 05/13

TITLE: DETECTION OF CARDIOVASCULAR DISEASES IN ECG IMAGES USING MACHINE LEARNING AND DEEP LEARNING METHODS

Volume 13, ISSUE 05, Pages: 120-134

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DETECTION OF CARDIOVASCULAR DISEASES IN ECG IMAGES USING MACHINE LEARNING AND DEEP LEARNING METHODS

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Abstract - This study is mostly about cardiovascular illnesses, especially heart problems, which are a major cause of death around the world. It is important to make accurate predictions on time, and the Electrocardiogram (ECG), which is a cheap and painless tool, is a key part of keeping an eye on heart activity. This project uses a special type of neural network (CNN) design and deep learning methods, like transfer learning from neural networks like Squeeze Net and Alex Net, to make predictions more accurate. The goal of these methods is to find four serious heart problems: an irregular heartbeat, a myocardial infarction, a history of a myocardial infarction, and cases that are normal. The model is one of a kind because it works so well. It does this by using both deep learning and regular machine learning methods to pull out important traits. This study shows how artificial intelligence has changed healthcare by making it much easier to predict medical conditions through picture analysis.

Keywords: *- Cardiovascular diseases, Heart conditions, Mortality, Timely prediction, Electrocardiogram (ECG), Deep learning, Transfer learning, Neural networks, Squeeze Net, Alex Net.*

I. INTRODUCTION

Circulatory disorders, such heart disease, kill the most people worldwide, according to the WHO. To preserve lives, cardiovascular problems must be diagnosed immediately. Early detection of cardiac issues improves patient outcomes by increasing treatment and health chances. Healthcare uses many approaches to diagnose heart disease. EKG, echocardiography, cardiac magnetic resonance imaging, computed tomography, and blood tests are examples. Common and safest is the electrocardiogram (ECG). It monitors and studies cardiac electrical activity. Healthcare professionals may utilize this information to diagnose cardiac issues. Machine learning and deep learning can rapidly detect cardiac diseases, according to the initiative. Patients benefit from fewer errors and faster, more accurate assessments.

In According to the American Heart Monitoring Organization and CDC, heart disease kills most people [1]. According to the CDC, 74% of Americans have heart disease annually. Early detection may prevent cardiovascular disease [2]. Medical research has provided powerful heart disease treatments. Coronavirus appeared in Wuhan, China, in December 2019. WHO declared this illness an emergency in January 2020. WHO renamed it COVID-19 in February 2020. A global pandemic was declared in March 2020 (Kim, 2021; Zhu et al., 2020). Global cases, illnesses, and fatalities fluctuated throughout the epidemic. The US, Italy, and Spain were substantially affected (Ceylan, 2021). COVID-19's rapid proliferation matters most. Viruses propagate easily.[3] The information age generates massive volumes of raw data from computer-aided systems, strengthening the new center of power. Practitioners struggle to utilize this data. Advanced statistical approaches may be applied with data mining, AI, machine learning, and deep learning, promising new technologies for detecting connections or valuable databases. The new and rising subject of medical data mining and knowledge discovery attracts many professionals. [2]

II. LITERATURE SURVEY

This research examines machine learning (ML) models for heart disease detection using ECG data. Support vector machine, logistic regression, and adaptive boosting were employed on unbalanced datasets. AdaBoost and LR excelled. A majority-voted aggregate of these models outperformed the individual models. They scored 0.946 for accuracy, 0.949 for F1-score, and 0.951 for AUC on PTB-ECG data and 0.921, 0.926, and 0.950 on MIT-BIH data. The recommended technique can categorize HD using other physical indications and may detect other disorders.Early heart disease detection saves lives. Because traditional approaches typically fail, a new paradigm is needed. SWCA-based DRN employs the water cycle algorithm and social optimization algorithm to improve identification. Preprocessing and feature merging using an RV coefficient-enabled Rider Optimization Algorithm-based Neural Network precede DRN classifier heart disease classification. SWCA runs the DRN better than other techniques, with accuracy, sensitivity, and specificity of 0.941, 0.954, and 0.925. This innovative method may help detect heart trouble early. [2]

This article emphasizes the need of understanding clinical facts concerning heart disease, the leading cause of mortality worldwide. The trial evaluation employs the Cleveland heart disease dataset, eleven feature selection techniques, and six classification systems. Backward feature selection yields the greatest decision tree classifier classification (88.52%). Accuracy is 91.30%, sensitivity 80.76%, and f-measure 85.71%. This research reveals how crucial strong characteristics are for heart disease prediction. Scientific instruments and healthcare systems benefit from it.[3]

March 2020 saw the WHO declare the COVID-19 pandemic. Countries reacted differently to altering case numbers. Many viruses are found using PCR assays. Instead, X-ray images may be employed with AI, specifically genetic algorithm-based Xception-based neural networks. Deep learning and convolutional neural networks helped this new approach recognize COVID-19 from X-rays. With 0.996, 0.989, and 0.924 for two-, three-, and four-class datasets, respectively, the findings outperform existing networks and studies. This suggests AI has great potential in medical research.[4]

Muzammil Hussain and Muhammad Kamran Malik's research examines global cardiac disease prevalence and emphasizes ECG testing for early detection. Their work recommends a uniform approach to ECG picture kinds from multiple medical equipment. Single Shot Detection (SSD) MobileNet v2-based Deep Neural Networks detect myocardial infarction and irregular heartbeats with 98% accuracy in the research. A examination of 11,148 hand-marked 12-lead ECG images reveals that the technique works, as certified by cardiologists. It may be a reliable cardiac screening technique. [5]

III. METHODOLOGY

Modules:

- Importing the packages
- Exploring the dataset - ECG Image Data
- Image processing
- Feature Extraction of Image - Squeeze Net, Alex Net, CNN
- Training and Building the model
- Trained model is used for prediction
- Final outcome is displayed through front-end

A) System Architecture

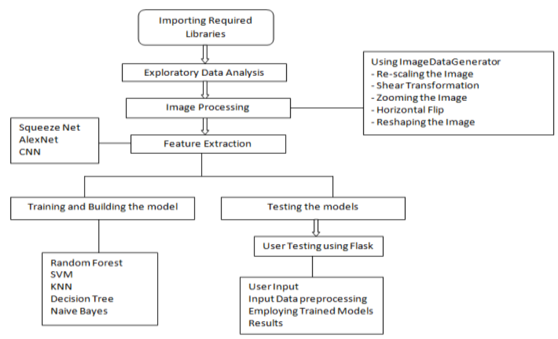

Fig 1: System Architecture

Proposed work

The suggested model for predicting cardiovascular disease includes a full system for importing data, exploring datasets, processing images, and using deep learning-based models like Squeeze Net, CNN, and CNN to extract features. This new method is combined with more standard machine learning techniques for sorting, with the goal of making predictions more accurate in healthcare settings. Notably, the model uses Xception, a cutting-edge deep learning system that Google created. Xception, which comes from "Extreme Inception," builds on the Inception design and is very good at jobs that require picture identification. Xception is unique because it uses depth-wise separable convolutions. It applies depth-wise convolutions to each channel separately before mixing the results with point-wise convolutions. This makes the computations simpler and improves network performance. Thanks to its one-of-a-kind method, Xception has become a popular, accurate, and

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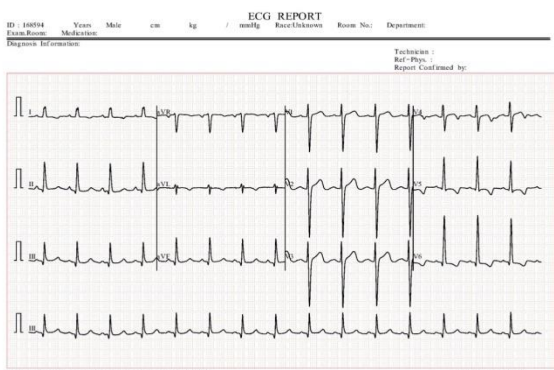
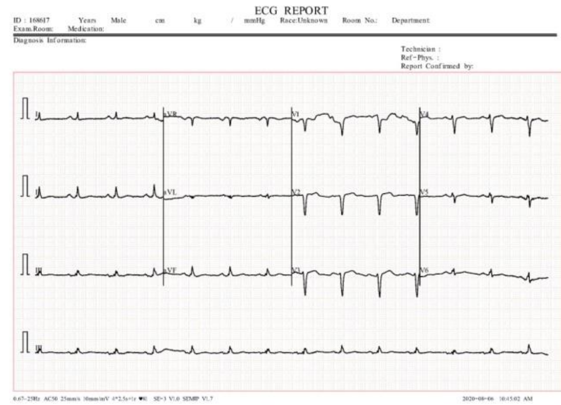
flexible answer in the field of deep learning for computer vision applications.

B) Dataset Collection

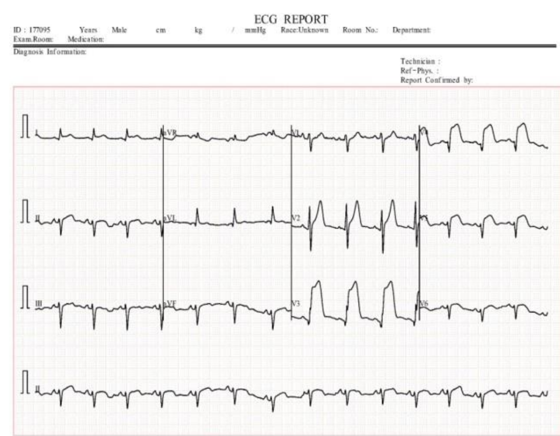
The ECG Image Dataset is a huge collection of pictures that show the complicated electrical activity of the heart. It is an important part of both diagnosing problems and doing cutting edge research. These pictures are very helpful for doctors and experts because they help them identify and study many heart diseases. They give them important information about the heart's health.



Each picture in the collection shows the changing patterns of electrical signals going through the heart. This makes it possible to find problems like arrhythmias, ischemia, and other heart problems. This large and varied dataset includes a lot of different heart-related conditions, which helps us get a better sense of how complicated cardiovascular health really is.



The ECG Image Dataset is also a key part of the process of creating machine learning methods that will help computers make diagnoses. The use of advanced computing methods unlocks the wealth of information hidden in these pictures, allowing artificial intelligence systems to pick out small details and trends that point to different heart problems. This means that the information not only helps to make medical processes more accurate and efficient, but it also pushes the boundaries of cardiac study, leading to improvements in heart health.



C) Pre-processing

Computer vision needs to process images and pull out features. For these tasks, deep learning models like Squeeze Net, Alex Net, and Convolutional Neural Networks (CNNs) have been used a lot.

Convolutional Neural Networks (CNNs):

CNNs, a form of deep neural network, are excellent at picture interpretation. They have fully connected, convolutional, and pooling layers. CNNs organically and adaptably arrange visual features by space. Layer every layer reveals increasingly complex features.

Alex Net:

Alex Net, a deep convolutional neural network, organizes photos. It won the 2012 Image Net Large Scale Visual Recognition Challenge, proving deep learning works for computer vision. Three completely connected and five convolutional layers make up Alex Net. It made deep neural networks better at image-related tasks.

Squeeze Net:

Squeeze Net is a lighter convolutional neural network that is made to be very accurate with fewer parameters. It cuts down on the number of factors in the network while keeping speed high by using a "fire module" structure. SqueezeNet works best when there aren't a lot of computing resources available, which means it can be used for real-time tasks on machines with less working power.

Feature Extraction:

One of the most important steps in picture processing and computer vision is feature extraction. It includes taking raw picture data and turning it into a form that can be used for a certain job. When CNNs and deep learning are used, feature extraction is done naturally as the machine learns.

A lot of the work that goes into CNNs like Alex Net and Squeeze Net is done by the convolutional layers. These layers add filters to the picture that come in and pick out lines, patterns, shapes, and other details. The network's higher levels can pick up on more general and complicated traits, which makes them good for jobs like picture recognition, object spotting, and segmentation.

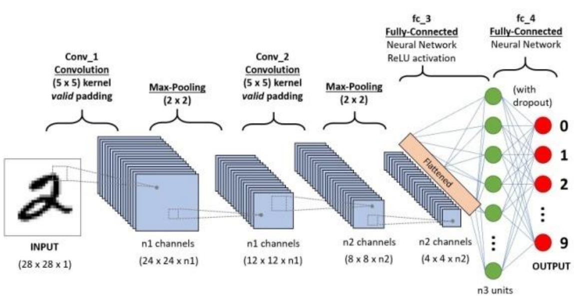
D) Training & Testing

After extracting features, the next step in the project is to train machine learning models that are specifically designed to predict heart problems. One important step to improve the project's effectiveness is to use transfer learning methods. Using deep learning models that have already been trained is part of this strategy. This saves time and resources that would otherwise be used to train models from scratch. This combination makes the models much better at accurately classifying things. Our machine learning models will be trained to find complex data patterns and connections hidden in the pictures using the images that have already been pulled and preprocessed. After that, their work will be carefully checked on a separate test set. We will use evaluation tools like accuracy, precision, recall, and F1-score to see how well the models can do in real-life picture recognition tasks. As an addition to the project, a Flask-based website that is easy to use and includes login features has also been created. This frontend makes it easy to work with the models, which makes the user experience smooth and keeps data safe. The project's dedication to accurate prediction of heart abnormalities and ease of use is shown by its all-encompassing method, which includes transfer learning and an easy-to-use interface.

E) Algorithms.

CNN (Convolutional Neural Network):

CNNs are a type of deep learning system used for recognizing images. They use convolutional layers to learn hierarchical patterns from the data they are given. CNNs are very good at finding patterns in space and have changed the way images are analyzed, giving us cutting-edge results in many areas of computer vision.



SqueezeNet:

SqueezeNet is a small deep learning framework that is made to make the best use of model space and computing resources. It uses fire modules with a squeeze layer to lower the number of dimensions and an expand layer to get complex feature extraction. SqueezeNet is good for settings with limited resources because it is very accurate with a lot fewer factors.

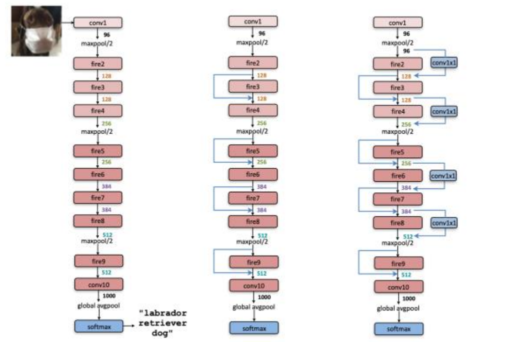
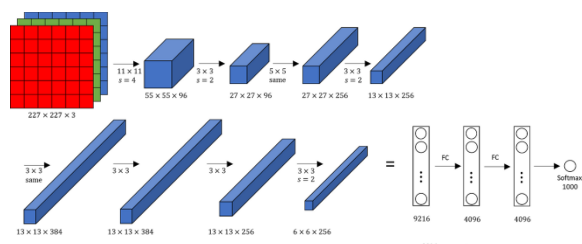


Figure 2: Macroarchitectural view of our SqueezeNet architecture. Left: SqueezeNet (Section 3.3); Middle: SqueezeNet with simple bypass (Section 6); Right: SqueezeNet with complex bypass (Section 6).

AlexNet:

AlexNet, a groundbreaking deep convolutional neural network, became well known when it won the 2012 ImageNet Large Scale Visual Recognition Challenge. It brought the idea of deep learning to the public eye and was created by Alex Krizhevsky. AlexNet uses convolutional and pooling layers to pull out hierarchical features. This shows that deep neural networks are good at classifying images.



Random Forest:

The Random Forest method uses groups of neurons to learn how to classify, predict, and do other things. It takes predictions from several decision trees and combines them to make the total accuracy and generalization better. Random Forest prevents overfitting and makes accurate predictions by adding chance to the tree building process. It's known for

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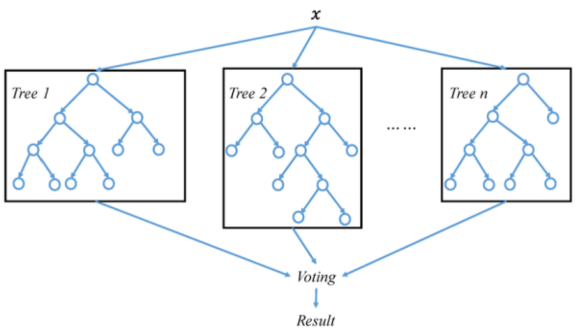
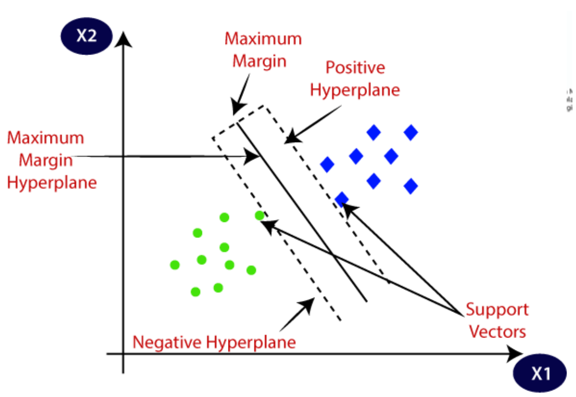
being flexible and able to handle large numbers. It's used in many different fields.



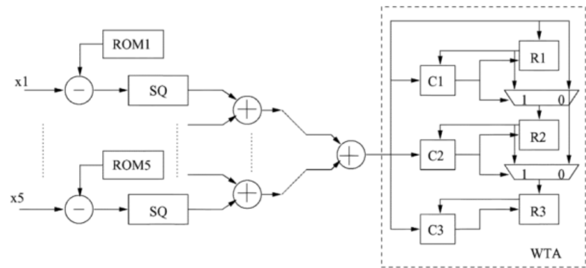
SVM (Support Vector Machine):

SVM is a method for machine learning that is used for jobs like regression and classification. It finds the best hyperplane that divides classes in a feature space as much as possible. SVMs work well in places with a lot of dimensions, and the support vectors they use make sure that decision limits are strong. SVMs are known for being flexible and having a strong theoretical base. They are used a lot in biology, picture recognition, and text classification.



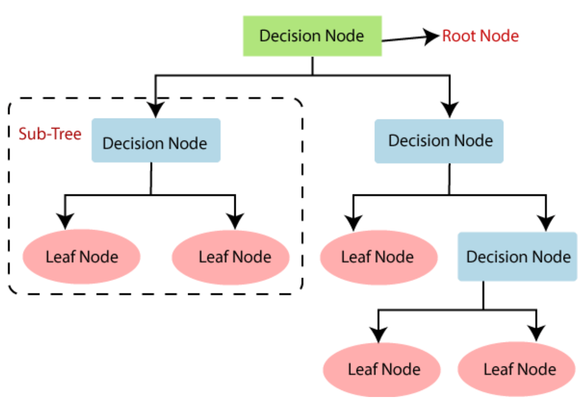
KNN (K-Nearest Neighbors):

There is a simple machine learning method called KNN that can be used for both classification and regression. It sorts data points into groups based on which group their k close neighbors in feature space are most likely to be in. KNN is not parametric, so it doesn't make many assumptions about how the data is distributed. It's easy to set up and can be used for many things, like pattern recognition and suggestion systems, but it is sensitive to extremes.



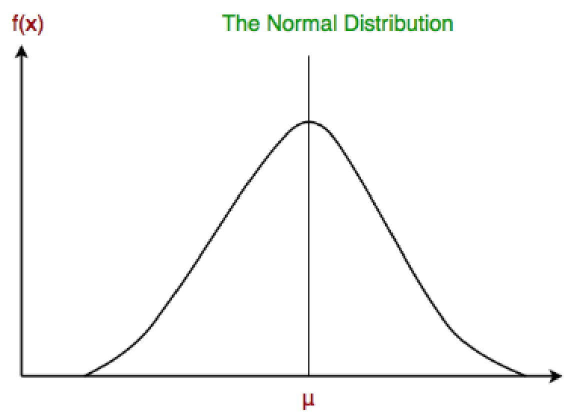
Decision Tree:

There is a type of machine learning called "decision trees" that are used for classification and regression. It splits data over and over again based on feature values, making a tree-like structure of decision nodes. Every leaf branch is a class or a regression number. It is easy to understand and model decision trees, and they work even when the data is confusing. They are what group methods like Random Forests are built on.



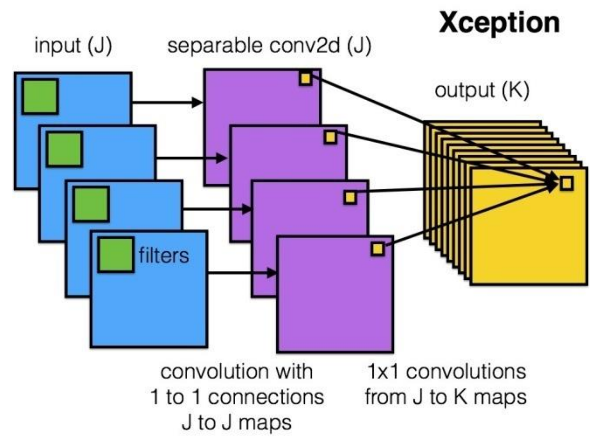
Naive Bayes:

Bayes' theorem is at the heart of Naive Bayes, a statistical machine learning method. Even though it is based on simple ideas (like the idea that traits are independent), it does well at sorting tasks. Naive Bayes figures out the chances of each class based on the traits that are fed into it. It is often used for text sorting and spam screening. Because it is quick and easy to use, it can be used in real time and when training data is restricted.



Extension xception:

As an add-on to the project we worked on, we made the Xception model. Xception, which stands for "Extreme Inception," is a deep learning design made by Google that is especially good at recognizing images. It's known for its fast depth-wise separable convolutions, which cut down on processing while speeding things up. Xception is a big step forward in computer vision deep learning because it is very reliable and can be used in many different ways. We used xception algorithm to get features and make prediction models for our project.



IV. EXPERIMENTAL RESULTS

A) Comparison Graphs → Accuracy, Precision, Recall, f1 score

Accuracy: correctness of a test is how well it can tell the difference between weak and strong examples. To figure out how accurate a test is, we should keep track of the very small number of real positive and negative results in all cases that were looked at. This could be shown with numbers as:

Accuracy = TP + TN TP + TN + FP + FN.

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

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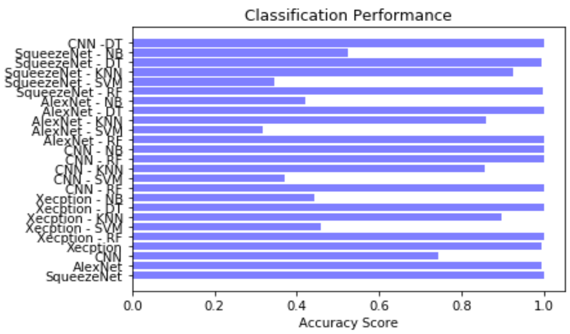

Fig 2: Accuracy Graph

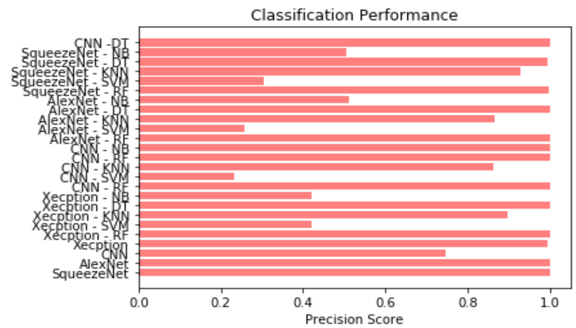

Fig 3: Precision Score Graph

ML Model	Accuracy
SqueezeNet	1
AlexNet	0.995
CNN	0.743
Xecption	0.995
Xecption - RF	1
Xecption - SVM	0.459
Xecption - KNN	0.896
Xecption - DT	1
Xecption - NB	0.444
CNN - RF	1
CNN - SVM	0.37
CNN - KNN	0.858
CNN - RF	1
CNN - NB	1
AlexNet - RF	1
AlexNet - SVM	0.317
AlexNet - KNN	0.861
AlexNet - DT	1
AlexNet - NB	0.42
SqueezeNet - RF	0.998
SqueezeNet - SVM	0.346
SqueezeNet - KNN	0.927
SqueezeNet - DT	0.994
SqueezeNet - NB	0.525
CNN -DT	1

ML Model	Precision
SqueezeNet	1
AlexNet	1
CNN	0.747
Xecption	0.995
Xecption - RF	1
Xecption - SVM	0.421
Xecption - KNN	0.899
Xecption - DT	1
Xecption - NB	0.421
CNN - RF	1
CNN - SVM	0.232
CNN - KNN	0.862
CNN - RF	1
CNN - NB	1
AlexNet - RF	1
AlexNet - SVM	0.257
AlexNet - KNN	0.865
AlexNet - DT	1
AlexNet - NB	0.513
SqueezeNet - RF	0.998
SqueezeNet - SVM	0.305
SqueezeNet - KNN	0.928
SqueezeNet - DT	0.994
SqueezeNet - NB	0.504
CNN -DT	1

Precision: Precision is the percentage of correctly classified events or samples that are among the hits. So, the following method can be used to figure out the accuracy:

Precision = True positives/ (True positives + False positives) = TP/ (TP + FP)

$$\text{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

Recall: Recall is a machine learning variable that measures how well a model can recognize all relevant examples of a certain class. It's the percentage of expected positive feelings that turn out to be real positive feelings. This tells us how well a model can catch instances of a certain class.

$$Recall = \frac{TP}{TP + FN}$$

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Fig 4: Recall Score Graph

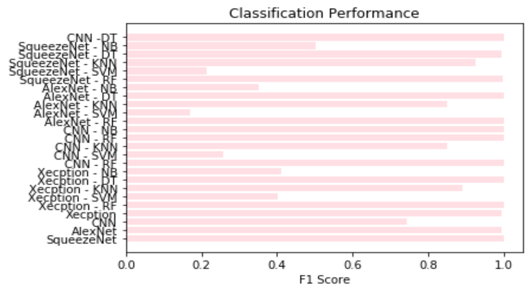

Fig 5: F1 Score Graph

ML Model	Recall
SqueezeNet	1
AlexNet	0.99
CNN	0.742
Xecption	0.995
Xecption - RF	1
Xecption - SVM	0.459
Xecption - KNN	0.896
Xecption - DT	1
Xecption - NB	0.444
CNN - RF	1
CNN - SVM	0.37
CNN - KNN	0.858
CNN - RF	1
CNN - NB	1
AlexNet - RF	1
AlexNet - SVM	0.317
AlexNet - KNN	0.861
AlexNet - DT	1
AlexNet - NB	0.42
SqueezeNet - RF	0.998
SqueezeNet - SVM	0.346
SqueezeNet - KNN	0.927
SqueezeNet - DT	0.994
SqueezeNet - NB	0.525
CNN -DT	1

ML Model	F1_score
SqueezeNet	1
AlexNet	0.995
CNN	0.745
Xecption	0.995
Xecption - RF	1
Xecption - SVM	0.403
Xecption - KNN	0.892
Xecption - DT	1
Xecption - NB	0.411
CNN - RF	1
CNN - SVM	0.259
CNN - KNN	0.85
CNN - RF	1
CNN - NB	1
AlexNet - RF	1
AlexNet - SVM	0.169
AlexNet - KNN	0.85
AlexNet - DT	1
AlexNet - NB	0.352
SqueezeNet - RF	0.998
SqueezeNet - SVM	0.215
SqueezeNet - KNN	0.925
SqueezeNet - DT	0.994
SqueezeNet - NB	0.503
CNN -DT	1

F1-Score: There is a machine learning rating tool called the F1 score that measures how accurate a model is. It adds up the accuracy and review scores of a model. The accuracy measurement figures out how often, across the whole collection, a model correctly predicted what would happen.

$$\textbf{F1 Score} = \frac{2}{\left(\frac{1}{\text{Precision}} + \frac{1}{\text{Recall}}\right)}$$

$$\textbf{F1 Score} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

B) Performance Evaluation table.

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ML Model	Accuracy	Precision	Recall	F1_score
SqueezeNet	1	1	1	1
AlexNet	0.995	1	0.99	0.995
CNN	0.743	0.747	0.742	0.745
Xecption	0.995	0.995	0.995	0.995
Xecption - RF	1	1	1	1
Xecption - SVM	0.459	0.421	0.459	0.403
Xecption - KNN	0.896	0.899	0.896	0.892
Xecption - DT	1	1	1	1
Xecption - NB	0.444	0.421	0.444	0.411
CNN - RF	1	1	1	1
CNN - SVM	0.37	0.232	0.37	0.259
CNN - KNN	0.858	0.862	0.858	0.85
CNN - RF	1	1	1	1
CNN - NB	1	1	1	1
AlexNet - RF	1	1	1	1
AlexNet - SVM	0.317	0.257	0.317	0.169
AlexNet - KNN	0.861	0.865	0.861	0.85
AlexNet - DT	1	1	1	1
AlexNet - NB	0.42	0.513	0.42	0.352
SqueezeNet - RF	0.998	0.998	0.998	0.998
SqueezeNet - SVM	0.346	0.305	0.346	0.215
SqueezeNet - KNN	0.927	0.928	0.927	0.925
SqueezeNet - DT	0.994	0.994	0.994	0.994
SqueezeNet - NB	0.525	0.504	0.525	0.503
CNN -DT	1	1	1	1

Fig 6: Performance Evaluation Table

C) Frontend

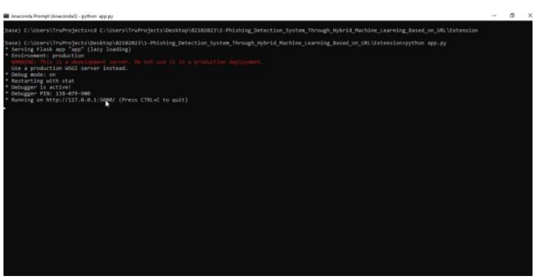

Fig 7: Url Link to Web Page

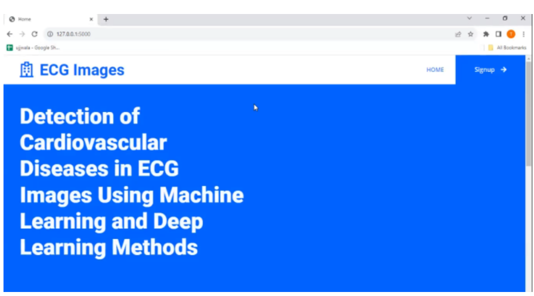

Fig 8: Home page

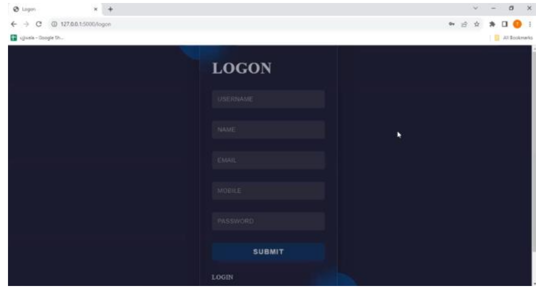

Fig 9: User Signup page

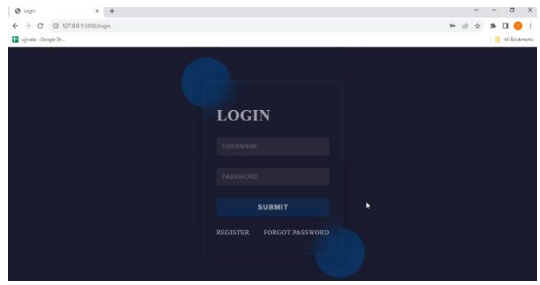

Fig 10: User Sign in Page

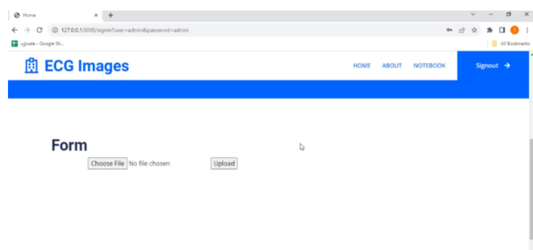

Fig 11: Enter Data

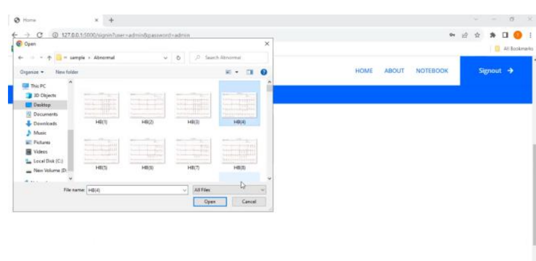

Fig 12: Sample data for testing

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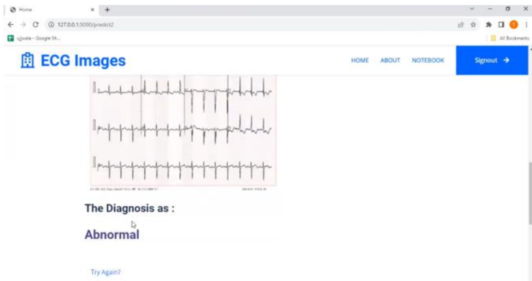

Fig 13: Result: Abnormal

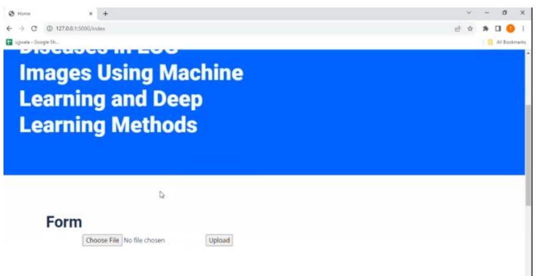

Fig 14: Enter New Data

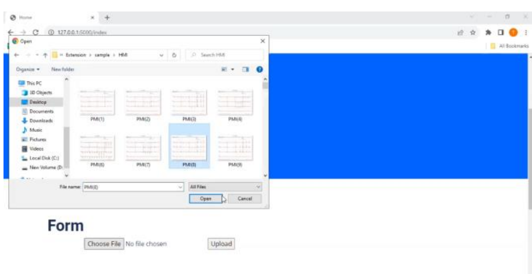

Fig 15: Sample data for testing

Fig 16: Result: HMI

V. CONCLUSION

In conclusion, combining deep learning methods, especially transfer learning from well-known neural networks like SqueezeNet and AlexNet, with a unique Convolutional Neural Network (CNN) architecture is a revolutionary way to improve the accuracy of Electrocardiogram (ECG) data-based predictions of cardiovascular disease. The suggested model does a great job of finding heart problems early by focusing on four main ones: an irregular heartbeat, a myocardial infarction, a history of a myocardial infarction, and normal cases. The new way the project is doing things uses artificial intelligence to pull out important details from ECG pictures. When these details are combined with regular machine learning methods, the results are better. This working together improves not only the accuracy of predictions but also a cheap and painless way to keep an eye on heart problems, which is a worldwide health issue. The data show that artificial intelligence is definitely changing the way healthcare is done, especially when it comes to predicting heart disease. The suggested model not only improves the skills of medical imaging, but it also shows how important it is to use cutting-edge technology to solve important health problems. The world still has problems with circulatory diseases, but this study opens the door to better and faster testing tools that will save lives and change the way healthcare is provided.

VI. FUTURE SCOPE

Future study could focus on fine-tuning the proposed CNN model's hyperparameters to make it work even better. The model can be made more accurate and useful by changing things like learning rates, batch sizes, and loss rates in a planned way. Adding the CNN model to the Industrial Internet of Things (IIoT) opens up a lot of interesting options. The model can be used for more than just predicting cardiovascular disease. It can also be changed to do different classification jobs in IIoT applications, like finding problems in industrial equipment or checking the quality of manufacturing processes. Performance can be improved by adding more layers or trying out different network designs. More convolutional or recurrent layers could be added by researchers, or even new network designs could be looked into to make the CNN model even better at finding cardiovascular diseases. The method can be made more useful by allowing for bigger and more varied information. To make sure the model can be used for a wide range of cardiovascular diseases and patient traits, this increase should include data from a number of different sources and groups.

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