Automatic Quality Assessment of Echocardiograms Using Convolutional Neural Networks: Feasibility on the Apical Four-chamber View

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Abstract

Neural network has been evolving day by day with many features. The core of the neural network lies in the interaction between the neurons in the hidden layer. The neurons interact with each other by considering the weights between them. This results in the output of the system. There are many applications in which neural network can be practiced. This paper proposes Convolutional Neural Networks in medical science. It focuses on echocardiography. The term echocardiography means that the internal structure of a patient's heart is studied through the images. The ultrasound waves create these images. The abnormalities in these images are found through echo.

The motive of this work is to decrease the overhead of the cardiologist. This approach will result in pointing the abnormality in the heart. Since, cardiologist and less experienced surgeons may take a while to figure out the defect or may miss the defect in the heart. This approach considers the view of apical four-chamber (A4C) which considers 4 chambers of heart. This is a powerful approach which can detect even a little defect in heart which human eye tends to ignore.

Keywords: Convolutional neural network, Deep learning, Quality assessment, Apical four-chamber, Echocardiography.

Introduction

Data mining has been gaining number of eye consideration in the past decades. Data mining has proved to be very effective in many fields. This paper focuses on a very popular field i.e. healthcare field where data mining has served many applications. One of the applications in healthcare field is predicting the disease through some parameters which will be useful in decision making before diagnosis. This can save a good amount of life since the decision to be taken for diagnosis should be fast. But what if the decision in incorrect and contain some error?

This kind of false decision for diagnosis can take a life out of a person. To avoid such kind of risk it is need to make a system which can be reliable and in which the doctor can easily trust. This paper has focused on echocardiography where the decision is to detect the defect in the four chambers of heart quick and this paper proposes Convolutional Neural Network.

The accuracy of estimations of chamber volumes, function and ejection fraction in 2D echo views, such as the A4C view, depends on the quality of the acquired cine. To assist the sonographer in acquiring optimal views, several research groups have made notable efforts in producing real time feedback to the operator regarding image quality. A set of studies have attempted to detect shadows and aperture blockage in echo images. Several groups have proposed content-based cardiac interview classification techniques using machine learning and statistical approaches as well as low-level features. However, intra-view quality analysis of echo is a much more challenging problem, as there is relatively higher correlation between the visual content of the different echo images that need scoring. System framework incorporates a regression model, based on hierarchical features extracted automatically from echo images, which relates images to a quality score determined by an expert cardiologist.

HEART disease is the main cause of premature death worldwide. 2D echocardiography (echo) is a non-invasive, low-cost, portable, and accessible imaging technology that allows diagnosis of various cardiac conditions, risk stratification, and prognostication with minimal risk. Echo provides an excellent assessment of structure and function.

Echocardiography can be performed with several different techniques, among which transthoracic echocardiography (TTE) is the most common. In TTE, images are obtained from different probe positions, which can be grouped into four main categories, i.e. parasternal, apical, subcostal and suprasternal.

The motive of this work is to decrease the overhead of the cardiologist. This approach will result in pointing the abnormality in the heart using Convolutional Neural Network. Since, cardiologist and less experienced surgeons may take a while to figure out the defect or may miss the defect in the heart. This approach considers the view of apical four-chamber (A4C) which considers 4 chambers of heart. This is a powerful approach which can detect even a little defect in heart which human eye tends to ignore.

System design:

Class diagram

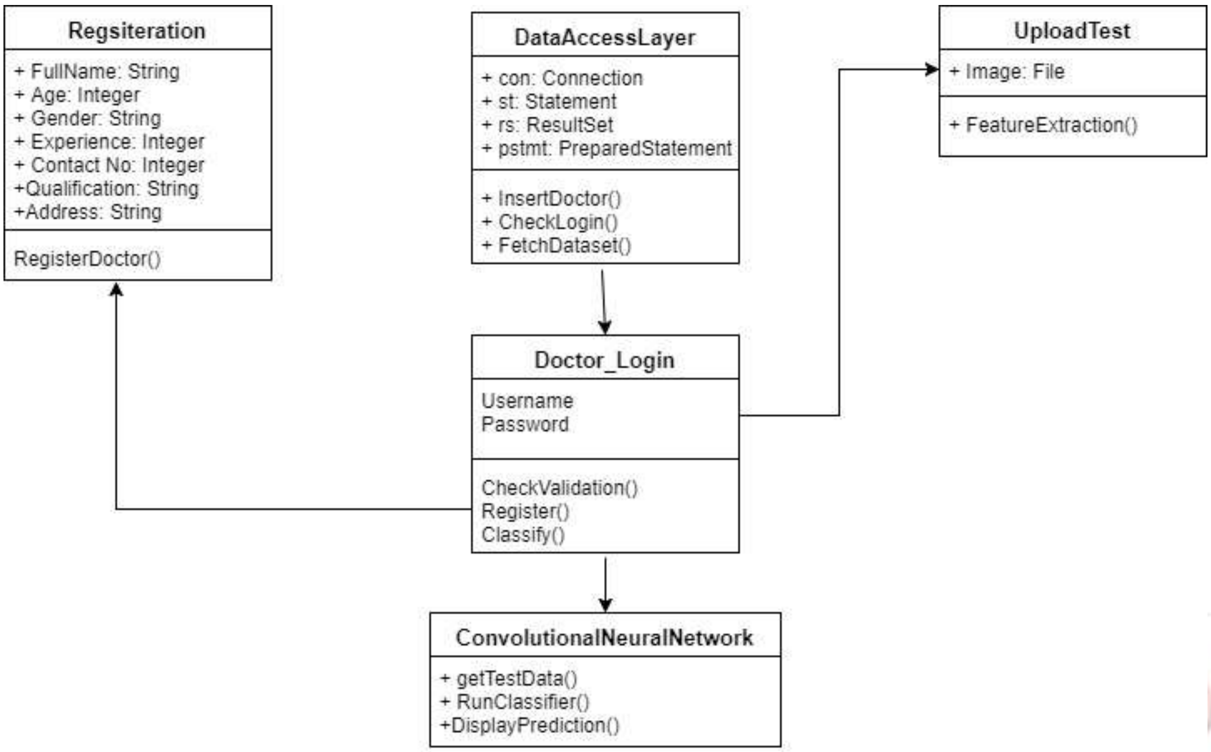

Fig Class Diagram

Sequence diagram:-

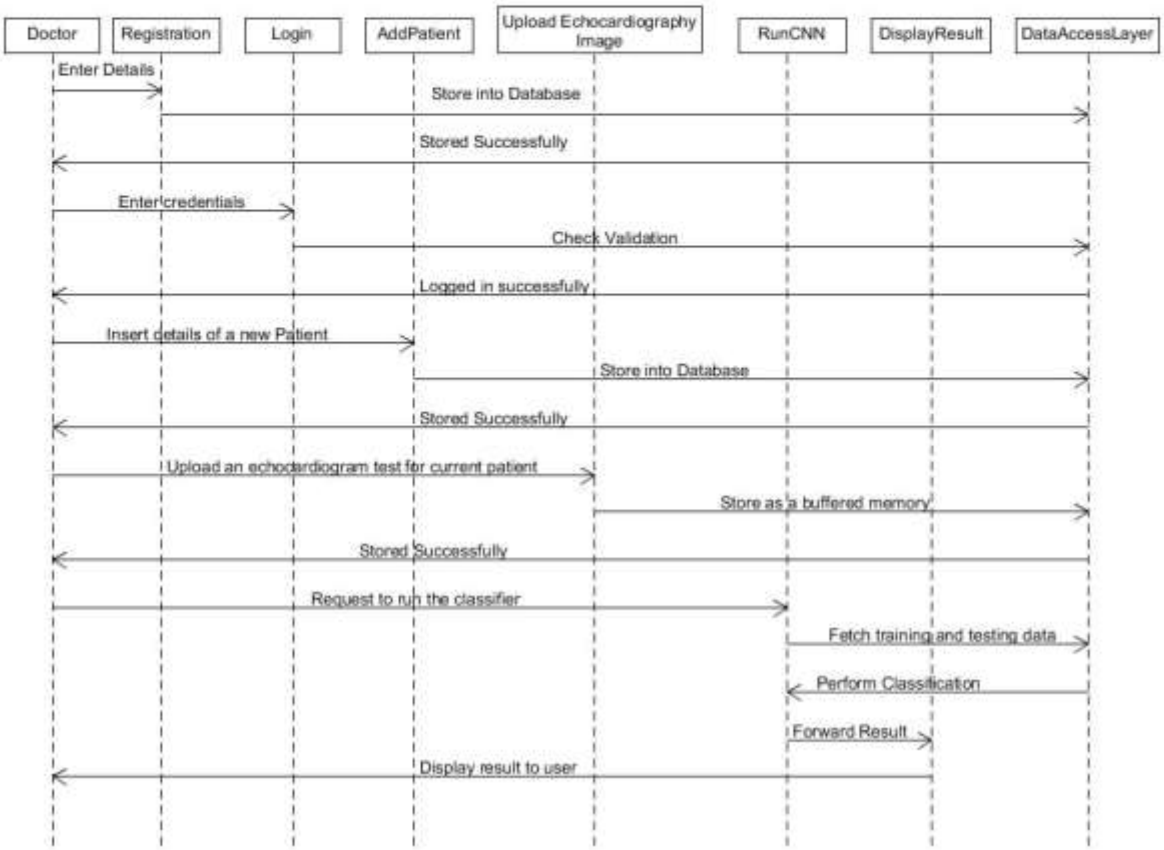

Fig :Sequence Diagram

Activity diagram:

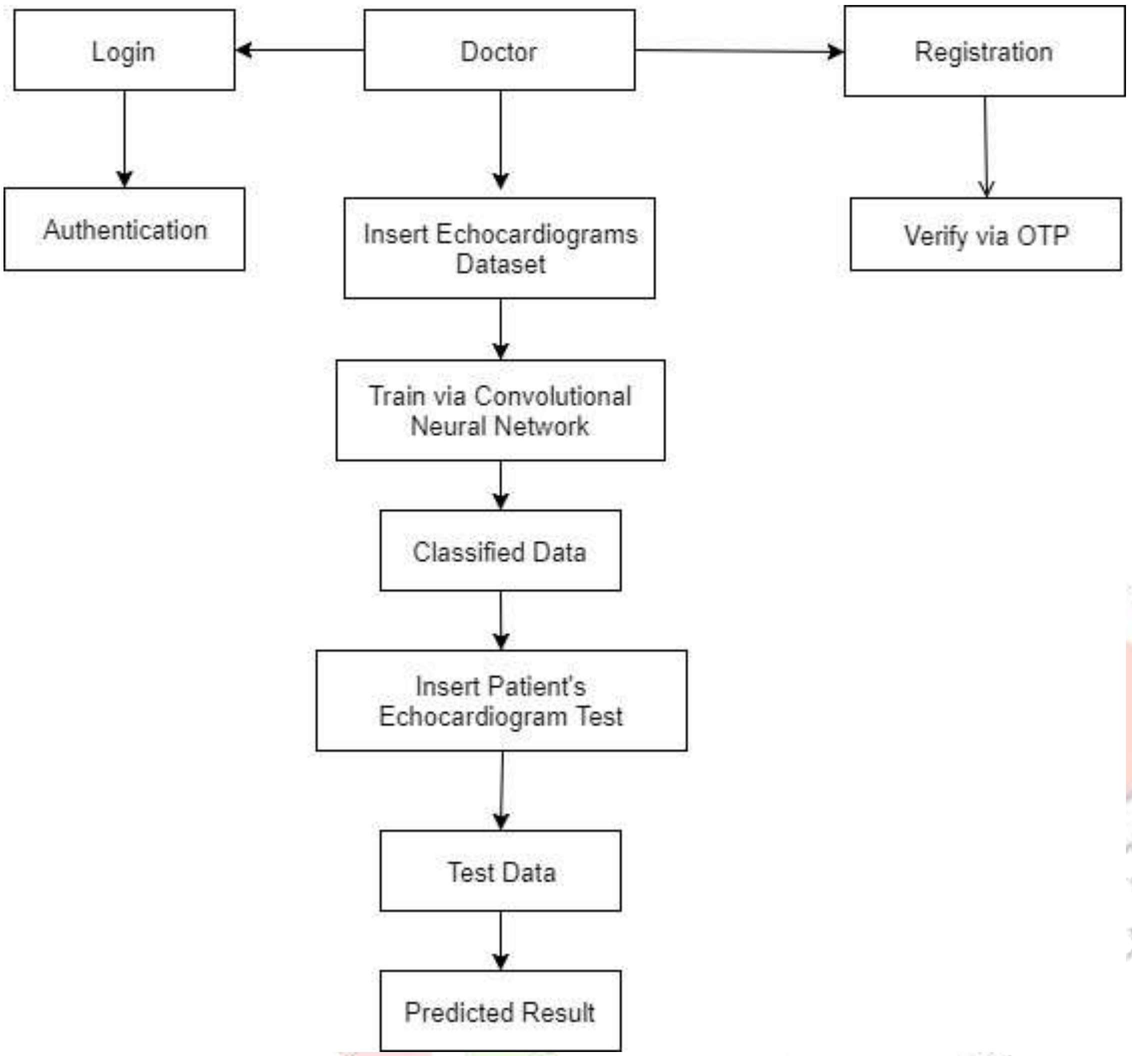

Fig : Activity Diagram

Use Case diagram:

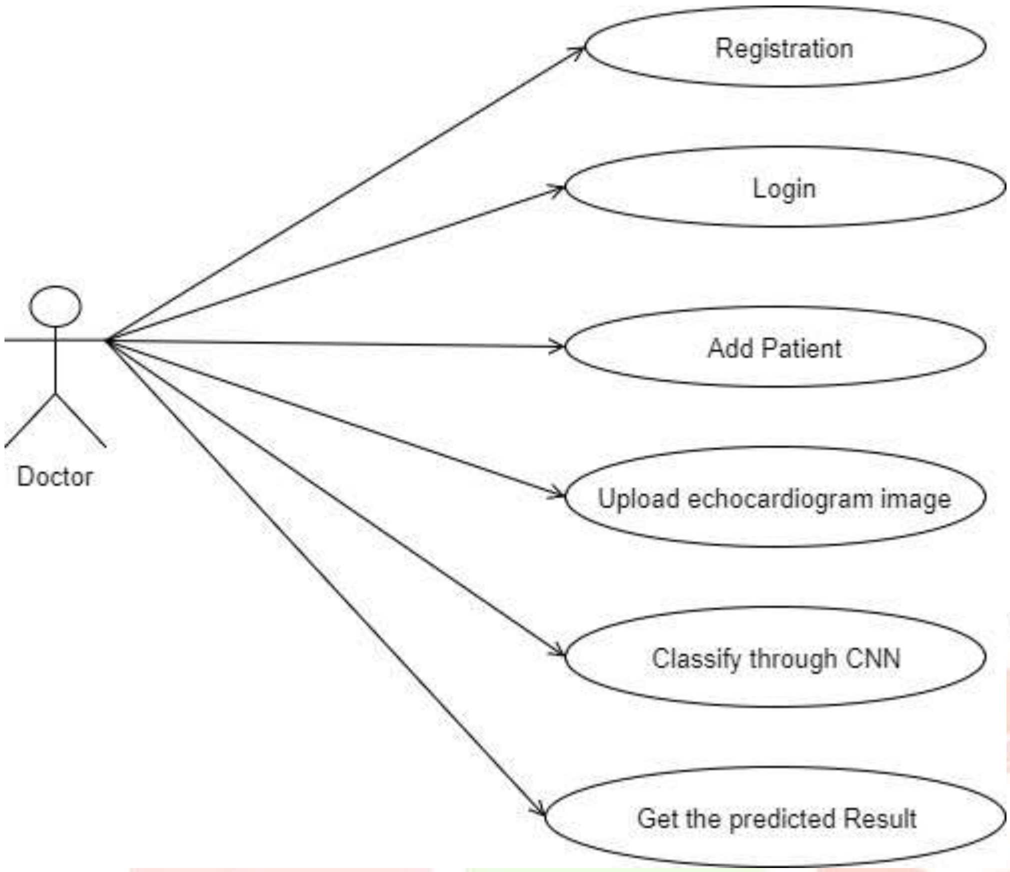

Fig :Use Case Diagram

3.2.5 Object diagram:

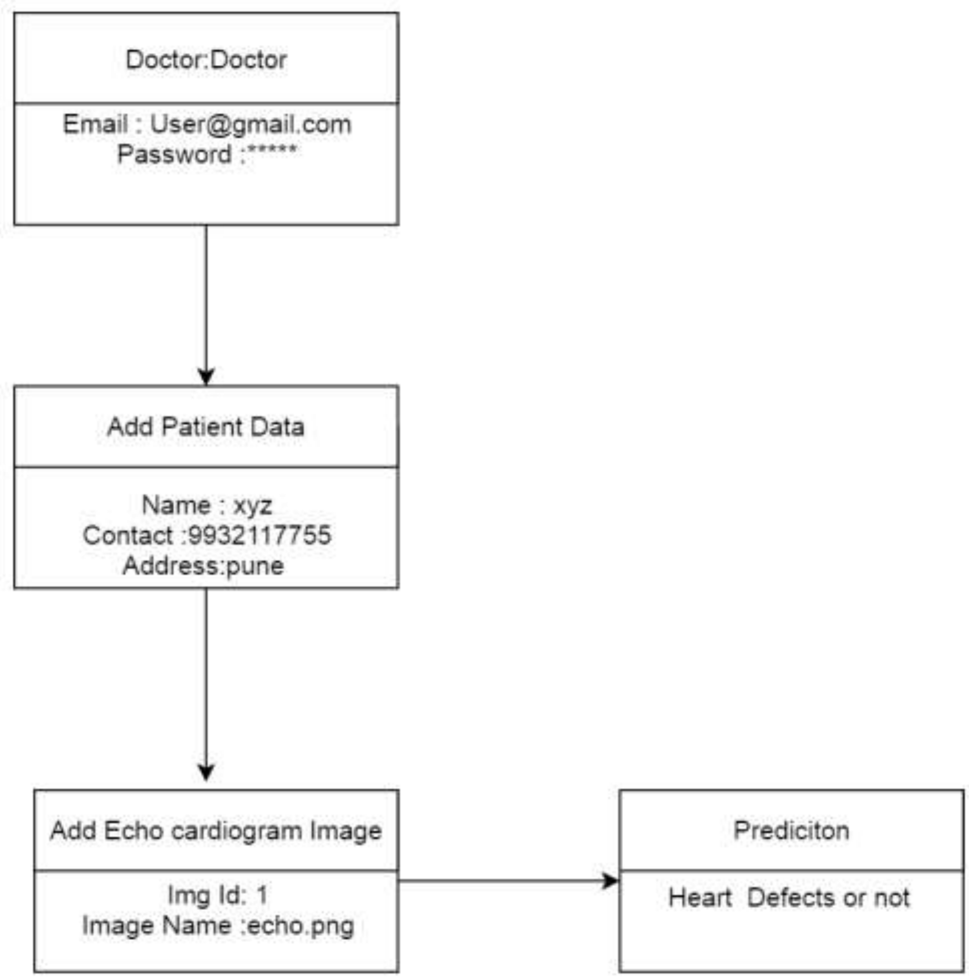

Fig: Object Diagram

Component diagram:

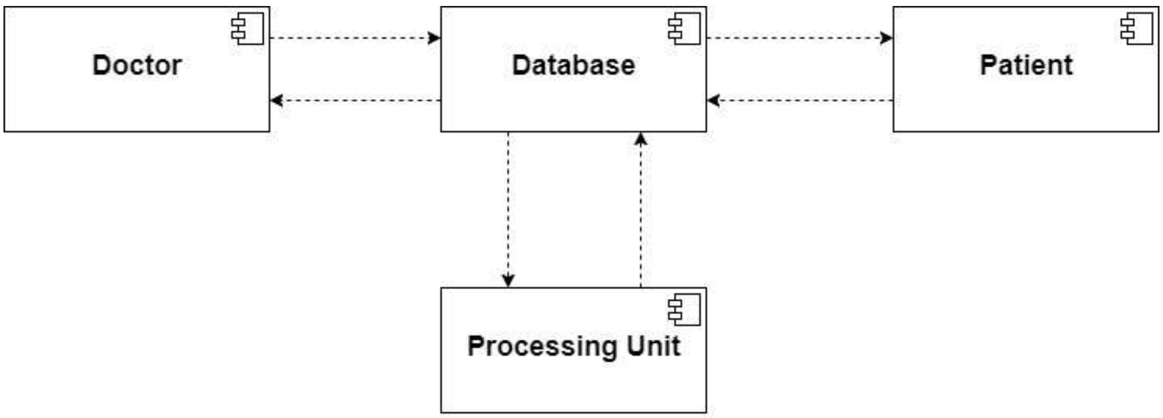

Fig: Component diagram

Deployment diagram:

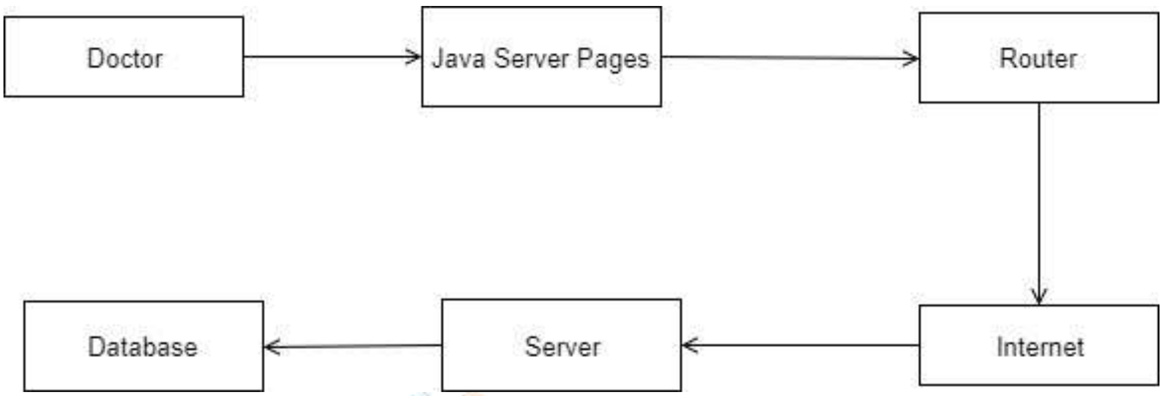

Fig: Deployment diagram

DFD 0 diagram:

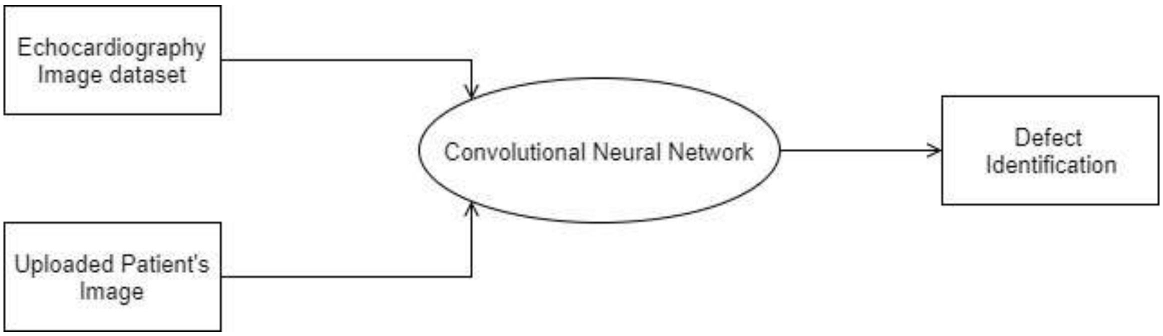

Fig: DFD 0 diagram

DFD 1 diagram:

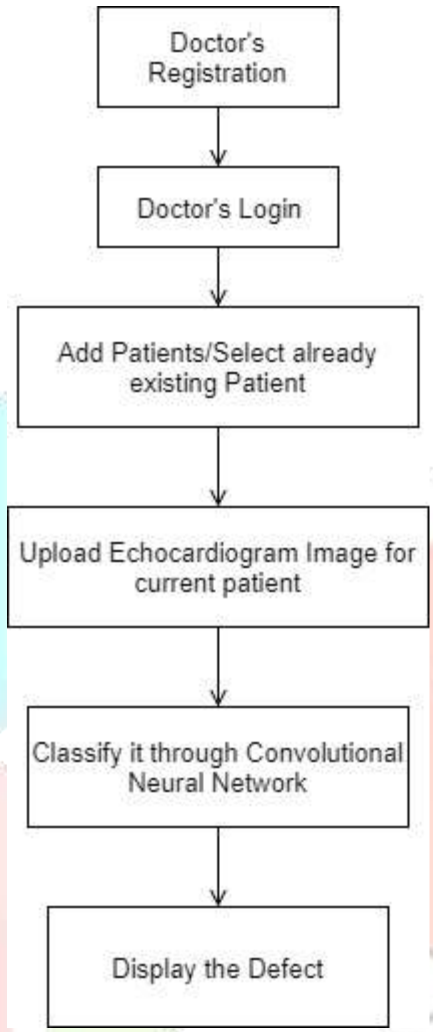

Fig: DFD 1 diagram

Related Works

[1] lasse løvstakken and fredrik orderud have proposed, a method for the visualization of the effective aperture of phased-array transducers is described. Reverberations from obstructing structures close to the transducer aperture may also cause problems for the proposed method.

[2] h. park1, s. k. zhou have proposed a fully automatic system for cardiac view classification of echocardiogram.[2] *Pierrick Coupé, Pierre Hellier, Charles Kervrann, and Christian Barillot* have an adaptation of the nonlocal (NL)-means for speckle reduction in ultrasound (US) images. The automatic tuning of the OBNLM filter and on the influence study on post processing tasks such as image registration or image segmentation is needed.

[3]*Xavier Glorot Antoine Bordes Yoshua Bengio* have proposed a technique, that shows rectifying neurons are an even better model of biological neurons. Problem could arise due to the unbounded behaviour of the activations in a network of rectifier units.

[4] *Fei Wang2, David Beymer* have proposed system for automatic view classification that exploits cues from both cardiac structure and motion in echocardiogram videos.

[5] *Pierrick Coupé, Pierre Hellier, Charles Kervrann, and Christian Barillot* have an adaptation of the nonlocal (NL)-means for speckle reduction in ultrasound (US) images. Originally developed for additive white Gaussian noise. The automatic tuning of the OBNLM filter and on the influence study on post processing tasks such as image registration or image segmentation is needed.

[6] *Sten Roar Snare , Hans Torp, Fredrik Orderud, Bjorn Olav Haugen* have proposed a novel method for assisting no expert users in capturing the apical 4-chamber view in echocardiography has been presented. there are some challenges remaining, in particular with respect to detection of oblique views, the results suggest that use of a real-time scan assistant may improve the results when no experts are acquiring apical 4-chamber echocardiographic views.

[7] *Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor MorAvi, PhD, FASE* proposed a technique to updated normal values for all four cardiac chambers . One may have presumed that since the convolutional layers don't have a lot of parameters, over fitting is not a problem and therefore dropout would not have much effect.

HYPOTHESES

1- We are developing a system that helps a user to predict the heart disease as per the category.

2- User will add patient details into the system such as personal details of patient.

3- Convolutional Neural Network is used to classify the images. CNN algorithm provides increased accuracy in the predication.

4- This approach considers the view of apical four-chamber (A4C) which considers 4 chambers of heart. This is a powerful approach which can detect even a little defect in heart which human eye tends to ignore.

System Architecture

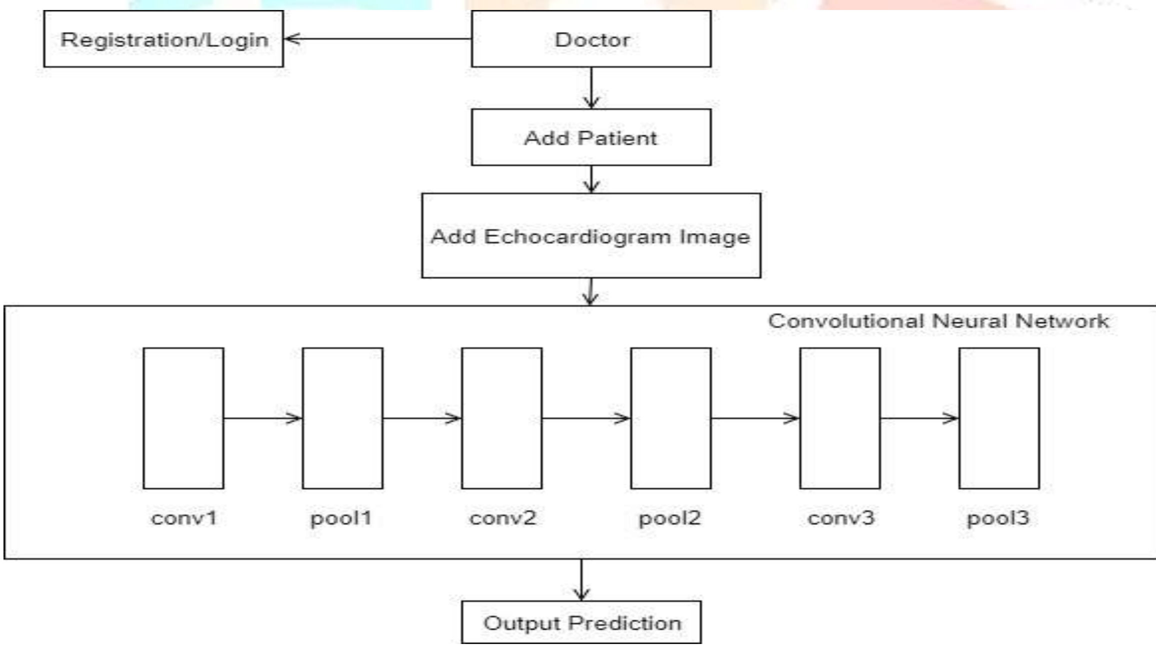

Fig: System Architecture

As shown in the above Architecture,

First user will register with the system by providing details like First name, last name, mobile number, service provider, mail id, and password. after that user will receive the Opt on his mail id .

If user enters correct OPT then user will get registered with the system. and users details will be get stored into the database

After registration user can login into the system with valid mail id and password.

User will upload the ecg image of heart .after uploading image , pass image to the CNN classifier .CNN classifier recognize the images and predict the disease .

Then user can logout from the System.

DESIGN OF THE STUDY

Implementation phase focus over system design objectives. Software implementation is the process of designing, writing, testing, debugging / troubleshooting, and maintaining the source code of computer programs.

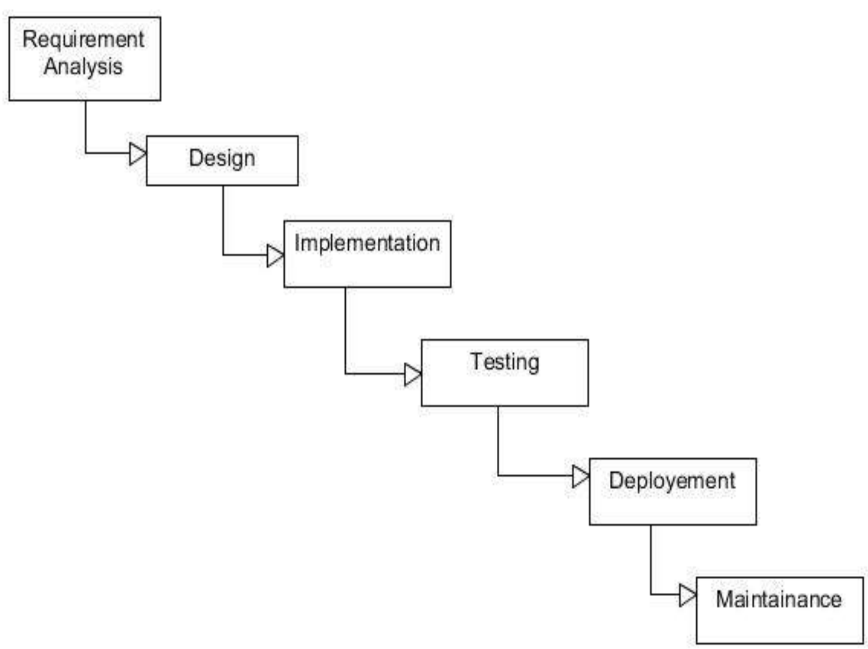

Fig : Software Development Process

Implementation of system is divided into 5 main modules. with the help of Register and Login module user will register and login into the system. User will store patients' details into the system. Upload ECG module is used to store ECG image of the patient into the database. After that user will fetch image id to pass image to the classifiers. Then we will get the final result.

SAMPLE OF THE STUDY

TOOLS UDED

Software Requirement:

- Operating System : windows 10
- Application Server : Tomcat 8.0
- Language : Java
- Front End : HTML, JSP
- Database : MySQL

Hardware Requirement: The hardware design of the system includes designing the hardware units and the interface between those units.

- Processor - Pentium –IV
- RAM - 1 GB (min)

Hard Disk - 20 GB

STATISTICAL TECHNIQUE USED

We have developed Login and Registration which manages the user profiles. User adds the patient details such as personal details and ECG image. User stores the image into the database and then sends it to the classifier for predication. After that classification process starts. System uses CNN classifier to predict the disease. Classifiers predict the disease as per the category.

Propose approach provides framework for automatic quality assessment of echo data. CNN classifier locates the defect in the four chambers of heart, like Left Ventricle (LV), Right Ventricle (RV), Left Atrium (LA) and Right Atrium (RA). After that suggestions or recommendation will be provided in the form of medicines to the patients as per the respective disease that occurs in part.

ALGORITHM

Convolutional Neural Network Layer

In this research CNN algorithm is used to detect the disease from given ECG image. System has used three layers of the CNN these are Convolutional Layer, Pooling Layer and fully connected layer. Here, convolutional layer and pooling layer, both layer work together. First it represents the image into three dimension vector space then applies filters to convert that image into 2 dimensions. Again fully connected layer applies the filters to recognize the image. After training the system when we pass the image to test it , As per the specified categories it classifies the image and detect the disease accurately . After disease detection system suggests the medicine on the detected disease.

The Conv layer is the core building block of a Convolutional Network that does most of the computational heavy lifting. To summarize, the Conv Layer:

Accepts a volume of size $W_1 \times H_1 \times D_1$

Requires four hyperparameters:

Number of filters K,

their spatial extent F,

the stride S,

the amount of zero padding P.

Produces a volume of size $W_2 \times H_2 \times D_2$ where:

$W_2=(W_1-F+2P)/S+1$

$H_2=(H_1-F+2P)/S+1$ (i.e. width and height are computed equally by symmetry)

$D_2=K$

With parameter sharing, it introduces $F \cdot F \cdot D_1$ weights per filter, for a total of $(F \cdot F \cdot D1) \cdot K$ weights and K biases.

In the output volume, the d-th depth slice (of size $W_2 \times H_2$) is the result of performing a valid convolution of the dd-th filter over the input volume with a stride of S, and then offset by dd-th bias.

$$a^l_{i,jk} = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} w^l_{i,mn} a^{l-1}_{(j+m)(k+n)}.$$

Notations	*Description*
a_i^l	output feature map of kernel.
w_i^l	is the Weight matrix.
a^{l-1}	Represents the input feature-map of the layer.

Pooling Layer:

Its function is to progressively reduce the spatial size of the representation to reduce the number of parameters and computation in the network, and hence to also control overfitting.

More generally, the pooling layer:

Accepts a volume of size $W_1 \times H_1 \times D_1$

Requires two hyperparameters:

their spatial extent F,

the stride S,

Produces a volume of size $W_2 \times H_2 \times D_2$ where:

$W_2=(W_1-F)/S+1$

$H_2=(H_1-F)/S+1$

$D_2=D_1$

Introduces zero parameters since it computes a fixed function of the input

Note that it is not common to use zero-padding for Pooling layers

It is worth noting that there are only two commonly seen variations of the max pooling layer found in practice: A pooling layer with F=3, S=2 (also called overlapping pooling), and more commonly F=2, S=2. Pooling sizes with larger receptive fields are too destructive.

Fully connected layer

Output of pooling layer is the input of fully connected layer .fully connected layer takes the output of polling layer and applies filer to recognizes the object.

$$f^{l}_{fc_i}(a^{l-1}) = \sum_{j=1}^{n} w^{l}_{ij} a^{l-1}_{j} + b^{l}_{i},$$

Notations	***Description***
f^{l}_{fci}	Fully Connected.
a^{l-1}	Represents the input feature-map of the layer.
w^{l}_{i}	Is the Weight matrix.
a^{l}_{i}	Output feature map of kernel.
b^{l}_{i}	Bias value.

OUR APPROACH

This paper proposes a framework incorporates a regression model, based on hierarchical features extracted automatically from echo images, which relates images to a quality score determined by an expert cardiologist. This paper has demonstrated the feasibility of proposed approach on the A4C echo view. Deep Neural Network is proposed to extract the feature, recognize the images and classify it. Echo Images are used to train and test the model. Trained network is able to assess the quality of an echo image in real time. Fully automatic system is proposed to cardiac view classification of echocardiogram. Since the design of the proposed architecture does not include any a priori assumptions on the A4C view, this approach could be extensible to other standard echo views.

To improve the quality of echocardiograms, this paper has implemented Computational Neural Network to detect the disease from given ECG image. System has used three layers of the CNN these are Convolutional Layer, Pooling Layer and fully connected layer. CNN algorithm first extracts the features from the images then it generates the patterns and finally it classifies the images.

Here, convolutional layer and pooling layer, both layer work together. First it represents the image into three dimension vector space then applies filters to convert that image into 2 dimensions. Again fully connected layer applies the filters to recognize the image. After training the system when we pass the image to test it, as per the specified categories it classifies the image and detects the disease accurately. After disease detection system suggests the medicine on the detected disease.

Experiment Result:

Data mining supports many different techniques for knowledge discovery and prediction such as classification, clustering, sequential pattern mining, association rule mining and analysis. Data mining is extensively used in business analysis, strategic decision making, financial forecasting, future sales prediction etc.

Our proposed model implements Computational Neural Network for analyzing the abnormality in a heart showed in echocardiogram in Apical Four Chambers (A4C).

In this research, we have collected echo image dataset from the hospital . These echo images were acquired mostly by echo-technicians, with a small contribution from cardiology trainees and trainee technicians, during routine cardiac exams. In an echo acquisition, the heart is imaged from at least seven standard (parasternal long and short axes, apical 2-, 3-, and 4-chamber, subcostal, and suprasternal) and atypical imaging views for which the sonographer places a transducer on the patient’s chest to obtain ultrasound frame stacks (cine clips) in a specific order from each of the standard echo views.

The designed DCNN (Deep convolutional neural network) was trained on the training data and was evaluated on the test set against expert cardiologist's manual scores. The performances of the trained models were evaluated as the mean absolute error

(MAE) between the predicted AES and the expert's manual echo scores (MES).

The designed model was trained three times on the training data and was evaluated on the test set against expert cardiologist's manual scores. The performances of the trained models were evaluated as the mean absolute error (MAE) between the predicted AES and the expert's manual echo scores (MES).

Table I presents the performance of the three trained models for each quality-level as well as the overall accuracy of each model.

TABLE I
THE PERFORMANCE OF THE THREE TRAINED MODELS ON EACH QUALITY-LEVEL AND IN TOTAL. ALTHOUGH THEIR PERFORMANCES IN EACH QUALITY-LEVEL SLIGHTLY VARIES, THEIR OVERALL ACCURACIES MATCH.

Model	Mean Absolute Error (MAE)						
	0	1	2	3	4	5	Total
model1	0.63	0.77	0.84	0.78	0.58		0.72
					0.85		
model2							0.72
	0.68	0.85	0.87	0.78	0.59		
model3					0.86		0.72
	0.69	0.84	0.85	0.77	0.58		
					0.87		
Average	0.67	0.81	0.83	0.77	0.58		0.71

model	0.86	

Future scope:

Future steps include covering other standard echo views and extending the framework to respond to the cardiac cycle (echo cine) as a whole, rather than a single frame.

Acknowledgment: (optional)

It gives us great pleasure in presenting the preliminary project report on ‘’.

I would like to take this opportunity to thank my internal guide Prof. ---------for giving me all the help and guidance I needed I am really grateful to them for their kind support. Their valuable suggestions were very helpful.

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In the end our special thanks to Prof. ----for providing various resources such as laboratory with all needed software platforms,

Student name

Student name

Student name

(B.E. Computer Engineering).

Conclusion:

Proposed approach provides framework for automatic quality assessment of echo data using deep neural network model. The goal of proposed technique is to improve echo by reducing observer variability in data acquisition using a real-time feedback mechanism that helps the operator to read just the probe and acquire an optimal echo.

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