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A Novel Technique for Prediction of Coronary Artery Disease from Human Fundus Images Using Machine Learning Approach

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Abstract: Traditionally, Coronary Artery Disease (CAD) is detected only when the person got a heart stroke. The coronary arteries blockages are identified by using a technique called Angiogram test, where a thin wire called catheter is inserted into an artery present in groin or arm and passed through the vessel to reach to heart. Later after identification of coronary artery blockages Angioplasty procedure is done to restore blood flow through the artery. The organ through which blood vessels are clearly visible is Eye. So, our research is in the line of detecting Coronary Artery Disease (CAD) by analysing fundus image of human eye instead of traditional process which is costlier and painful process. Through this technique we can help patients by knowing about the risk of CAD early before having symptoms of heart attack. Machine Learning and Image Processing [10,11] approaches are used in this work of early detection of CAD risk. This is an innovative attempt of detecting Coronary Artery Disease.

Keywords: Machine Learning, Coronary Artery Disease, Classification, Convolution Neural Networks.

1. INTRODUCTION:

There are 2 sorts of blood-vessels which carries blood in our body. One is Artery and other is Vein. Arteries distribute the blood to all the parts of the body. They carry blood wealthy in oxygen to the organs of the body. So, they are brighter in color. Veins collect the blood from all the organs of the body. They carry blood which is impure so that the oxygen level will be very low compared to Arteries. So, they are darker in color. For several Clinical applications, classifying arteries and veins from blood vessels will be so helpful. As for detecting many diseases it is important to classify the arteries and veins.

The important features that will differentiate arteries from the veins are as follows.

- Arteries are more splendid in shading than veins.
- Arteries are slenderer than neighboring veins
- The focal reflex is more extensive in corridors and littler in veins.
- At the optic circle veins and supply routes are generally substitute to other before fanning out.
- Near the optic circle one vein is commonly by 2 arteries.
- Arteries and Vein classification is main requirement for identifying the several retinal disorders or problems. Here we predict the heart attack possibility by calculating the A/R ratio.
- In the area of retinal image analysation, the investigation of the vasculature of the retina from eye fundus pictures assumes a key job in early malady determination.
- Especially, differentiation of retinal blood-vessels into arteries and veins can be crucial step for the mining of retinal biomarkers and finally we can investigate several eye related diseases.

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- In certain, unusual-less proportion between arteries and veins widths is understood as that there is a extrapolative chances of numerous cardiovascular diseases and also may be cause of diabetic retinopathy.

2 RELATED STUDIES:

In [1] authors proposed graph based approach for classification of blood vessels in Retinal fundus images and artery or vein classification. In [2] authors worked on MESSIDOR dataset to calculate AVR quantitatively for detection of Hypertensive Retinopathy. In [3] authors proposed automatic detection and bifurcations among blood vessels in color fundus images using Convolution Neural Networks (CNN). Authors proposed method for junction detection in blood vessels and then classification was done whether it is a bifurcation or crossing. Authors used DRIVE data set. In [4] authors aim is to analysis and detect retinopathy , glaucoma and haemorrhage.

In [5] authors focused their work in vessel extraction with enhanced filtering and unsupervised classification. Authors implemented in four stages pre-processing, enhancement with gabor filters, clustering using K-means and Fuzzy C means and post processing. In [6] Authors made extensive study for computational analysis for flow of blood in retinal blood vessels using fundus images. In [7] authors proposed methods for pre-processing and feature extraction for early detection of diabetic-retinopathy. Authors extracted green channel from retinal fundus image and performed histogram equalization, enhancement of imageand resizing. Authors used Kaggle data set for retinopathy. In [8] authors used reflection features in retinal vessel classification. Accuracy rates of average 87% were achieved. In [9] authors performed comprehensive study of classification methods for retinal vessels in fundus image**.**

3. EXISTING SYSTEM:

According to current medical trend when a person gets a cardiac arrest, the doctors initially identify the blocks in arteries by using Angiogram technique. Angiogram techniqueis a process that uses X-ray imaging to view heart's blood vessels. This is generally performed to check whether there is any restriction in the blood flow going to heart. Cardiac catheterization is a procedure where a thin tube (named as catheter) is inserted into an artery in the groin or arm and passed to reach heart. Then a dye is injected through the catheter passing through artery and reaches to the heart. The movement of the dye is then imaged and recorded as video and viewed on monitor, which helps doctors to diagnose operation of artery vessels and chambers of heart

After that, a process known as Angioplasty is carried out where in which the doctor inserts a tube through the blood vessel to reach the blockage site in the artery with a small balloon attached at the end of the tube. Therefore the identified blocks are cleared by inserting Stents into arteries. But either of angioplasty or bypass procedure is a costly and also a complex process.

4. PROPOSED SYSTEM:

Our work has been divided into two modules as shown in Fig 1.

- In first module, we take human eye fundus images and perform blood vessel segmentation and blood vessel classification for differentiating Arteries and Veins using **UNet** model.
- In second module, we find A/V ratio for several fundus images and apply CNN along with some other factors like BMI, Cholesterol, Food habits, diabetes, hypertension, Smoking etc., by taking it as a training set and later we will take a new patient fundus image and perform entire process by calculating A/V ratio and it is given as a input to CNN for the prediction of Coronary Artery Disease (CAD).

When a human fundus image is given as the input to the system, it undergoes blood vessel segmentation followed by blood vessel classification is done by using basic image processing techniques. Later the thickness of the Arteries and Veins are identified and the ratio of their thickness is calculated. Then a Convolution Neural network model is trained with this data and later used for the prediction of the CAD of the new patients.

Artery-Vein Classification:

Arteries and Vein classification is main requirement for identifying the several retinal disorders or problems. Completing training of proposed model in a portion of the RITE & DRIVE datasets, we start building the predictions in such a way that every input fundus image will be pre-processed and given as input to the model. Then the probabilities of being a pixel belongs to particular class is calculated. Later by applying Data Augmentation techniques transformations of image

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are generated and then each transformed image will be given as an input to model and predictions are done. After completion of all predictions, average of the predictions is calculated and then divided into classes and generated new images with classified arteries and veins.

Calculating A/V Ratio:

By computing the Euclidian Distance transform of Binary Image & Skeletonization methodology, we can calculate radius of arteries and veins individually. Later, calculate the ratio of artery-vein thickness.

Prediction of CAD:

After artery-vein classification, A/V ratio is calculated and CNN model is trained along with some other entities to correctly predict the chance of Coronary artery blockages.

Methodology:

The Proposed methodology is shown in Figure 1.

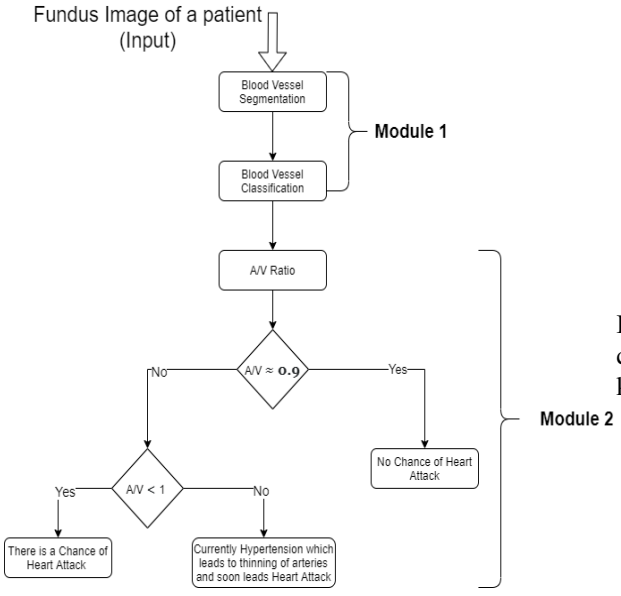

Fig 1: Proposed methodology

UNet:

It follows semantic segmentation process in which along with segmentation (partitioning of image into different regions or segments for identifying the essential features) it classifies the pixels present in the image into classes. For an instance, we can separate all pixels related to arteries and identify then with red color.

The final result of the CNN is a vector which contains the probability scores representing how every feature is likely to be into a particular task.

But in image segmentation we also need to reconstruct the image from this vector. So, to do that we use UNet .

It is especially used for medical analysis.

It mainly consists of 3 blocks of code.

1. Contraction block or Encoding block
2. Expansion block or Decoding block
3. Final block

Each block follows the convolution hidden layer processing mechanisms.

After applying the model, we get unscaled or un normalized tensor values. After that by using nn.functional.softmax function we convert them into scaled or normalized tensor values under 4 classes as we defined no. of classes as 4.

The 4 classes are

1. Red – probability of the pixel being an Artery.
2. Blue – probability of the pixel being a vein.
3. Green – probability of the pixel being an uncertainty (not known) pixel.
4. Background – 1 – (Artery-Vein-Uncertain)

Later these Tensor values are converted into Image matrices based on the corresponding channels or classes and stored as 3 different images known as

1. predicted vessels in which the background is omitted that shows as white.
2. artery-vein-uncertainty are merged into a single class (vessels) i.e., o/p of vessel segmentation method.
3. predicted vessels that are colour coded into 4 classes where background is represented as black.

Distance transform of binary image:

Bwdist (img): It calculates the distance to the nearest pixel which is one and if the current pixel itself is one it returns zero. It generally calculates the Euclidean distance b/w the pixels and is shown in Figure 2.

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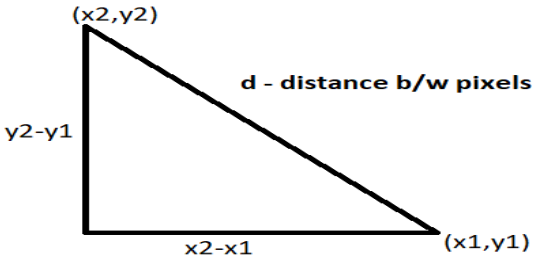
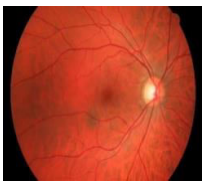
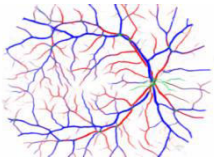
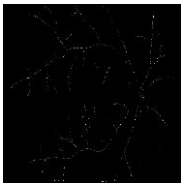
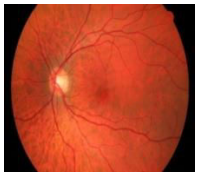
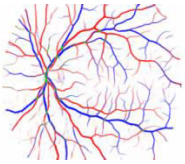
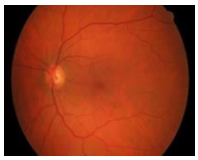
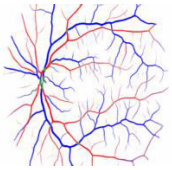
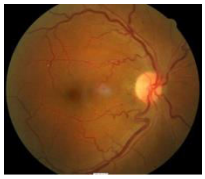
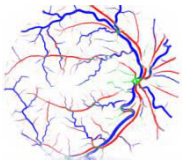
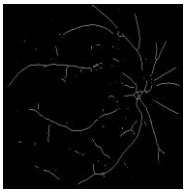
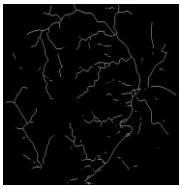
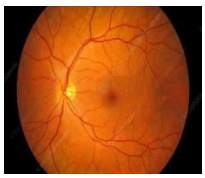
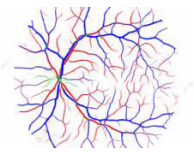
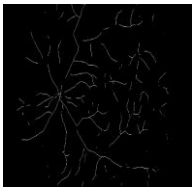
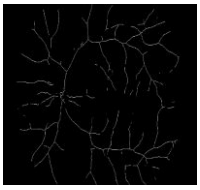


Fig 2: Calculation of Euclidean distance between pixels(√ ((x2-x1)2 + (y2-y1)2))

Skeletonization: The process of reducing all the objects in the image into 1-pixel wide lines i.e., for reducing the foreground regions in the binary images to skeletal remains. That is sometimes used

5. RESULTS:

Results for different fundus imagesis shown in Figure 3.

Experimentation	Fundus Image	Classification of Blood vessels	Separated Arteries	Separated Veins
Healthy Fundus				
High Glaucoma Fundus				
Glaucoma Fundus				
Diabetic Fundus				
Smoking Fundus				

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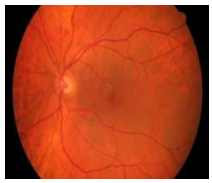
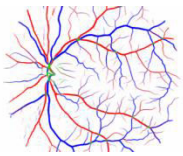
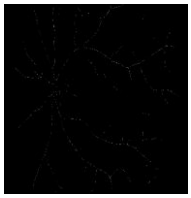
Hypertension Fundus				

Fig 3: Results for different fundus images

Analysis of Experimentation 1:

Arteries-radius: 1.073349489004769, Veins-radius: 1.198717988127983

A/V Ratio: 0.8954

From the above results for healthy person, A/V ratio is in range (0.8-0.9) which indicates there is Constant Blood flow in both Veins and Arteries. i.e., There is no Blockages in the Coronary Artery.

Analysis of Experimentation 2:

Arteries-radius: 8.249159627187673, Veins-radius: 8.852781659373860

A/V Ratio: 0.931815551833131

For un-healthy person, A/V ratio will become less than or equal to (0.8) which indicates there is Un-even Blood flow in Arteries. i.e., there are some Blockages in the Coronary Artery. But here it is 0.930 so the person doesn't have some coronary artery blockages because of high value of Glaucoma but it may occur soon.

Analysis of Experimentation 3:

Arteries-radius: 7.607788812117003, Veins-radius: 9.168123899608362

A/V Ratio: 0.830

For un-healthy person, A/V ratio will become less than or equal to (0.8) which indicates there is Un-even Blood flow in Arteries. i.e., There are some Blockages in the Coronary Artery. But here it is 0.830 so the person doesn't have any coronary artery blockages even having Glaucoma but it may occur soon.

Analysis of Experimentation 4:

Arteries-radius: 1.690039664381797, Veins-radius: 1.944047065745611

A/V Ratio: 0.869340919857621

For un-healthy person, A/V ratio will become less than or equal to (0.8) which indicates there is Un-even Blood flow in Arteries. i.e., There are some Blockages in the Coronary Artery. But here it is 0.87 so the person doesn't have any coronary artery blockages even having Diabetics but it may occur soon.

Analysis of Experimentation 5:

Arteries-radius: 1.666788471456665, Veins-radius: 2.139186601297579

A/V Ratio: 0.779169274174413

For un-healthy person, A/V ratio will become less than (0.8) which indicates there is Un-even Blood flow in Arteries. i.e., There are some Blockages in the Coronary Artery. There is always a high risk for a person with smoking habit to have CAD.

Analysis of Experimentation 6:

Arteries-radius: 9.026880511208471, Veins-radius: 8.908830818439520

A/V Ratio: 1.013250862562640

For a person with Hypertension, A/V ratio will be greater than (0.9) which indicates there is High Blood flow in Arteries than in Veins. i.e., There is High Blood Pressure.

A/V Ratio:

A/V Ratio of different experimentation Fundus images is shown in Table 1.

Table 1: A/V Ratio of different experimentation Fundus images

Fundus Image Types	Values of A/V ratios
Healthy person Fundus	0.8954
High Glaucoma Fundus	0.931815551833131
Glaucoma person Fundus	0.830
Diabetic person Fundus	0.869340919857621
Smoking person Fundus	0.779169274174413
Hypertension person Fundus	1.013

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By computing the Euclidian Distance transform of Binary Image & Skeletonization methodology, we get the Radius of Arteries.

Graphical Analysis:

Graph showing the A/V ratios of the various Fundus is shown in Figure 4.

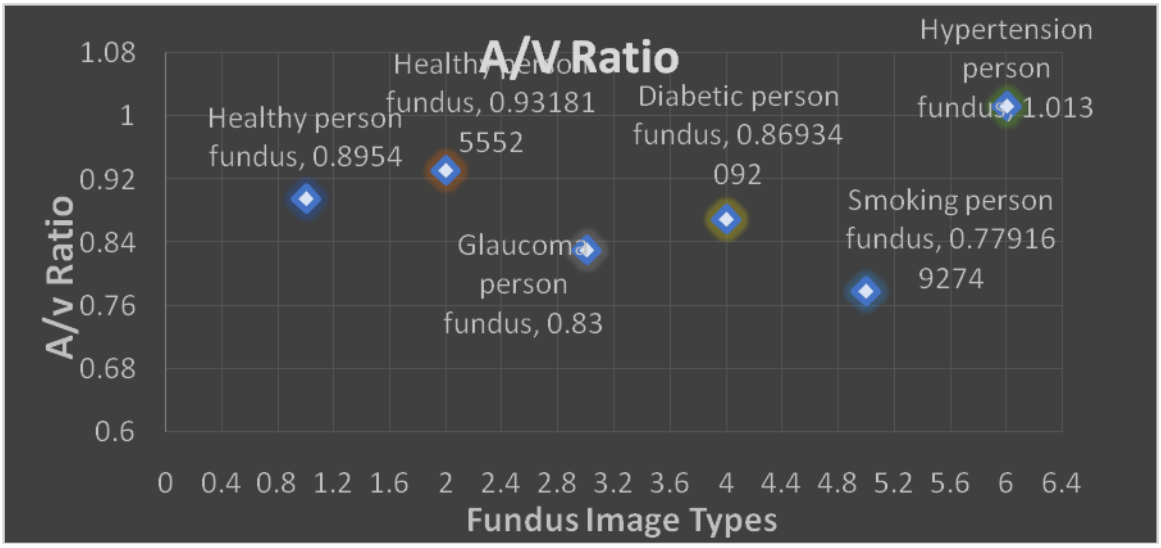

Fig 4: Graph showing the A/V ratios of the various Fundus

From the above graph it is evident that persons with high glaucoma and smoking habit as well with diabetes have high risk for having CAD in near future.

6. CONCLUSIONS AND FUTURE ENHANCEMENT:

In this work an automated and structural method for classification of retinal blood vessels into arteries and veins has been proposed. Here the classification is performed on the foremost vessels. Here we have classified the vessels into arteries and veins and showed them by different colours in the retinal fundus layout by using the resident nature of the classification process. The result obtained on the DRIVE dataset of 120 images of the validation set is satisfactory, since main vessels have been correctly classified.

This method will find the ratio of the radius of the arteries to the radius of the veins which differentiate the person who has the chance of Coronary Artery Disease from the persons who are healthy. In addition to classification and predicting the risk of Coronary Artery Disease (CAD), some more enhancements like calculating the width of the blockages, predicting the duration of occurrence of heart stroke if it is neglected and so on which can make system more attractive. And this Artery-vein classification can be used to predict the risk of other diseases like Diabetes, Blood pressure etc.

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