CLASSIFICATION OF NAILFOLD CAPILLARY IMAGES IN PATIENTS WITH HYPERTENSION

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Abstract: Nailfold Capillaroscopy is a non-invasive technique for imaging capillaries at the base of fingernails. It is used clinically to assess the degree of micro vascular abnormality and has the potential to provide quantitative bio-markers for systemic sclerosis, Diabetes mellitus, Hypertension etc. Nailfold capillary images in Hypertensive subjects show decreased density of capillaries and distance between them is large. The capillary images are acquired using USB Digital Microscope. Image enhancement is achieved using Adaptive Histogram and smoothing filter as Adaptive median filter. Daubechies wavelet features have been used which is followed by dimension reduction using PCA. Image classification is done using KNN technique.

Index Terms— Nailfold capillaroscopy, Adaptive median Filter, Daubechies, PCA and KNN

I. INTRODUCTION

Nailfold capillaroscopy is a study of microcirculation in capillaries present underneath the finger nail folds. Nailfold is one of very few areas in the human body where the capillaries are seen to be parallel to skin making it convenient for physiological and functional study. Interestingly, Nailfold capillary images present various patterns of static and dynamic parameters of capillaries such as capillary dimensions, capillary architecture and capillary blood flow rate which correlate very well to different diseases. For example, in hypertensive subjects the capillary density is very low as compared to healthy controls [3]. In diabetic patients the disorganization of capillary architecture such as capillary elongation, enlargement and tortuosity along with the presence of microhaemorrhages is observed. In fact, Cutolo et al have defined SSc(Systemic Sclerosis) patterns of capillary images for various stages of severity of the disease [2]. A computerized analysis of Nailfold capillary images can provide both qualitative and quantitative inputs to the medical practitioner. This information is accurate and can also reduce the diagnosis time. It reduces the need for trained staff in capillaroscopy. Hence, in this study, we propose an optimized technique for the classification of Nailfold capillary images in Indian patients with hypertension.

The article is organized as follows- Section 2 gives the current scenario in Nailfold capillaroscopy by reviewing the literature. Section 3 deals with the methodology. Preprocessing techniques such as contrast stretching using adaptive histogram equalization followed by smoothing using Adaptive median filter. Discrete Wavelet Transform (DWT) is considered with Daubechies wavelet. Further, the number of features selected is reduced using Principal Component Analysis (PCA) by computing the Eigen values for the DWT matrix. Finally classifier namely k Nearest Neighbor (KNN) is considered for features obtained from Daubechies wavelet.

1.1 Motivation:

Although capillaroscopy is quite rigorously researched and widely used in many parts of the world, it is yet to become popular in Indian subcontinent. Vivek vasdev et al relates this to the cost of the required equipment apart from lack of trained professionals. They have suggested the use of inexpensive digital microscope to obtain the images. The images so obtained are poor in contrast and resolution, hence need to be processed. In this study, we have considered some of the enhancement, feature extraction and classification techniques for Nailfold capillary images obtained using USB digital microscope, in normal controls and hypertensive subjects.

1.2 Literature survey

Study of microcirculation in capillaries has been used for diagnosing various diseases such as rheumatic diseases, auto-immune diseases and systemic diseases. H. R. Maricq first described SSc pattern as enlargement of capillary loops, loss of capillaries, disruption of capillary bed and distortion and budding of capillary or hemorrhage. The physiological and functional parameters of the capillaries are useful even as an early bio-marker for various diseases. The structural abnormality of reduced capillary density in hypertensives is well demonstrated by Tarek et al [3]. Penna et al [8] explained Patients treated for essential Hypertension showed Micro vascular rarefaction, regardless of the type of therapy used. Nailfold videocapillaroscopy is the technique employed by various researchers, who convert the video frames into image by image mosaic technique [16]. Different image enhancement techniques are evaluated by Niraj et al [4]. Y. Zhang and L. Wu et al. explains a novel method to classify a given MR Brain images as normal or abnormal. They first employed Wavelet transform to extract features from the images and followed by PCA to reduce the dimensions of features [13]. The imaging equipment we have used is Digital microscope as suggested by Vivek et al [7, 9]. Berks et al have discussed automation of Nailfold capillaroscopy using high resolution video sequences [15]. Although not much literature was found about processing of images obtained directly from a camera, we have used different image processing techniques discussed above to reach an optimal solution having good performance.

II. METHODOLOGY

Image Acquisition using USB Digital Microscope with 200x magnification: Normal & Hypertensive

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Image Enhancement: Histogram Equalization+filter (Adaptive median filter)

⇩

Feature Extraction: DWT (Daubechies)
Dimensionality reduction: PCA

⇩

Image Classification: KNN

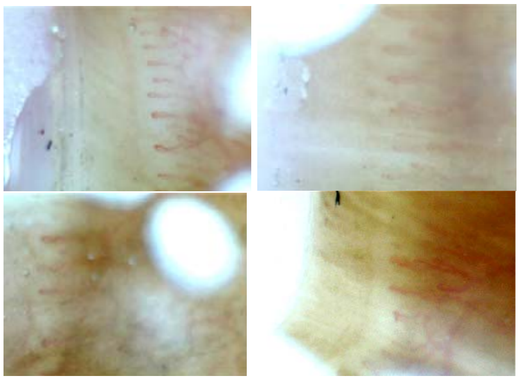
Figure1: Proposed optimization with the different techniques considered

The acquired images are contrast stretched using Adaptive Histogram Equalization. Smoothing attempts to capture important patterns in the image, while leaving out noise or other fine-scale structures and rapid phenomena. For Smoothing, Adaptive median filter is considered. Next, DWT is employed for feature extraction. Daubechies wavelet is employed and features thus extracted are further reduced in number using dimensionality reduction techniques. Lastly k-nearest neighbor classifier are used to classify the given capillary images as Normal and Hypertensive as shown in Figure 1.

2.1 Database collection

Nailfold capillary images are acquired by making the person sit with hands at heart level; immersion oil is applied to the base of the 4th finger of non-dominant hand and the beam of light is focused vertically so that the capillaries could be seen. The room temperature was maintained at 25 degree Celsius, while collecting the images. 60 sample Nailfold capillary images of normal controls and 60 of hypertensive subjects is collected. Ethics committee clearance is obtained from the M S Ramaiah medical college, Bangalore for the data collection.

Informed consent is obtained from the controls as well as the patients. Figure 2 shows some sample Nailfold capillary images.



a)&b) Normal c)&d) Hypertensive
Figure2: Sample Nailfold Capillary images

III. ENHANCEMENT AND FEATURE EXTRACTION

Initially the RGB color image of the capillaries is converted to gray images. This does not alter the quality of the morphological features of interest namely the capillary density and disorganized capillaries. Manual cropping of the capillary images is done next to obtain the region of interest which is only the first row of capillaries. The Nail-fold capillary images are low on contrast as shown by the histogram. The pixels are gathered predominantly around pixel value 150. Adaptive Histogram equalization is carried out. Figure 3 shows the original, contrast stretched images with their histograms and Adaptive median filtered image.

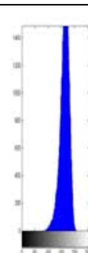
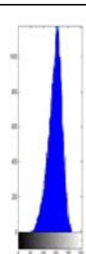
Original Image	Gray image	Original histogram	Histogram Equalized image	Equalized Histogram	Adaptive median filter (AMF)
					

Figure3: Original ,contrast stretched images with their histograms and Adaptive median filtered image.

Adaptive Median Filter (AMF): Adaptive median filtering has been applied widely as an advanced method compared with standard median filtering. The Adaptive Median Filter performs spatial processing to determine which pixels in an image have been affected by impulse noise. It classifies pixels as noise by comparing each pixel in the image to its surrounding neighbor pixels. The size of the neighborhood is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbors, as well as being not structurally aligned with those pixels to which it is similar, is labeled as impulse noise. These noise pixels are then replaced by the median pixel value of the pixels in the neighborhood that have passed the noise labeling test.

3.1 Feature Extraction using DWT: Discrete We have considered the features in Transform domain due to the limitations of feature vector in spatial domain. Features extracted in spatial domain have a high dependence on position and orientation of the feature while the differences in intra-personal observations also heavily influence the selection of features. Frequency domain analysis is computationally convenient as well as helps in accurate classification of images.DWT is a tool that separates data into different frequency components, and then studies each component with a resolution matched to its scale. The 2-D DWT is computed by successive low-pass and high-pass filtering of the image. By applying 2D DWT on an image, the image is decomposed into four subbands LL, LH, HL, HH subbands, corresponding to approximate, horizontal, vertical, and diagonal features respectively. The subband denoted by LL is approximately at half the original image. While the subbands HL and LH contain the changes of images or edges along vertical and horizontal directions, respectively. The subband HH contains the detail in the high frequency of the image. LL subband is further decomposed into four subbands. But as the level of decomposition is increased, there is a loss of resolution in the newly created subbands.

3.1.1 Daubechies: Daubechies wavelets are the family of orthogonal wavelets defining a DWT and characterized by maximal number of vanishing moments for some given support. The properties of Daubechies wavelet are

Asymmetric, Orthogonal and Biorthogonal. We used “db4” wavelet for our method.

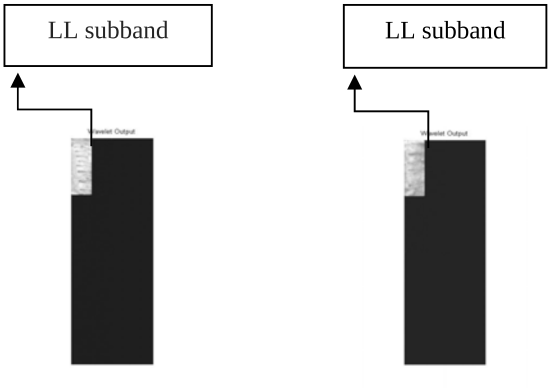


Figure3.1.1: Level DWT output for both Normal control and Hypertensive subject

3.2 Dimension Reduction using PCA

Principal component analysis performs a linear mapping of the data to a lower-dimensional space in such a way that the variance of the data in the low-dimensional representation is maximized. The correlation matrix of the data is constructed and the eigenvectors on this matrix are computed. The eigenvectors that correspond to the largest eigenvalues (the principal components) can now be used to reconstruct a large fraction of the variance of the original data. Moreover, the first few eigenvectors can often be interpreted in terms of the large-scale physical behavior of the system.

3.3 Classification

The dataset which is obtained from the PCA after dimension reduction forms a feature vector for classification. The dataset is divided into a training data and test data for each image sample. Classification of the image sample as Normal or Hypertensive which is performed using KNN (k-nearest neighbor) Classifier. In KNN model, a nearest neighbor classification object, where both distance metric (‘nearest’) and the number of neighbors can be altered. The object classifies new observations using the predict method. The object contains the data used for training, so can compute re substitution prediction and cross validation. Given a set X of n points, k nearest neighbor search finds the k closest points in X to a query point or set of points Y.

IV. Results and Discussions

Figure 3 shows the spreading of pixel values after Adaptive Histogram equalization (AHE) of capillary images bringing out more detail. In the next step, we apply smoothing filter to remove the noise while retaining the edges and lines. AMF is applied after AHE. In the next step, 2-level DWT for the image is computed as shown in Figure 3.1.1. Here the Image is decomposed into 4 sub-bands LL, LH, HL, HH sub-bands respectively. The sub-band denoted by the LL is approximately at the half the original image. Here daubechies2 is considered. PCA is employed to reduce the dimension of the data. After this, the images are classified as Normal and Hypertensive using k-NN classifier independently.

V. Conclusion and Future Work

In this study, we have employed various image enhancement techniques on Nailfold capillary images of normal controls and hypertensive subjects acquired using USB digital microscope. Histogram equalized images are further smoothened using Adaptive median filter. Adaptive median filter also has the advantage of noise reduction without significant loss of edges. Daubechies wavelet has been employed for feature extraction. PCA is used for reducing the feature vector size. Classifier used is KNN, of which KNN demonstrated higher classification accuracy. Thus a histogram equalized capillary image is smoothed using Adaptive Median filter followed by feature extraction using db2 wavelet. Our classification model can be further checked using more number of samples of Nailfold capillary images. Also, the model needs to be tested for other diseases such as Diabetes Mellitus. A combination of classifiers can also be tried to improve the classification of capillary images.

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