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PERFORMANCE ANALYSIS OF TRANSFORMATION TECHNIQUES WITH PREDICTION ALGORITHMS ON DIAGNOSING CAROTID PLAQUES

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ABSTRACT

This paper, attempts a novel prediction algorithms involving smart concepts is being developed for the medical diagnosis field applications. Premature diagnosis of cardiovascular diseases (CVD) is of paramount significance, being the principal basis of fatality in western countries. Fat or cholesterol deposition on the walls of the arteries results in the growth of intima media thickness (IMT). These depositions also called, as carotid plaques are the potential indicators of the CVDs like atherosclerosis. Although majority of the literatures have dealt the prediction of carotid plaque ominously, but, this paper attempts to put a light on the performance indications of different prediction algorithms which involves intelligent techniques like Artificial Neural Network (ANN) and Support Vector Machines (SVM), with the transform based feature extraction methods like Wavelet transform, Curvelet transform, Haar method and Integer wavelet transform. Matlab^{TM} simulations on about 20 images of arteries with and without carotid plaques is carried out which indicates that, the integer wavelet with Haar Wavelet method performs better in the faster prediction of the plaques. The proposed methods depicted in this paper show the efficacy of the developed method which is justified by the simulation results.

Keywords: carotid plaque detection, wavelet transform, curvelet transform, integer wavelet, artificial neural networks, support vector machines.

1. INTRODUCTION

The Carotid plaque in the human cardiovascular system reflects the ageing problems occurring in the arteries and valves. The physical stress occurring on the carotid artery would heavily damage it. The stress is due to the blood pressure, blood flow and tethering due to the nearby tissues. The physical estimation like the artery wall structure, thickness, and stiffness are indicators of the presence of carotid plaque in the arteries. High-resolution ultrasound imaging has given a more defined visualization of the carotid artery images. The techniques for the carotid plaque estimation includes measurement of intima-media thickness (IMT), severity of stenosis etc,. For decades, the prediction of the carotid plaque was a challenge for medical fraternity in terms of early detection and diagnosis.

Different methods as discussed by Efthyvoulos [1] have given us the review on different carotid plaque prediction methods. The snake-based approach as explained by D. Cheng [2] and the contouring approach in N. Santhiya Kumari [3] were used to segment out the IMT. For more accuracy, the snake method was introduced with the manual initialization as referred by C. P. Loizou [4]. The snake method has a disadvantage; if it is not initialized properly with the region of interest then it would predict a false contour and also a false IMT. So in order to overcome this, morphological methods like the multilevel decomposition were used where the threshold values will be separated as low medium and high values.

The more stable plaque values are found in the higher values of the sub-bands of the multilevel decomposition as inferred by E. Kyriacou [5]. In the same line, many different classification techniques are used for the prediction process like, neural classifiers, which include Self Organizing Map (SOM) as defined by C. I. Christodoulou [6], Back Propagation Network (BPN) as used by S.G. Mougiakakou [7], Radial Basis Function (RBF) and Probabilistic Neural Network (PNN) as used by E. Kyriacou [5], [8]. An experiment which included around 32 features containing some grey scale features along with the severity of stenosis were used by Rajendra Acharya U [9], to classify the symptotic and asymptotic images of carotid artery using the SVM classifier. Güler N.F. [10] had employed a procedure through which the Doppler signals from the carotid arteries are gathered as the feature to be trained on the neural network for the carotid plaque prediction.

Wismüller A [11] employed SOM in ANN for predicting the segmented carotid plaque on the carotid artery images. Nikolaos N [12] had defined a method that takes the mean and the standard deviation from the details obtained from different transformation techniques like Discrete wavelet transform, Stationery Wavelet Transform, Wavelet packet and Gabor Transform are trained and tested using SVM and ANN and a comparative study is elaborated. The experiment done by U Rajendra Acharya [13] used three sets of features like, Discrete wavelet transform that too the horizontal component of it, Higher Order Spectra (HOS) and the texture features like the standard deviation, the third moment of co-occurrence matrix and Run Length Non-uniformity and the classification technique used was the

SVM technique. Radial Basis Function (RBF) was used as the kernel in the classification.

Rajendra Acharya [9] [13] had introduced the index called Symptomatic Asymptomatic Carotid Index which is a feature generated by the combination of HOS feature, Wavelet feature and the texture feature. In their paper the features that are extracted are the decomposed images from the transformation technique itself. Wavelet transform, Curvelet transform and integer wavelet transform were considered as tools for feature extraction and the ANN and SVM are used as the classification technique. Multiple plaque deposit and by the way thicken the artery thus causing Atherosclerosis [15].

Atherosclerosis and high blood pressure are the main causes for heart disease and stroke [14]. Therefore, atherosclerosis is a real problem [15]. A brief literature review of work done by various researchers till date was analyzed, some of the drawbacks & lacunas were observed, where were taken into consideration in our work.

The organization of the paper is as follows. A brief review of the work done by various authors in the relevant field was presented in the introductory section. Section II presents the overview of the feature extraction using some transformation techniques. Inferential techniques are presented in section III along with the implementation part in section IV. The section V deals with the Matlab simulation results and its discussions. Conclusions are presented in section VI followed by the references.

2. FEATURE EXTRACTION USING TRANSFORMATION TECHNIQUES

Sparse representation of the image data, which would pack the larger image data into a typical data, has been used in an exclusive manner for the feature extraction in many diagnosis techniques. Wavelet Transform, which is specialized for the local analysis, is more suitable for the local feature extraction on the medical images like the Carotid Plaque. The ability of the wavelet transform to extract the local intensity information makes it a powerful feature-extracting tool. But the orientation selectivity of the wavelets is poor which would only obtain limited directional information. Horizontal, vertical and the diagonal activity of the images are captured by the high pass and the low pass filter used for wavelet based decomposition.

The wavelet transform does not act effectively on the edges and curves in the images. Curvelet transform is the extension of the wavelet transforms, which would be able to capture the structural information from an image based on the multiple orientations in frequency domain. Although the Curvelet transform has the disadvantage of ringing effect during the image reconstruction, which does not affect the carotid plaque prediction because this paper deals only with feature extraction in terms of image decomposition. The work done in this paper uses the block based Ridgelet transform as the Curvelet transform. The images were collected from the internet for applying different methods such that the robustness of the method can be

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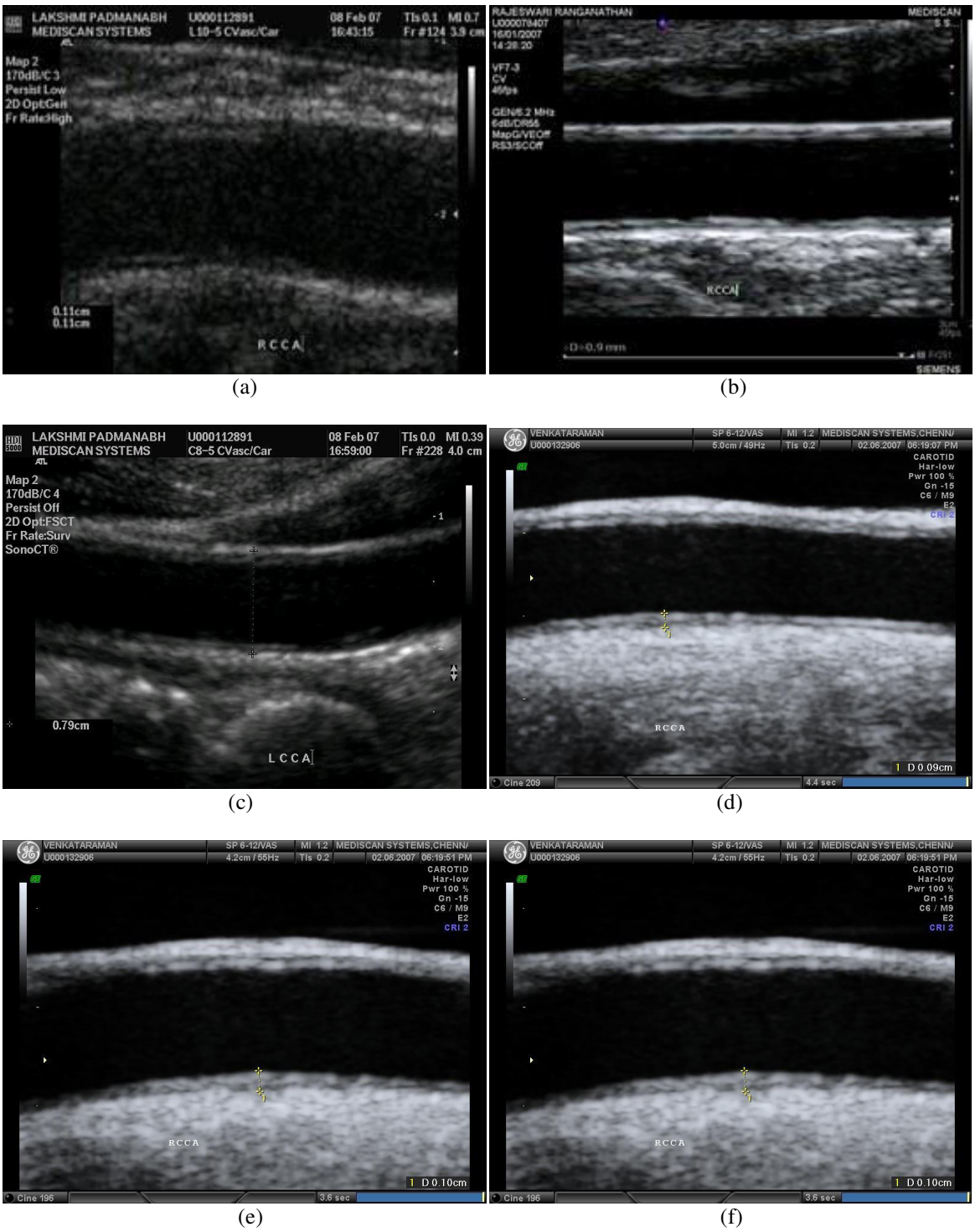

Figure-1 (a) - (f). Carotid artery images from the database & the results of the simulation effects the images into sub-bands for the prediction to occur. Some carotid artery images used are as shown in Figure-1(a) & (b).

In the wavelet and the Curvelet transforms, the decomposition and the reconstruction of the images takes place using the convolution properties of the filters and are quite involved. Integer Wavelet transforms or the lifting wavelet transform, which is computationally faster, is also taken for comparison. Lifting Scheme is advantageous to the wavelet transform technique because unlike wavelet transforms, which involves floating point calculation, it involves the integer calculations for decomposition and reconstruction. Lifting scheme goes through both forward and inverse transform in a symmetric pattern, which would help in reducing the computational complexity.

Low pass filters and the high pass filters used in Haar Wavelet transform, Daubechies Wavelet transform, Curvelet Transform and Integer wavelet transform from

the literature and are defined as follows. The image is cut for the region of interest by the use of cropping technique and a new performance is obtained with more accuracy. When the image was not cut for the region of interest (ROI) the accuracy was as low as 60% and after the ROI removal the accuracy has gone upto above 90 %, which shows that the accuracy is highly better in the research work proposed in this paper. The wavelet coefficients are obtained by interpolating the low pass and the high pass filter on the images and down sampling it. The tabular column that mentions the low pass and high pass filter coefficients of the different wavelet, Curvelet and integer wavelet transform for decomposition is given below in Table-1.

Table-1. Filter Coefficients.

Filter Name	Low pass Coefficients	Hugh pass Coefficiemts
Haar	[0.7071 0.7071]	[-0.7071 0.7071]
DB2	[-0.1294 0.2241 0.8365 0.4830]	[-0.4830 0.8365 -0.2241 -0.1244]
Curvelet	Ridgelet based	Ridgelet Based
Integer Wavelet	Lifting Scheme	Lifting Scheme

Compared to the segmentation techniques like snake contour methods, the transformation techniques are fast and detailed in analysis. As mentioned in the literature survey, we could make out that the snake contour methods need the initial prediction of region of interest from the images. The computational complexity gets reduced in the transformation technique based image segmentation because that would reduce The ridgelet wavelet transform used in the Curvelet transform is a convolution technique as defined as below in algorithm steps …..

1. Calculate the length of given array
2. Divide the length by 8
3. Taking the parameter x1 =ones (1, 2*length/8)
4. Taking the parameter y1 =convolution with x1 and x1
5. Taking the parameter z1 =convolution with y1 and y1
6. Taking the parameter x2 =ones (1, length/8
7. Taking the parameter y2 =convolution with x2 and x2
8. Taking the parameter z2 =convolution with y2 and y2
9. Find out filter size row m and colum n m = length (z2)/2 and n = length (z1)/2
10. Taking the normalize of z1 and$z2$ as za = z1/max (z1) and zb= z2/max (z2)
11. Creating the filter zb/za = z then do fftshift(z) this is the final filter

The lifting scheme of integer wavelet transform is defined in the following manner w.r.t. 3 important parameters, viz., splitting, prediction, update and is explained as follows.

Splitting: Split the signal x *into* even samples and odd samples: Si is the even sample denoted by (*X2i), di* is the even sample denoted by *X2i+l*. This splitting is the process of removing the odd and even columns of the image into separate matrices of half the size of the columns each.

Prediction: Predict the odd samples using linear interpolation: di is found using the expression in Eq. (1) as:

di {1(Si + Si + d)} (1) The prediction is finding the error between the odd and even samples of the images divided.

Update: Update the even samples to preserve the mean value of the samples: Si is found using the expression in Eq. (2) as:

Si + U (diI +di)} (2) Update step updates the even samples by adding the error with the even samples values.

3. INFERENTIAL TECHNIQUE

An inferential engine that would classify the Carotid Plaque in the images, using the transform-based features is developed in this paper. ANN and SVM were used as the inferential engine and trade-off analysis was done between these two engines. The transformed image becomes the feature of the image to be classified either it was with or without Carotid plaque. ANNs are NP-complete problem that would take more time training the dataset given to it. The number of epochs and the number of nodes are changed in runtime in order to make the classification accurately.

ANN often converges to the local minima not considering the overall picture of the process but SVM is away from this disadvantage. Sometimes ANN may oversee the noise values as also a training signal and it does the same in the prediction phase also, which may lead to false prediction. SVM has reduced structural risk compared to the ANNs. But ANNs are parametric unlike SVM models which are non- parametric, which gives an advantage to ANNs. Another major advantage of the ANNs is that they can have multiple outputs but the SVM does give a single output after prediction.

The ANNs approximates to any kind of process but one have to choose a kernel for the SVM to approximate. SVMs are very fast in learning, but slow in predicting while ANNs learn slow and predict faster. In order to parameterize these advantages and disadvantages, these papers take up the specific problem of Carotid Plaque prediction and analyze the trade-off among different transformation technique for feature extraction with the prediction techniques discussed. The advantages and disadvantages would affect the comparative parameters like the execution time,

performance, training time and number of iterations for each of these methods.

4. IMPLEMENTATION

The implementation of ANN and the SVM techniques using 4 methods, viz., Harr, DB2, Curvelet, Integer method involves two phases, one is the training phase and the other is the testing phase. During the training phase, the important features like in this case, the wavelet transform of the images with and without carotid plaque are taken and trained using the Back Propagation Network in the Artificial Neural Network and in SVM; we use sequential minimal optimization technique. This training will create a mathematical model of the prediction process for both of the above techniques mentioned. In the testing phase the images for the carotid plaque diagnosis is provided as an input for the prediction to be done.

Apart from the traditional wavelet transforms, Curvelet transform and the integer wavelet transforms are used with both ANN and SVM technique to find out which of this combination would perform better in each of the comparative parameters considered. The verification of the output is done with the clinicians and the comparison is extracted from these testing phase of the prediction algorithm. ANN uses the Levenberg-Marquardt algorithm for optimization. The Sequential Minimal Optimization (SMO) as the training method and For ANN simulation using different types of filter, the main parameters used:

Function used for learning: Sigmoidal
Tolerance: 0.0001
Number of hidden layers: 2
Algorithm used for learning: *Levenberg-Marquardt algo*
Kernel function: Linear kernel Function
Optimization method: SMO
Kernel Cache limit: 5000
KKT tolerance measure: $1.0000e^{-3}$
Maximum number of iterations: 15000

5. SIMULATION RESULTS AND DISCUSSIONS

Simulation has been carried out by using MATLABTM using the image processing tool boxes & other subroutines. The database of the MRI images with and without the carotid plaques were taken and subjected to different transformation techniques and the transformed values are taken and provided to the ANN and the SVM models for training. The hardware configuration is as mentioned below required for the process of simulation work. We could obtain the results tabulated in the Table-2.

Table-2. The Outputs after Taking the Region of Interest & Parameter Comparison for Different Transformation Technique with ANN.

Parameter	Wavelet Haar Filter with ANN	Wavelet DB2 Filter with ANN	Curve let with ANN	Integer Wavelet With ANN
Input	67	67	67	67
Hidden layer	30	10	2	0
Output layer	1	1	1	1
Output	1	1	1	1
Epoch (iterations)	4	5	8	12
Neural Network time	0.2 s	0.1 s	0.1 s	2 s
Validation checks	2	5	6	4
Neural network General time	Elapsed time is 7.711450s	Elapsed time is 0.278824s	Elapsed time is 0.282217s	Elapsed time is 2.85 s
SVM time	Elapsed time is 0.807328s	Elapsed time is 0.077782s	Elapsed time is 0.078705s	Elapsed time is 0.082 s

Processor Intel(R) Core (TM) i5-2500k CPU @3.30GHz
The specs of the computing system that were used are mentioned in this context.
Installed memory (RAM): 8.00 GB
System type: 32 bit Operating system
OS: Windows 7 Ultimate (SP-1) service pack-1

In Table-2, the total time taken for the classification that is including training and testing is given as time taken. We could infer that wavelet DB-2 filter method with ANN based method takes less time than any other transform based technique while integer wavelet based method takes more time for training and testing. The classification parameters that are used for simulation using the ANN are mentioned as below. The analysis of the elapsed time taken by each of the algorithm is a key parameter to be analyzed considering the hardware realization of the implementation. The overall time that SVM takes in the testing mode has proved to be very less compared to the ANN testing time as shown in the Table-2. The computer that is used for the purpose of the implementation is as given in the above and that is to mention that a machine with such a capability can be able to classify the carotid plaque. Thus this helps in analyzing what kind of the parameters are

needed to develop the hardware based carotid artery classifier.

For ANN simulation using different types of filter, the main parameters used…….
Function used for learning: Sigmoidal
Tolerance: 0.0001
Number of hidden layers: 2
Algorithm used for learning: *Levenberg- Marquardt algo*
Kernel function: Linear kernel Function
Optimization method: SMO Kernel Cache limit: 5000
KKT tolerance measure: 1.0000 e^{003}

The parameter comparison for the different types of transformation technique with ANN is shown in the Table-2. From the Table-2, it can be observed that DB2 wavelet transform technique fares better results compared to the others w.r.t. the SVM time (0.077782 s) & w.r.t. the neural network general time (0.278824 s) taken for simulations that too for the same inputs (67), thus the method is working faster compared to the other techniques.

The outputs after taking the regions of interest are shown in the quantitative results Table-2. From these simulation results, it can be finally concluded that the work done in this paper is highly improvised compared to the other methods. Different feature extraction technique had reacted to the algorithm in a different way and thus having a thin line between the implementation advantages. Although the difference is thinner when the testing on a large database is carried out then this thin differences would be very much indicative. The combination of different feature extraction algorithm and the decision making algorithms put light on how each of these algorithms are very effective by means of hardware implementation. The performance evaluation being the prime need for the hardware feasibility study for feature extraction and the classification method.

6. CONCLUSIONS

Performance analysis of transformation techniques with prediction algorithms on diagnosing carotid plaques was successful carried out in this paper with good results. The classification of the carotid plaque using different transformation technique with the classification technique was implemented and the comparative analysis was done for the different combination of methods in order to develop a trade-off among the methods. It is observed that the Wavelet DB2 Filter with ANN has performed better among all these methods w.r.t. least run time.

The classification of the carotid plaque using different transformation technique with the different classification technique was implemented and the comparative analysis was done to develop a tradeoff among the methods. This paper suggests that for faster classification of carotid plaque it is optimal to choose Wavelet DB2 Filter with ANN as the classification algorithm. As the number of images taken for this experiment is less in number that does not affect the classification time much, but further implementing on a large database would affect the time taken for classification. The analysis was done for the whole image which was working for only few images. But now, we have taken out the region of interest from the image and done the analysis which has more accuracy.

NOMENCLATURE

CVD	Cardio Vascular Diseases
IMD	Intima Media Thickness
ANN	Artificial Neural Network
BPN	Back Propagation Network
SVM	Support Vector Machines
RBF	Radial Basis Function
HOS	Higher Order Spectra
SACI	Symptomatic Asymptomatic Carotid Index
ROI	Region of Interest
SMO	Sequential Minimal Optimization
KKT	Karush-Kuhn-Tucker

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