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Robustness to Noise Test for the Machine Learning Model of Neurology Problems

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ABSTRACT

Cerebral Vasospasm (CV) is a narrowing of the blood vessels in thehuman brain. Transcranial Doppler (TCD) is anoninvasive device and can be used~~as~~ for diagnosis various brain diseases and CV detection. TCD signals can be contaminated with noise from sources power line and electrodes before using these signals in signal processing steps. The goal of this study is to evaluate the CV detection model accuracy against the noise. Time-frequency feature extraction ~~was~~isused as a technique to enhance the detection accuracy and efficiency. In theprevious studies, we extracted CV and normal classifier model by using the combination of 12-time frequency features, but the results generateda moderate accuracy when examined in real-time[put a reference]. In this study, we test the robustness to noise of proposed model; experiments~~were~~areapplied in real-time on the recorded TCD signal from theright and left middle cerebral artery (MCA) region of thebrain of 160 subjects. The experimental results give~~us~~87.5% sensitivity for CV. Thispercentage starts to decrease at 30%???of signal to noise ratio (SNR), and 89% specificity for normaland this percentage starts to decrease at 60%??? of SNR.

KEY WORDS: *Neurology, Signal Processing, Machine Learning, Feature Extraction.*

INTRODUCTION

Transcranial Doppler (TCD) is generally used to diagnose cerebral hemodynamics, stenosis, trauma, aneurysm and hemorrhage [1]. ~~To measure~~The measurement of the brain blood flow rate requires ~~an~~ advanced imaging processing techniques. The Doppler concepts in the medical field depended on transmitting frequency to thebrain and observingthe difference between the transmitted and reflected frequencies.The Doppler shift $\mathbf{\Delta f}$ is given by ~~the equation (1):~~[put a reference]

$$\mathbf{\Delta f} = 2\frac{v}{c}\,\mathbf{F}\cos\theta \qquad (1)$$

where $\mathbf{F}$ is the transmitted frequency, $\boldsymbol{v}$is the velocity of blood, $\boldsymbol{\theta}$ is the beam-vessel angle and $\mathbf{c}$ is the speed of sound in tissue. TCD can detect the decreaseor increase in blood flow rate or resistivity variation. The second choice is the magnetic resonance or angiography techniques, but those techniques are very expensive, and ~~they~~ require~~the~~continuous attendance of expert's physicians.

In the literature, TCD signals were classified by Ozturk et al. ~~by~~ using neuro-fuzzy classifier of the non-stationary chaotic invariant TCD signal [2]. Uguz proposed the Rocchio-based hidden Markov model(HMM) and fuzzy discrete hidden Markov model (FDHMM) for enhancing the classifications of TCD signals [3,4]. Guler et al. applied the fast Fourier transform (FFT) and adaptive autoregressive-moving average (A-ARMA) for spectral image analysis of TCD signal. A-ARMA produced the best spectral resolution [5]. Serhatlioglu et al. used the neural network as a classifier of FFT transcranial signals [6].

As seen in many studies, Fourier transform is usedwidely, but it is a technique thatcannot display all time and frequency information details which means that it has a significant problem to detect many diseases due to poor of spectralresolution and the different noise power especially in non-stationary signals. So, we will tryin the future to use the wavelets as a feature extraction methods~~due to~~becauseit gives optimal time-frequency resolution in all ranges of frequencies. Themajor advantage of the wavelet transform isthat the window size can be varied for low and high frequencies~~and ahigh one~~. For this benefit, thewavelet transform is applied in image processing [7,8], signal processing [9,10] and biomedicine [11].

In this work, TCD signals recorded from the right and left middle cerebral arteries (RMCA, LMCA) of 16 patients were sent by auxiliary cable to a personal computer (PC) ~~by~~ using a 16-bit sound card. The machine learning model methodwas applied to the recorded signals in order toclassify the CV.The resultswere compared with the physician's decision for verification ofthe proposed work and then,~~testing~~ the extracted model is tested at~~with~~ different noise power. Internal or external noise to the signalwill cause appearanceof anew or extra frequency which can influence the estimation detection of neurology problems.

The following sectionpresents the structure of the methods and techniques for TCD signal processing for medical diagnosis the cerebral vasospasm(CV). In the Results and Discussion section, we display the results of CV detection ~~with~~

taking into consideration the effect of noise on the dataset and the performance of the different SNR. Finally, the Conclusion section summarizes our studies and proposes future research directions.

RESEARCH METHODOLOGIES

A.TCD Signal Collection

An audio database has 160 wave files of 3-10 seconds in duration with ~~sampled~~a samplingrate of 44.3kHz. All of them were transferred from TCD to the PC~~personal computer~~ by anauxiliary audio cable. Two steps are applied on the dataset to detect the CV subjects. The first is the feature extraction and then the classifier. All the results are compared with the decision of vascular neurologist.

B.1 Feature Extraction

This stepis used in machine learning and audio signal processing to compress the redundancythat is found in thedataset [12], where the outputs datasets are small in size and help toenhance~~increase~~ the performance of the classifier. We used the two domains,time and frequency, features. The time domain features are zero cross rate, energy, and energy entropy. The frequency features ~~that~~ used are Mel-frequency cepstral coefficients (MFCC), chroma coefficients, spectral centroid, spread, entropy, spectral roll-off, spectral flux and harmonic ratio. We displayed the effect of each of these 12 features on the CV detection in the results section. These features were fed to different classifiers.

B.1.1 Zero Crossing Rate and Harmonic Ratio

ZCR isused as a feature in the narrowband signals. It occurred when the sample changes the algebraic sign [13]. The average rate can be used as a feature in the classifier input.On the other hand,concerningthe harmonic ratio, we can assume the TCD signals as quasi-periodic to calculate the fundamental period by applying thealgorithmexplainedin [14]~~.~~ ~~By~~bycomparing the signal with itsshifting.

B.1.2 Energy and Energy Entropy

They are usedfor feature extraction in theaudio signal analysis. The energy entropy is measured ~~my~~bydividing each wave file into frames and each frame to segments then ~~normalized~~normalizingby the energy of the frame [15].It can reflect the sudden energy transition.

B1.1.3 Mel-Frequency Cepstral Coefficients and Chroma

MFCC is defined as the short time speech spectrum; it can be measured by taking the log to thepower spectrum of nonlinear Mel frequency and then applying the linear cosine transform [16]. MFCC ~~are~~isused in speech analysis and in theapplication of human speech prediction [17,18]. It also measures the signal cepstral;wecalculated the first 13 coefficients forCV detectionجملة غريبة. On the other hand, Chroma is the displaying of spectral energy as Wakefield. It can be measured by transforming the Discrete Fourier transform (DFT)coefficients into bins. It iswidely used to predict the music thatis produced from piano [19].

B.1.4 Spectral Centroid, Spread, and Entropy

They are used for music~~[20]~~ and speech discrimination [20]. The spectral centroid represents the mass center of the spectrum, and the spectral spread is the calculated by the second moment of the spectral centroid. With regards tospectral entropy, it can be obtainedusing the same technique like the energy entropy. But,in this technique, the frame spectrum is dividedto sub-bands and is then normalized by the energy of spectrum frame.

B.1.5 Spectral Roll-off and Flux

Spectral roll-off isused to distinguish between the voiced and unvoiced signal [21]. It can be ~~measured~~obtained by calculating the frequency ~~that~~ under 85% of the concentrated spectrum magnitude. With regard to the spectrum flux, it monitored the deviation between two successive frames.

B.1.6 Classifiers

First,for standardizingthe feature values, we apply feature scaling and mean normalization as a preprocessing step. We applied various classifying methods like adecision tree, K-nearest neighbors (KNN), support vector machine (SVM), and logistic regression. We found that bagged decision tree

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and KNN gives highest detection percentage.

RESULTS AND DISCUSSION

Firstly, we should test the efficiency and evaluate the success of the proposed algorithm that isbased on 12 features. The 12 featureswere added and the results are calculatedin terms of sensitivity, specificity, and accuracy using thedecision tree classifier. The main purpose in this article is to test the influence of noise on the tested dataset. The experimental results of 160 wave files with thebagged decision tree classifier are 87.5% for sensitivity and 89.77% for specificity, but all these results from the previous studies [22] and without adding any type of noise to signal amplitude؟؟صلحها شوف قصدك إيه.

In the TCD device, Power M-mode program is built-in TCD. Itcan simulate the velocity of blood in RMCA, LMCA, and Basial artery (BA) with calculating its power, the number of samples, mean, DIAS (Desmoteplase (chemical compound) in Acute Stroke) and PI (pulsatility index is calculated by peak systolic velocity-end diastolic velocity)/time averaged velocity). Thiscan be shown in Figure 1.After that, the recorded wave file is taken from TCD to Matlab to confirm signal processing on wave file and then to detect the patient in normal case or CV.~~ where~~Figure 2 shows the signal before training and testing by machine learning. Later in, it would be desirable to predict CV before it happens.

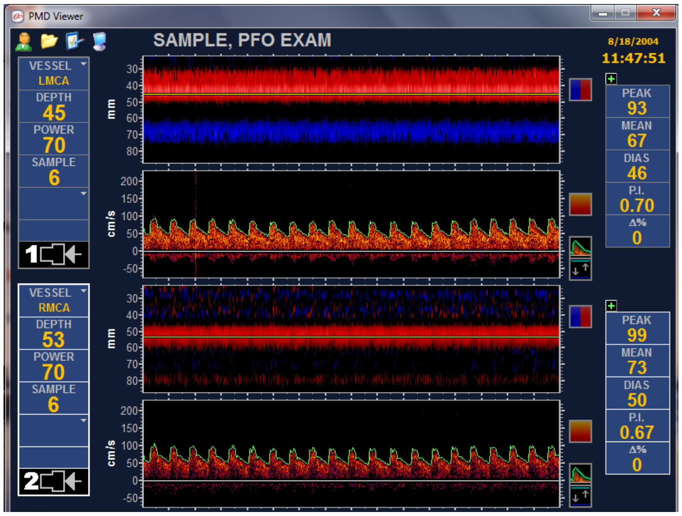

Figure1. TCD Signal Monitoring.

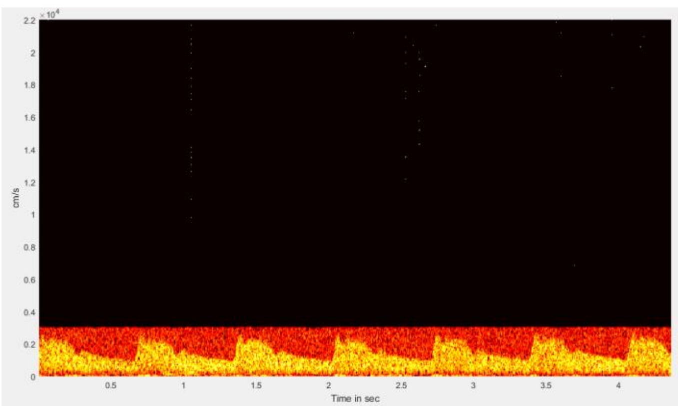

Figure 2. Simulated TCD Signal Before Appling Machine Learning Step.

As seen, there are slight differences between the TCD signal and the signal that reached the Matlab. So,it is important to study the robustness to noise on the dataset with different noise power. Figure 3 shows the evaluation of the proposed model to noise robustness, by adding the Additive White Gaussian noise (AWGN) to the dataset~~, where the x axis is the signal to noise ratio (SNR) percentage and y axis are the sensitivity and specificitypercentage. ~~The experiments show thatthe CV detection model is robust~~ness~~ to noise until 30dBSNR and~~but~~in the normal detection until 60dBSNR. ~~These~~ThisAWGN can ~~come~~yieldfrom the TCD cable, power line or TCD probes.

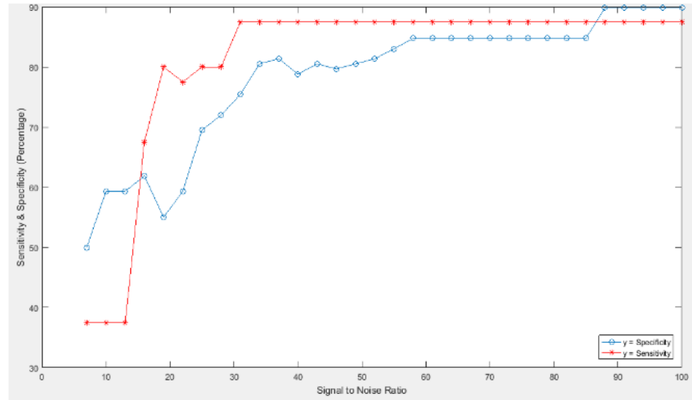

Figure3. SNR Percentage with Sensitivity and Specificity Percentage.Put unit dB in x-axis

CONCLUSION

Thisresearch aimed to test CV detection model against the noise by using 12 features with ensemble bagged decision tree. When the developed algorithm is tested, the classification efficiency performance ~~is~~achieves87.5% sensitivity and 89% specificity.

But, by applying difference noise power ratio, it givesus a different results at 60 dBSNR for sensitivity and 30 dBSNR for specificity. In a future work, we can use the wavelet feature~~s~~as anadditional feature with the proposed model as an assistant diagnostic tool for brain problems evaluation and decreasing the physician's attendance in the neurology clinics and on other hand denoising or eliminating ~~of~~ noise using infinite impulse response filter (IIR).

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