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Time Frequency localized Improved S-transform for EEG Signal Analysis

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Abstract Many signals in nature are non-stationary and their attributes vary with time. Time-frequency analysis is the approach used to detect the time-varying behavior of the signal. Due to the change in the frequency with time, Fourier based approaches does not provides useful results. In this paper, we applied the stockwell transform (ST) based approach for time-frequency decomposition on Electrocardiograph (ECG) signal. The S-transsfrom based approach detects the condition on which frequecy of ECG signal changes for the detection of the driving Fatigue condition. The results show that the S transform can detect the various stages of drivers fatigue condition efficiently which can helps to prevent the accidents on roads.

Index Term EEG, time-frequency analysis, S-transform, driving fatigue.

I. Introduction

EEG (Electroencephalogram) signal[1] is the electrical changes of the mind, which is recorded by joining cathodes to the scalp. The mind is a tremendously complex structure and contains various data related to the human soul and natural structures. Along these lines, numerous scientists from sorts of fields constantly separate and break down the understood data of EEG by a wide range of signal processing techniques. Here, the fundamental strategies in EEG examination are time-frequency analysis. Time-frequency analysis is a useful method by which one-dimensional signal can be transformed two-dimensional signal. When we apply it on any time series data, not only it reveals the frequency distribution but also the time duration of every component[2-7]. Various time-frequency methods to analyze the EEG Data are Short-Time Fourier Transform (STFT), Wavelet Transform (WT), Gabor Transform, Wigner-Ville Distribution (WVD), Hilbert-Huang Transform (HHT) and so on. S-transform is developed based on the Short Time Fourier Transform(STFT) and Continous Wavelet Transform(CWT). The S-transform, time-frequency representation of a time series. It uniquely combines frequency-dependent resolution that simultaneously localizes the real and imaginary spectra. The basis functions for the S-transform are Gaussian modulated cosinusoids so that it is possible to use intuitive notions of cosinusoidal frequencies in interpreting and exploiting the resulting time-frequency spectrum. With the advantage of fast lossless invertibility from time, to time-frequency, and back to the time domain, the usage of the S-transform is very analogous to the Fourier transform. In the case of nonstationary disturbances with noisy data, the S-transform provides patterns that closely resemble the disturbance type and, thus, requires a simple classification procedure. Further, the S-transform can be derived from the continuous wavelet transform (CWT) choosing a specific mother wavelet and multiplying a phase correction factor. Thus, the S-transform can be interpreted as a phase-corrected continuous wavelet transform. It has been successfully used in electrical engineering [8], geological engineering [9], noise filtering [10] and other fields.

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II. The S-transform

A. Introduction

In recent years, Time-Frequency analysis of the non-stationary signal is one of the most concerned topics of research in seismic signals processing. It is the capable technique for investigation of the non-stationary signals. It provides the jointly distributed information between time domain and frequency domain, which provides knowledge about the time instants where frequency changes along with time. Such as the Short-Time Fourier Transform (STFT), Wavelet Transform (WT). Both transform algorithm is easy and also free from the interference of crossover terms. The only limitation is the Heisenberg uncertainty principle; that is why peak time-frequency resolution is not achieved. In STFT resolution is destitute due to fixed window length. While basis functions are used in Wavelet Transform (WT), which expands and contracts with frequency.

III. The Stockwell Analysis

let consider a signal h(t); The Stockwell[11] change is characterized as the Fourier transform of the result of time arrangement h(t) with Gaussian window $\psi(t)$ situated at t= τ.

$$S(\tau, f) = \int_{-\infty}^{\infty} h(t)\psi(t-\tau, f)e^{-j2\pi ft}dt \qquad (1)$$

where f is the frequency, τ is the center of time window function.

Another way to define this integral in more efficient way is to define the integral

$$U(t,f) = h(t)e^{-j2\pi ft}dt \quad (2)$$

then substituting in equation

$$S(\tau,f) = \int_{-\infty}^{\infty} U(t,f)\psi(t-\tau)dt = U(t,f) * \psi(t,\sigma) \quad (3)$$

where * denotes the convolution operation. if $B(f,\alpha)$ is the fourier transform of $S(\tau,f)$. then

$$S(\tau,f) = \int_{-\infty}^{\infty} U(f,\alpha)e^{-j2\pi\alpha\tau}d\alpha \quad (4)$$

from convolution theorem, we know that

$$U(t,f) * \psi(t,\sigma) = \int_{-\infty}^{\infty} U(f,\alpha)e^{-j2\pi\alpha\tau}d\alpha \quad (5)$$

since $U(t,f) = h(t)e^{-j2\pi ft}dt$

$$\begin{gathered} U(f,\alpha) = H(\alpha) * \delta(\alpha - f) \\ B(f,\alpha) = [H(\alpha) * \delta(\alpha - f)] * \Psi(\alpha) \end{gathered} \quad (6)$$

$$B(f,\alpha) = \int_{-\infty}^{\infty} [H(\alpha) * \delta(\alpha - f)]\Psi(\alpha)e^{-2\pi f\alpha\tau}d\alpha \quad (7)$$

$$B(f,\alpha) = \int_{-\infty}^{\infty} S(f,\tau)e^{j2\pi\alpha\tau} \quad (8)$$

$$B(f,\alpha) = [H(\alpha) * \delta(\alpha - f)] * \Psi(\alpha) \quad (9)$$

$$[H(\alpha) * \delta(\alpha - f)] = \frac{B(f,\alpha)}{\Psi(\alpha)} \quad (10)$$

Since $H(\alpha) = \delta(\alpha - f)$ is the forward translation of $H(\alpha)$, we can perform a backward translation to recover $H(\alpha)$ from $H(\alpha)*\delta(\alpha - f)$.

$$[H(\alpha) * \delta(\alpha - f)] = H(\alpha - f) \quad (11)$$

$$[H(\alpha - f)] = \frac{B(f,\alpha)}{\Psi(\alpha)} \quad (12)$$

$$[H(\alpha - f) * \delta(\alpha, f)] = \frac{B(f,\alpha)}{\Psi(\alpha)} * \delta(\alpha + f) \quad (13)$$

$$[H(\alpha)] = \frac{B(f,\alpha + f)}{\Psi(\alpha + f)} \quad (14)$$

Therefore $S(f,\tau,\eta)$ is the transform of $h(t)$ at $t = \tau$ and η represents the width of the Gaussian g(t).

$$\int_{-\infty}^{\infty} S(\tau,f,\eta) = \int_{-\infty}^{\infty} X(\alpha + f)W(\alpha,f,\eta)e^{j2\pi\alpha t}dt \quad (15)$$

where

$$X(\alpha + f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi(\alpha+f)t}dt \quad (16)$$

and

$$W(\alpha,f,\eta) = \int_{-\infty}^{\infty} w(t,f,\eta)e^{-j2\pi(\alpha)t}dt \quad (17)$$

we know that Gaussian window $\psi(t)$is defined as

$$\psi(t) = \frac{1}{\sigma\sqrt{2\pi}}e^{\frac{-t^2}{\sigma^2}} \quad (18)$$

and the Fourier transform of the Gaussian window function defined in equation 3.18, is given as

$$\psi(f) = e^{-2\pi f^2\sigma^2} \quad (19)$$

So it is seen from equation 3.18 and 3.19 that in the time domain, the width of Gaussian window is conversely about frequency while in the frequency domain, frequency window $\psi(f)$ is corresponding to scaling variable σ. So we can say that σ is a solitary parameter which controls both time and frequency resolution. In S-Transform scaling parameter(σ) is function of frequency f.

$$\sigma = \frac{1}{|f|} \quad (20)$$

thus the standard S-transform of time series h(t) is given as

$$S(\tau,f) = \int_{-\infty}^{\infty} h(t)\frac{|f|}{\sqrt{2\pi}}e^{\frac{-(t-\tau)^2 f^2}{2}}e^{-j2\pi ft}dt \quad (21)$$

Let consider a three frequency sinusoid signal contain low frequency 20 Hertz, medium frequency 40 Hertz and the high-frequency burst of 75 Hertz. Zero frequency component is also present for at 0.2784 second and 0.8824 seconds. All these signals are present for the short duration of time as shown in Fig. 3.2. Improved S-transform of the signal [Fig.3.2] is as shown in Fig.3.3 and 3.4. It is clearly visible that the Improved S-transform provides better control in the energy concentration over S-transform and both time and frequency resolution is improved. Typical range of m is 0.25 to 0.5 and k is 0.5 to 3. Here the value of m and k are 0.25 and 1.9 respectively. The MATLAB code to generate the given signal is as follows:

$h1 = zeros(1,256);$
$t1 = 1 : 70;$
$h1(1 : 70) = 0.5 * cos(2 * pi * t1 * 100/256);$
$h1(71 : 125) = 0;$
$t2 = 1 : 100;$
$h1(126 : 225) = cos(2 * pi * t2 * 20/256);$
$t3 = 150 : 180;$
$h1(150 : 180) = x1(150 : 180) + cos(2 * pi * t3 * 85/256);$

So we can observe that Improved S-transform gives significant improvement over fundamental s-transform in both time and frequency domain.

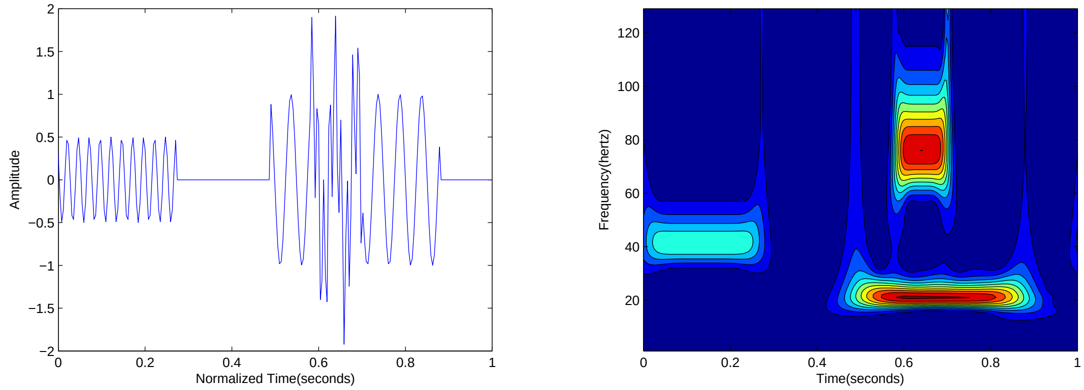

Fig. 1: *Analysis of Synthetic signal with three frequencies using S-transform (a) Input signal with three frequency component 20Hz, 40Hz and 75Hz (b) Time-Frequency distribution of Input signal (a) Using S-transform*

A. Selecting Parameters m and k

Assous and Boashash suggested that the value of m and k need to be selected in agreement with the property of the signal to be analyzed. The two parameters are to be varied linearly such that they control the window and thus improve the time and frequency resolution. The parameter m is approximately set to four times the variance of the signal. The value of k is set to $\frac{1}{N}$ where N is the total number of samples in the signal. Typical range of m is 0.25 to 0.5 and k is 0.5 to 3.

IV. IV. THE ANALYSIS OF EEG FOR DRIVING FA TIGUE

A. Driving Fatigue

Driving Fatigue is a condition of the driver's decreasing driving capacity after a long stretch of constant driving. It is an exceptionally normal l traffic offence and has turned into the "culprit. Therefore, it's of useful significance to Recognize and distinguish distinctive driving states. At the point when the driver is in weakness driving state, irritating temperament, truant personality, memory decay, diminished thinking capacity, diversion and different manifestations create, in another word, driving weakness causes diminished cerebrum work. Hence, distinguishing driving exhaustion in EEG examination is prudent. The EEG signals were recorded when members were driving on the drive test system, and the plan is displayed as takes after.

B. Simulation platform and parameter setting

The simulation studies of all five algorithms are carried out in MATLAB R2015a in an Intel Core i3 processor with 4 GB RAM and 500GB hard disk on Windows 8 (64-bit) platform. All algorithms are allowed to run for 500 iterations, and the obtained performance is recorded.

C. Test Conditions

The examination was intended to inquire about driving fatigue on the drive test system. The driving system software was keep running on the PC and the show demonstrated the street condition like expressway with mountains or bluffs on the two sides. we took the EEG data of four different driving subjects with various driving conditions. The Data is downloaded from the website http://www.cs.colostate.edu/eeg/. The records contain the driver's subjective feelings and physical reactions.

D. The Result analysis

The EEG signals from 4 different drivers were analyzed. The analysis of all data sets revealed consistent performance. Here we will consider the only result of one driver conditions After analysis of the record results shows, the signals from the normal driving state (the lowest score data) and fatigue driving state (the highest score data) were gotten. As is shown in Fig.2, the plots are normalized signals of both normal driving condition and fatigue driving condition respectively.

Even though judging the mind's state by watching the brain waves have general application in the fields medical, research, business and so on, it is hard to watch an extensive measure of data covered up in EEG, for example, essential rhythms of EEG and indicator brain condition. In this manner, as it was watching the EEG signals isn't sufficient.

Figure 3 (a) and 3(b) show time-frequency distributions of S-transform based on the above EEG signals respectively. In Fig.7, clearly shows the huge difference between the two states. When the driving is in the Normal Condition the energy of the signal lies between the 15 to 30 Hz range of the frequencies. this range is considered as a beta activity of the Range. The beta activity is considered about the alertness and an excitation state of the driver, thus indicating the good spirits of the driver. When the driver is in fatigue driving state, the major existing frequencies are 4-15Hz, which is within alpha activity and theta activity. It is observed that with the increase in time there is a decrease in time Beta Activity and an increase in alpha activity

The presence of alpha activity and the decrease of beta activity shows the performance of the central nervous system restrained, thus showing the tiredness and drowsiness.

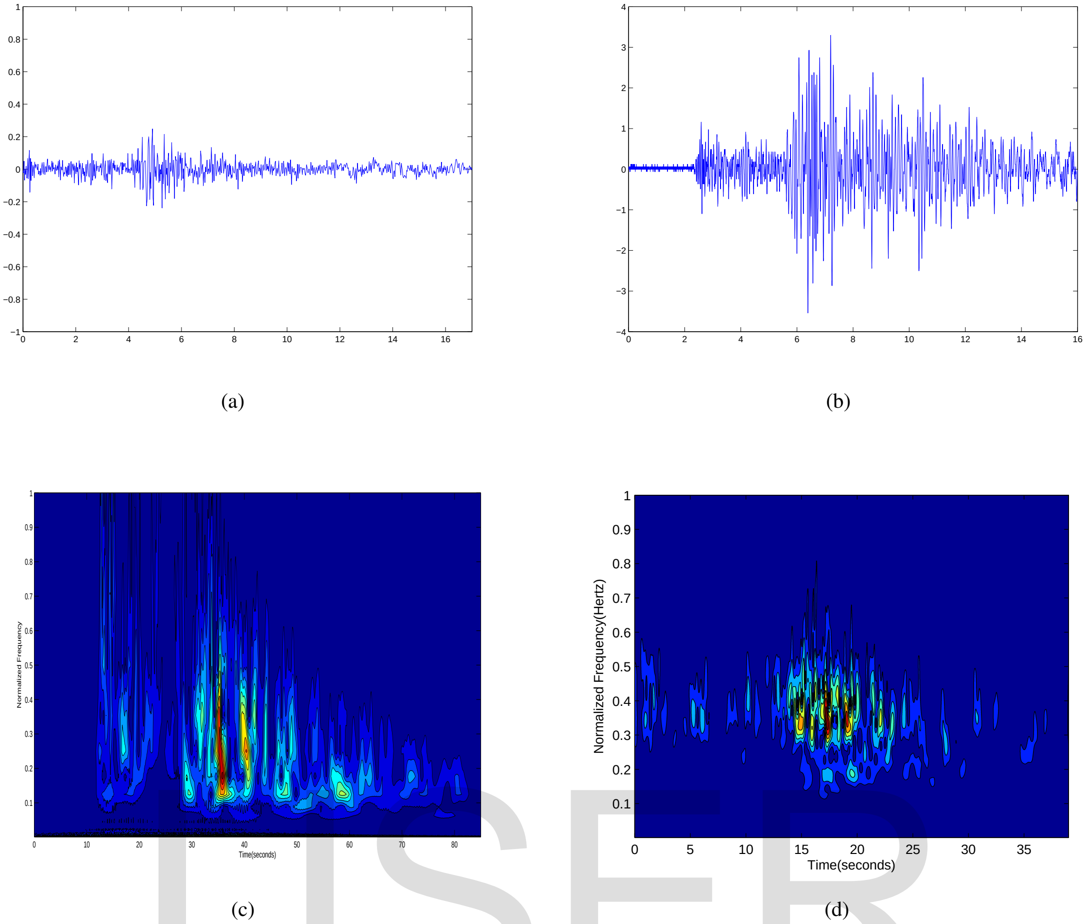

Fig. 2: *Analysis of EEG data Using S transform. (a) EEG signal under Normal driving condition (b) EEG signal under driving Fatigue condition (c) S-transform of EEG signal under Normal driving condition (d) S transform of EEG signal under driving fatigue condition*

The above results depict that the central nervous system is restrained, and the tiredness and dizziness with time at the different driving states can be distinguished well by S-transform.

V. CONCLUSION

In this, we tried to identify to detect various driving states by analyzing the Time-frequency distribution using S transform, Which shows the application of S-transform on EEG signal. EEG signal has very vital information can be used to detect a various physical condition of the Human Being. Here in this paper, we concluded that S-transform can be utilized to analyze the EEG Signal. EEG signal is involved in various kinds of areas and plays a very important role. Since it is random in nature, strong interference, the mass of data so no of problems is remains unsolved. The Time-frequency analysis based on S-transform is a suitable technique and can be used more application on EEG signals and worthy of our intensive and future Studies.

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