Stress Quantification using Fuzzy Analysis of ECG Parameters

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ABSTRACT
Mental stress quantification using fuzzy analysis of ecg parameters is presented here. ECG signal is decomposed using the BIOR-3.9 wavelet family upto three levels. The approximates signals are used for computation ecg parameters like energy, entropy, power, standard deviation, mean and covariance. A fuzzy classifier is designed using trimf function as associate membership in fuzzy analysis. The ecg data base is taken from MIT data base web site.

Keywords
ECG, BIOR-3.9 wavelet, Entropy, Energy, Power, Standard Deviation, Covariance, Fuzzy Logic, Mental Stress

1. INTRODUCTION
The stress assessment is now-a-days a very common need for the peoples who are extra busy in their daily life. Also, the life is becoming more and more busy due to fast moving era. Therefore, stress/pressure on mind is quite inevitable. To cop up with the mental stress, it is first to measure or quantify the stress level so that a proper cure could be initiated. However, for a person responding to the outside world, it is easier to measure the stress and cure for the same. But for a person who is in coma or can not respond, in that case it becomes a tedious task to determine the stress level and cure for the same.

There is previous research in the direction of mental stress assessment. It has observed that the research leads to qualitative model. That is , the model present the state of mind that whether the person is stressed or not stressed. This gives an incomplete picture of the person under scanner. If the same attribute is made quantitative, then the treatment may be more calculated and the response of the treatment may also in turn be quantitative. The presented work is based on this assumption that the stress could be numerically quantified and labeled according to its numerical figure.

2. RELATED WORKS
Fetal ECG (FECG) tele-monitoring is an important branch in telemedicine. The design of a tele-monitoring system via a wireless body-area network with low energy consumption for ambulatory use is highly desirable. [1].

In some cases Wearable ECG sensors can assist in prolonged monitoring of cardiac patients. In this paper, compressed sensing is employed in ECG compression. [2].

A wavelet-based method for the compression of electrocardiogram (ECG) signal is also prepared. The discrete wavelet transform (DWT) is applied to the digitized ECG signal; then the resulting wavelet coefficients are threshold using a threshold based on energy packing efficiency of the wavelet coefficients. [3].

Emotional stress refers to the inducement of stress due to the consequence of a continuous experience of negative emotions (sad, anger, fear and disgust). This work aims to investigate the effect of negative emotions in emotional stress inducement through Electrocardiogram (ECG).

Self Assessment Manikin (SAM) and Self Assessment Form is used to evaluate the subject emotional response during and after the data acquisition, respectively. Statistical features such as heart rate (HR), approximate entropy (Ap En), mean R amplitude (MRA), mean R-R interval (MRRI), standard deviation of normal to normal RR intervals (SDNN) and root mean square of successive heartbeat interval differences (RMSSD) are extracted from HRV signals.[4]

QRS complex is analyzed using the geometrical feature extraction algorithm. A fuzzy classifier is presented for computing the heart rate of the person under test[5]

Heart rate variability is assesses and a correlation is established between HRV and mental stress. A fuzzy clustering is also proposed for clustering of different data leading to construction of mental stress computation[6].

A fourier transform based approach is used to analyse the ecg signal and draw the conclusion for computation of mental stress. [7]

A wavelet approach is presented for analysis of ecg signal and denoising of the same. The denoised ecg signal is then exposed to stress assessment algorithm.[8].

3. METHODOLOGY
ECG data base used in the presented work is based on MIT data base. Stressed and normal ECGs are taken from the MIT data base directory web site for testing and validation purposes. The ecg is decomposed using BIOR-3.9 wavelet family upto three levels and the approximate signal is used for computation of ecg parameters like energy, entropy, power, standard deviation, mean and covariance. The parameters are defined as follows:

$$Energy\ (E) = \sum_{i=1}^{n} x_i^2$$

$$Power\ (P) = \frac{1}{n}\sum_{i=1}^{n} x_i^2$$

$$Mean\ (\mu) = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$Entropy\ (Ent) = -\sum_{i=1}^{n} p(xi).\log_{10} p(xi)$$

$$SD = \frac{1}{n}\sum_{i=1}^{n} (x_i - \mu)^2$$

4. ALGORITHM

Membership Function Used: Triangular-shaped built-in membership function

Matlab Function → trimf

The triangular curve is a function of a vector, 'x', and depends on three scalar parameters 'a', 'b', and 'c', as given by:
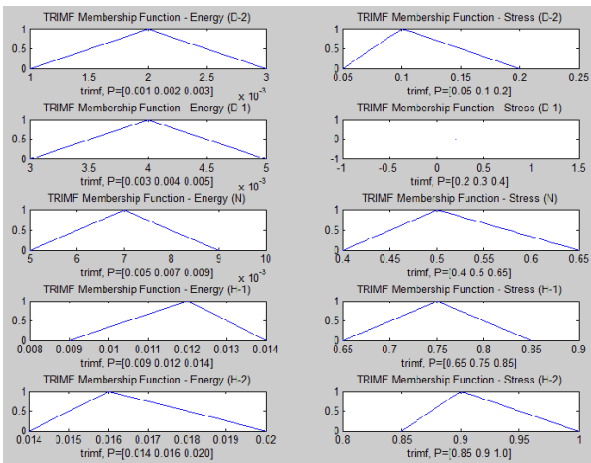
$$f(x;a,b,c) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ \dfrac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases}$$
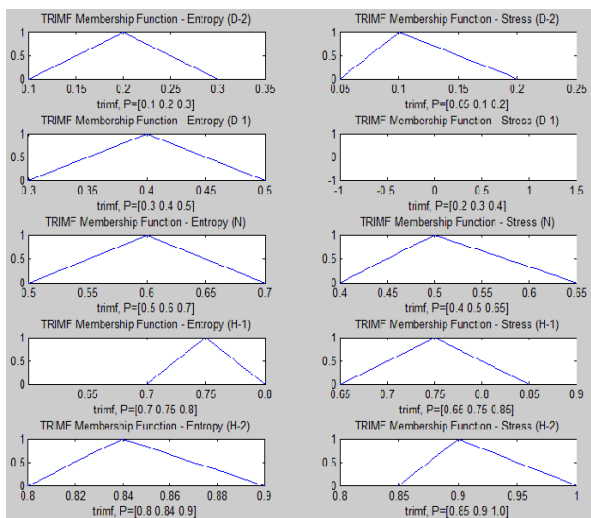
or, more compactly, by :

$$f(x;a,b,c) = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), o\right)$$

The parameters 'a' and 'c' locate the "feet" of the triangle and the parameter c locates the peak.

The membership functions for the energy and entropy values Vs Stress for ecg are shown below:

Energy Vs Stress Fuzzy Membership Function

Entropy Vs Stress Fuzzy Membership Function

Stress Computation using Fuzzy Logic Membership Functions

Rule Base:

Rule # 1: if(Energy is V. Low AND Entropy is V. Low),

Then Stress case → D-2

Rule # 2: if(Energy is Low AND Entropy is Low),
Then Stress case → D-1

Rule # 3: if(Energy is Normal AND Entropy is Normal),

Then Stress case → N

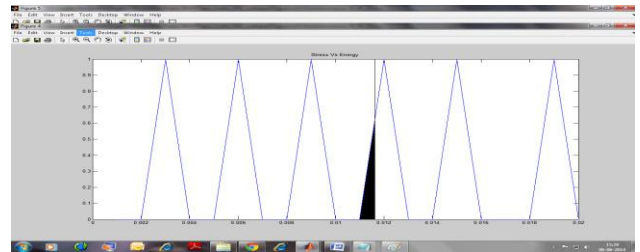Rule # 4: if(Energy is High AND Entropy is High),

Then Stress case → H-1

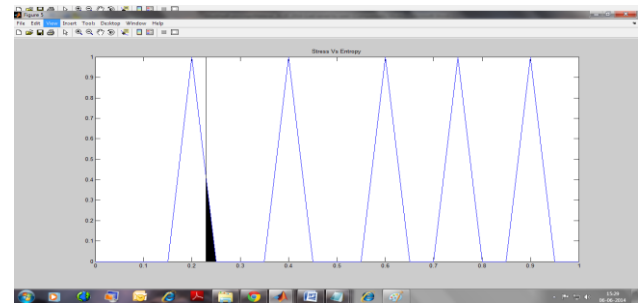Rule # 5: if(Energy is V. High AND Entropy is V. High),

Then Stress case → H-2

5. RESULTS

Case-1

Energy Plot of Case-1

Entropy Plot of Case-1

ECG Analysis

File Path = F:\ Project_Sneha_GNE, Ludhiana\Programs\final_normal_ecg_6.TXT

Date: 6- 6-2014   Time: 15-34-36

Data Base Type --> MIT

ECG Data Length = 4960

Feature Vector Set at Level- 0

Power	Energy	Mean	Std. Dev.	Entropy	CV
0.000	0.002	-0.000	0.001	0.161	0.000

Feature Vector Set at Level- 1

Power	Energy	Mean	Std. Dev.	Entropy	CV
0.000	0.002	-0.000	0.001	0.208	0.000

Final Stress = 0.602511

ECG --> Normal Case

Case-2

Energy Plot of Case-2

Entropy Plot of Case-2

```
                        ECG Analysis
File Path = F:\ Project_Sneha_GNE,
Ludhiana\Programs\final_stress_ecg_2.TXT
Date:  6- 6-2014      Time: 15-31-44
Data Base Type --> MIT
ECG Data Length =  4960
Feature Vector Set at Level- 0
Power   Energy   Mean    Std. Dev   Entropy    CV
0.000   0.012    -0.001   0.001      0.229      0.000

Feature Vector Set at Level- 1
Power   Energy   Mean    Std. Dev.  Entropy    CV
0.000   0.012    -0.001   0.002      0.362      0.000
 Final Stress = 1.265727


ECG --> Hyper Case - 2
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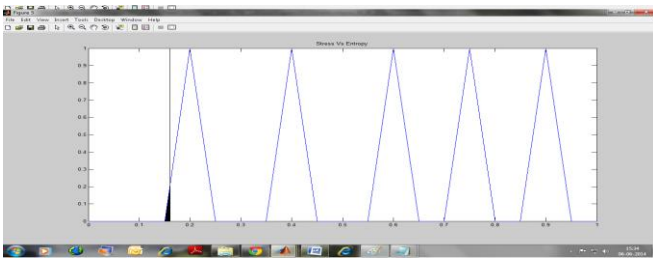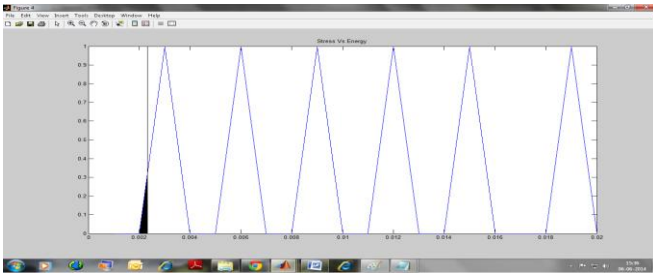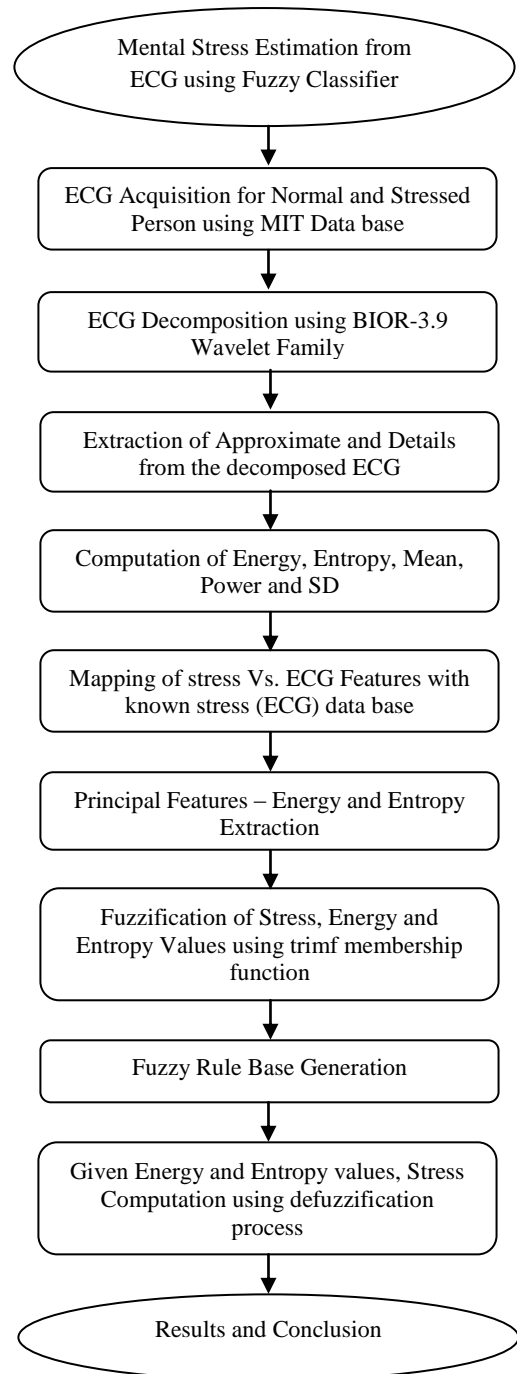
6. CONCLUSION

The presented algorithm has been tested and validated on MIT data base of ecg under normal and stressed conditions The results trends show a fair correlation with medical symptoms of the stress and normal condition persons. It is observed from the results that energy and entropy play a significant role in deciding the stress level. These two are dominant factor in the assessment of mental stress. More work could be done on improving the computation of entropy and energy of the ecg signal so as to authenticate the mental stress computed from the same.

Mental Stress Estimation from ECG using Fuzzy Classifier

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ECG Acquisition for Normal and Stressed Person using MIT Data base

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ECG Decomposition using BIOR-3.9 Wavelet Family

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Extraction of Approximate and Details from the decomposed ECG

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Computation of Energy, Entropy, Mean, Power and SD

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Mapping of stress Vs. ECG Features with known stress (ECG) data base

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Principal Features – Energy and Entropy Extraction

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Fuzzification of Stress, Energy and Entropy Values using trimf membership function

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Fuzzy Rule Base Generation

↓

Given Energy and Entropy values, Stress Computation using defuzzification process

↓

Results and Conclusion

Flow Chart of the System

7. REFERENCES

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8. AUTHOR'S PROFILE

Sneha Mittal has received the B.Tech. Degree in EIE from,IITT POJEWAL, Punjab in 2005 and pursuing his M.Tech in ECE from GNDEC Ludhiana, Punjab.. Her field of interest is in Bio medical based application system developments