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A PATH FOR HORIZING YOUR INNOVATIVE WORK

IMPLEMENTATION OF VOICE-BASED FATIGUE DETECTION SYSTEM

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Abstract: Long duration assignments of work and mental stress cause the development of physical and mental fatigue. Various techniques are being used for detecting the presence of fatigue in human body. If a person is tired or having fatigue developed inside, then it is reflected from his voice or speech. However, there are numerous challenges which have to be overcome in order to have reliable fatigue detection systems based on voice. In this paper, implementation of voice-based fatigue detection system is presented for detecting the presence of fatigue in human body. The proposed system is based on the feature extraction algorithm and soft computing technique, such as Fuzzy Logic. The crisp values of feature vectors are mapped onto the fuzzy values by using fuzzy membership functions and the quantum of fatigue is assessed by evaluating fuzzy inference rules.

Keywords: Fatigue detection, Soft computing techniques, Fuzzy Logic.

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INTRODUCTION

Fatigue (also called exhaustion, lethargy, languidness, languor, lassitude, and listlessness) is a weariness caused by exertion. It can describe a range of afflictions, varying from a general state of lethargy to a specific work-induced burning sensation within one's muscles. It can be both physical and mental. Physical fatigue is the inability to continue functioning at the level of one's normal abilities. It is ubiquitous in everyday life, but usually becomes particularly noticeable during heavy exercise. Mental fatigue, on the other hand, rather manifests in somnolence. Fatigue is considered a symptom, as opposed to a medical sign, because it is reported by the patient instead of being observed by others. In addition to physical, fatigue also includes mental fatigue, not necessarily including any muscle fatigue. Such a mental fatigue, in turn, can manifest itself both as somnolence (decreased wakefulness) or just as a general decrease of attention, not necessarily including sleepiness. In any case, this can be dangerous when performing tasks that require constant concentration, such as driving a vehicle. For instance, a person who is sufficiently somnolent may experience micro-sleeps. However, objective cognitive testing should be done to differentiate the neuro-cognitive deficits of brain disease from those attributable to tiredness. Fatigue is typically the result of working, mental stress, over stimulation and under stimulation, jet lag or active recreation, depression, and also boredom, disease and lack of sleep. The unique characteristics of the military and aviation environment make war fighters and civilian pilots particularly susceptible to fatigue. Being able to quickly and non-intrusively monitor an airman's or soldier's level of alertness prior to and during the undertaking of a critical mission activity would provide commanders with critical information regarding personnel assignments and certainly save lives and increase the likelihood of mission success. Unfortunately, there are no cognitive assessment tests that have been proven to be effective in the field under conditions of high stress and limited testing time per subject. This project work is an approach to the development of a voice-based fatigue prediction system. Changes in the articulation of voiced sounds due to fatigue could be considered representative of changes in the body's voice production mechanisms. Change in discrete voice parameters (such as fundamental frequency and word duration) has been reported in the literature, however, no single voice characteristic demonstrates a consistent and reliable change as the speakers become fatigued. Rather than study any one specific voice parameter, our approach is to observe a more holistic representation of the speech signal, the cepstral transformation associated with specific speech phonemes. The coefficients of this transformation, referred to as Mel-frequency cepstral coefficients (MFCCs) are used in association with an automatic speech recognition system (ASR). Therefore, a straightforward way to automate this process is to use the output of an ASR system to identify the location of

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key phonemes. The time marks produced from the recognition segmentation are used to identify the corresponding MFCC vectors for a given phoneme, and these vectors are in turn used in the fatigue detection system. Since these systems tend to be deployed in extremely noisy environments, the ASR system must be extremely robust, and the fatigue detection system must be tolerant of recognition errors.

Military and civilian experience has shown that long duration assignments present increased risk of performance failures as the mission progresses. This is due to interruption of normal sleep cycles and psychological pressures of the work environment. There continues to be a need for a non-intrusive fatigue assessment system to successfully monitor the level of alertness of person during critical missions and activities. Fatigue is a common symptom of multiple sclerosis (MS) that is purported to cause significant distress and have detrimental effects on daily functioning, social and occupational obligations, and overall well-being. The prevalence of fatigue in MS is high, with 53-87% of patients reporting significant problems with fatigue. The cause of fatigue in MS is still poorly understood. Some researchers have suggested that fatigue is a direct consequence of the MS disease severity and MS fatigue.

- **RELATED WORK**

Various scientists on fatigue detection do lot of research work and most of them are based on human speech. Neha Dhole et al. [1] presented an approach for detection of speech under stress using spectral analysis. Supratim Gupta, Sibsambhu Kar, Shakuntala Gupta, Aurobinda Routray[2] presented the techniques of fatigue detection for drivers. These methods are based on Auditory Vigilance test (AVT) and Visual Response Test (VRT), facial image based measurement of fatigue and Electroencephalographic (EEG) signal analysis. The present paper concludes that the human fatigue should be assessed by Meta-Analysis as it is a complex psycho-physiological phenomenon**.** Ashish Panat et al. proposed a novel approach for analysis of affective speech signals for emotion detection and speaker verification [3]. H.P. Greeley, E. Friets, J.P. Wilson, S. Raghavan, J. Picone J. Berg [4] introduced the Automatic Speech Recognition (ASR) system for detecting fatigue from voice. Milan Sigmund carried out Spectral Analysis of Speech for stress detection [6].

- **Proposed work**

The fundamental purpose of speech is communication, i.e., the transmission of messages. According to Shannon's information theory, a message represented as a sequence of discrete symbols can be quantified by its information content in bits, and the rate of transmission of information is measured in bits/second (bps). In speech production, as well as in many human-

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engineered electronic communication systems, the information to be transmitted is encoded in the form of a continuously varying (analog) waveform that can be transmitted, recorded, manipulated, and ultimately decoded by a human listener. In the case of speech, the fundamental analog form of the message is an acoustic waveform, which we call the speech signal. The following block diagram depicts proposed fatigue detection system as shown in Fig 1

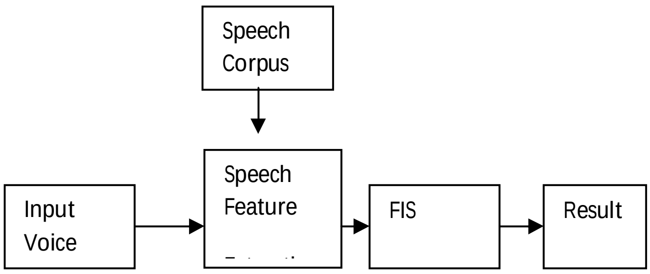

Fig.1 fatigue detection

3.1 Speech Corpus

It is a collection of speech samples taken from persons from various age groups at different periods such as morning, afternoon and night.

Table 1 Speech Corpus

Persons	Number of Speech Samples		
	Morning	Afternoon	Night
Male(age<18)	20	20	20
Male(age>18&age<24)	60	60	60
Male (age > 40)	20	20	20
Female (age <18)	20	20	20
Female(age>18&age<24)	60	60	60
Female (age>40)	20	20	20

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3.2 Speech Feature Extraction

The Feature extraction is the most useful step in this project. There are many features such as fundamental frequency, short time energy, short time zero crossing, spectrum, cepstrum, spectral centroid etc; but out of which mainly three features are more useful i.e. fundamental frequency, short time energy, power spectral density. The feature consists of mean and standard deviation values of all these features. The Feature vector is organized in the format given below:

MFF	SFF	MSTE	SSTE	MSPC	SSPC

Fig. 2 Format of Feature Vector

3.3 Fuzzy Inference System (FIS)

The fuzzy logic is nothing but the rule based system in order to make a well decision. Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than accurate. Fuzzy set theory defines fuzzy operators on fuzzy sets. Fuzzy logic usually uses IF-THEN rules. The Fuzzy Inference system as shown in figure 7 is of 'mamdani' type and has three input variables such as Fundamental Frequency, Short Time Energy, and Power spectral Density. The Result is the output variable of this FIS. The input and output variables are mapped onto various membership functions.

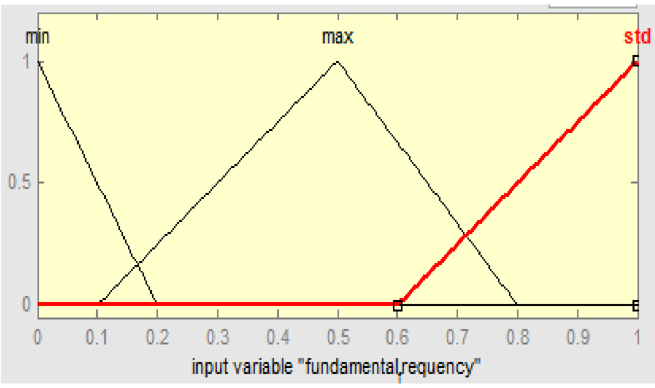

Figure 3: Membership function for fundamental frequency

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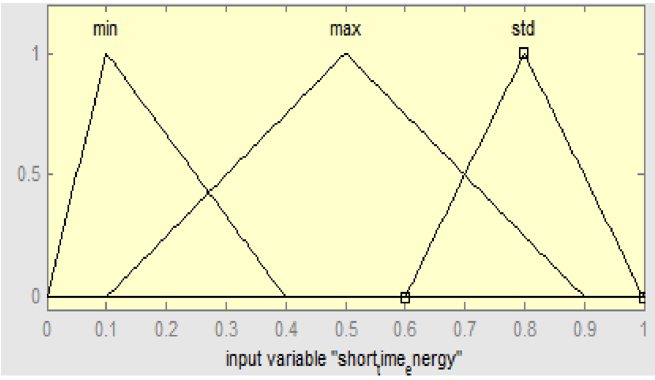

Figure 4: Membership function for short-time energy

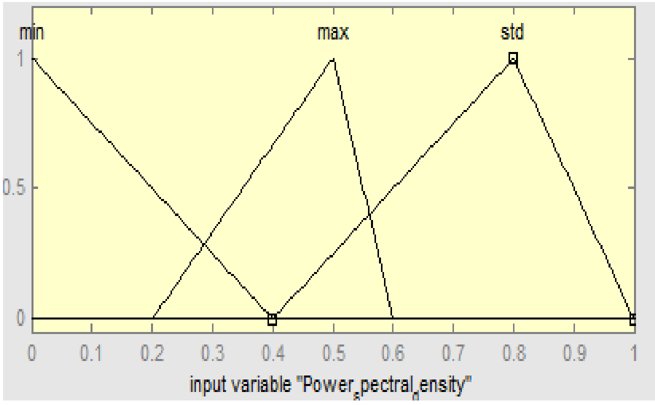

Figure 5: Membership function for Power spectral density

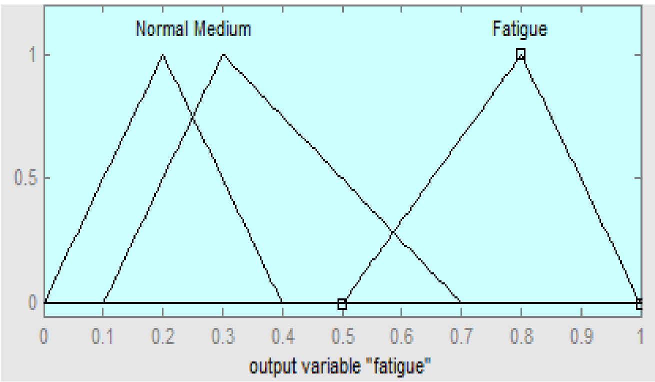

Figure 6: Membership function for output

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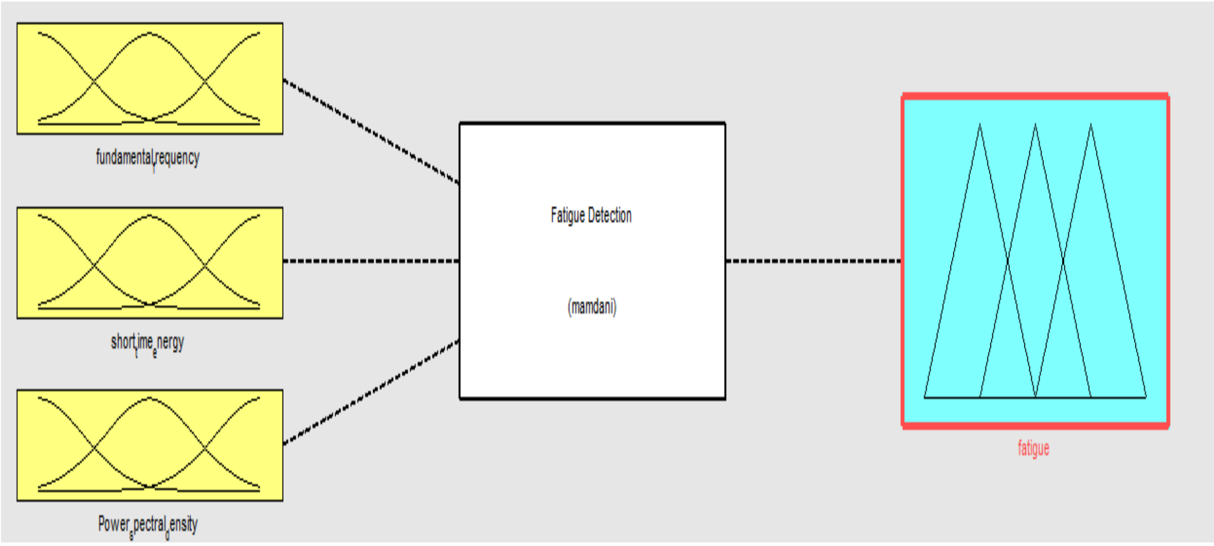

Figure 7: FIS for Fatigue Detection

In the FIS, Fuzzification process takes place when input voice signal of the speaker is applied to the system. Crisp values of the feature vector are converted into fuzzy values through membership functions. The presence of fatigue can be detected by evaluating the Fuzzy Inference rules.

IV. RESULTS

The experiments are carried out on the Neutral samples and samples containing fatigue. The graphs of normal or neutral samples and fatigued samples are plotted below.

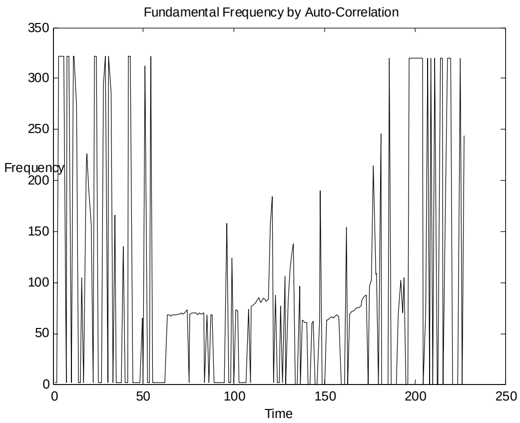

Fig.8: Fundamental Frequency for Neutral Sample

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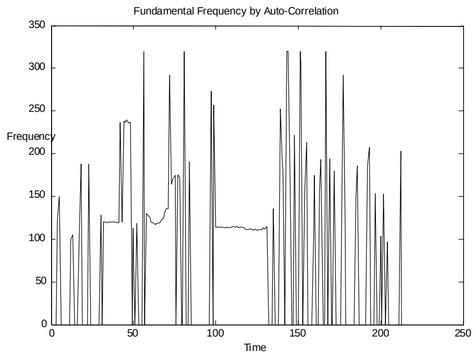

Fig.9: Fundamental Frequency for fatigue Sample

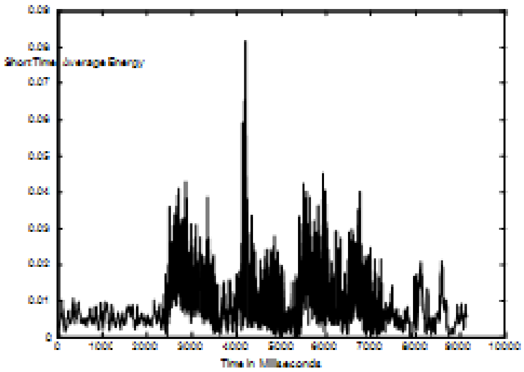

Fig 10: Short Time Average Energy for Neutral Sample

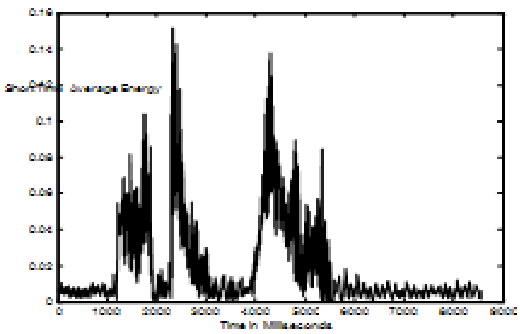

Fig.11: Short Time Average Energy for Stress Sample

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