Brain status recognition using FPGA)

(AI based brainwave capture & processing using FPGA)

Dr. Jayashree Vaddin, Akhilesh Kelkar, Rohini Hedavu, Apoorva Pise.

Abstract—Human brain, the most complex and confusing control system controls the entire human body and its activities just by sending electric impulses to relevant body parts. While doing that, it processes data such as sensory information, awareness, thinking etc. The six brainwaves viz.; Infrared, Delta, Theta, Alpha, Beta, & Gamma are generated by brain are in the range of 0.5 Hz to 30 Hz. The main objective of this proposed project is to acquire and process the human brain waves. Filtering and amplifying of brain signals are big issues while processing brain waves, since the brain signals have very low amplitude and are in the low frequency. We aim to identify the brain state such as awake, normal alert consciousness, physically and mentally relaxed, awake but drowsy, deep (dreamless) sleep, loss of bodily awareness, reduced consciousness, deep meditation, dreams, light sleep, REM sleep, heightened perception etc in real time. To carry out real time processing of digital signals and to maximize the efficiency, processing on a powerful signal processor viz., FPGA is selected. It supports programming for a

specific task without hardware restrictions besides being faster than its embedded counterparts which are not powerful enough for real time processing. So in this paper, we propose a system for the brain wave capturing, filtering and classification using artificial intelligence in MATLAB IDE. The developed program will be converted to HDL using HDL coder of MATLAB and then it would be dumped in FPGA for testing the functionality of proposed system.

Keywords—Brain waves, NeuroSky Headset, FPGA, signal processing, MATLAB, EEG, psycho physiological .

I. INTRODUCTION

Brainwaves or neural oscillations are rhythmic or repetitive patterns of neural activity in the central nervous system. Brainwave speed is measured in Hertz (cycles per second) and they are divided into bands delineating slow, moderate, and fast waves. There are five major types of brain waves [1]. The human brain comprises of around 20 billion neurons which all produce small electrical forces known as signals. At the point when these neurons come in synchronization, small cadenced, electrical possibilities happen in the neuron-transmitters which are particular intersections between the neurons. The more neurons that work in synchronization, the bigger the potential of the electrical motions; the quicker the neurons respond, the higher the recurrence of the oscillations, which will be measured in Hertz.

Brain activity is an essential key to understand the psycho physiological state of humans. Using non-invasive electroencephalograms (EEG) with a dry electrode at the forehead, brain states can be measured and analyzed without complex medical procedures. The electrical signals can be measured by terminals that can be placed on the scalp making use of some conductive glue. After enhancement by an EEG enhancer, the signals can be sustained and readings can be taken which can be then analyzed. These devices are usually big, expensive, and operated by people that have been taught how to use them. However, same activity can be recorded using much smaller, inexpensive and easy-to-use wearable technology. [2]. Table 1 shows the summary of different types of brain waves viz.; Delta waves, Theta waves, Alpha brainwaves, Beta waves & Gamma waves and are also are explained further.

TABLE I. VARIOUS BRAIN SIGNLAS AND THEIR FUNCTIONS

Sr. no.	Types of Brainwave	Frequency Range	Brain State
1.	BETA	14-30 Hz	Awake, normal alert consciousness
2.	ALPHA	9-18 Hz	Physically & mentally relaxed, awake but drowsy
3.	DELTA	Below 4 Hz	Deep(dreamless) sleep, loss of bodily awareness
4.	THETA	4-8 Hz	Reduced consciousness, deep meditation, dreams, light sleep, REM sleep.
5.	GAMMA	30 Hz & above	Heightened perception

Delta brainwaves (0.5 TO 3 HZ) are slow, loud brainwaves (low frequency and deeply penetrating, like a drum beat). Delta waves suspend external awareness and are the source of empathy. Healing and regeneration are stimulated in this state.

Theta brainwaves (4 TO 8 HZ) in theta, the senses are withdrawn from the external world and focused on signals originating from within. In theta dreams are experienced; vivid imagery, intuition and information beyond normal conscious awareness. It's where data is held, fears, troubled history, and nightmares.

Alpha brainwaves (9 TO 18 HZ) are dominant during quietly flowing thoughts, and in some meditative states. Alpha is the power of now, being here, in the present. Alpha waves

aid overall mental coordination, calmness, alertness, mind/body integration and learning.

Beta brainwaves (14 TO 30 HZ) dominate normal waking state of consciousness when attention is directed towards cognitive tasks and the outside world. Beta is a 'fast' activity, present when alert, attentive, engaged in problem solving, judgment, decision making, or focused mental activity, experiences, high anxiety, or excitement.

Gamma brainwaves (30 HZ & ABOVE) are the fastest of brain waves (high frequency like a flute), and relate to simultaneous processing of information from different brain areas. Gamma brainwaves pass information rapidly and quietly. The most subtle of the brainwave frequencies, the mind has to be quiet to access Gamma. [5]

II. HISTORICAL BACKGROUND & CURRENT SCENARIO

These electrical signals can be measured by terminals that can be placed on the scalp making use of some conductive glue. After enhancement by an EEG-enhancer, the signals can be sustained and readings taken can be then analyzed. These devices are usually big, expensive, and operated by people that have been taught how to use them. However, same activity can be recorded using much smaller, inexpensive and easy-to- use wearable technology. Biofeedback headsets like above can measure brain waves, using EEG. They're small bands that sit easily on the head and measure activity through sensors. EEG stands for Electroencephalography; it measures voltage fluctuations from ionic current flows within the neurons of the brain. [2]

Advancements in brain science have produced theories on the relationships between brainwave characteristics and psychophysiological states, where the challenge is to consolidate accurate measurements to capture subtle signals using simple instrumentation, and then interpret the data into meaningful signatures. Since many applications which need brainwave analyzers for activities, a small and lightweight sensor system must be used and applied for testing. This requires massive instrumentation and places several constraints on the subject. The conventional multi-point EEG has a special headset that needs use of electrolyte gel which is not comfortable to humans and results in the collection of erroneous data if applied during normal daily activity. This gives rise to a thought of a lightweight, dry single-point EEG contact solve these problems and provide data for processing. FPGA can provide a low cost, compact solution for the proposed application. [8]

III. APPROACH: PROPOSED METHODOLOGY

A technique for measuring the psychophysiological status of the human and associated applications based on normal brain signals are proposed where the brainwaves are captured using brainwave sensor. EEG stands for Electroencephalography; it measures voltage fluctuations from ionic current flows within the neurons of the brain. A small single-point dry electrode for mobile use can capture brainwave activity from among dense external and internal electrical noise and subsequently extract targeted frequency components. Continuous measurements during day and night will help to provide a brainwave profile including wake and sleep states. These can be used to explain states of human awareness. Also statistical evaluation provides psychophysiological state change patterns which can be used to distinguish levels of alertness, this assist to prevent or avoid hazardous situations [7].

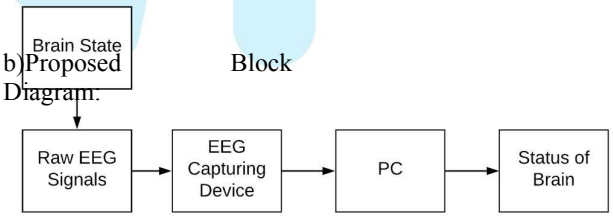
The basic principle of the project is application specific signal processing. The application here is acquiring and processing the specific bands of frequencies (0.5 to 30 Hz) and using Fast Fourier Transform, the signals can be studied and analyzed by extracting various statistical features such as Mean, Standard Deviation, Variance, Third Moment & Fourth Moment etc. and then give them as input to classifier such as Back Propagation classifier with an appropriate training function.

The minimum hardware requirements are a) Brain wave Sensor (Brain Sense / Neuro Link), b) FPGA Board (Xilinx, ZYNC), c) Bluetooth 4.0 recommended & d) Computer.

a) Brainwave Sensor : Biofeedback headset (NeuroSky Headset) as shown in Fig. 1, is used to measure brain waves, using EEG. They're small bands that sit easily on the head and measure activity through sensors This headset collect and output data in digital format essentially removing analog to digital filters for converting the data. Its output can be used for monitoring and/or processing the brainwaves of subjects.

Figure 1: Brainwave Sensor (NeuroSky headset)

b) Proposed Block Diagram:



The approach is to interface an EEG capturing device or Brainwave capturing device to a controller to process brainwaves and comparing the processed waves with available data to analyze the brain state [10].

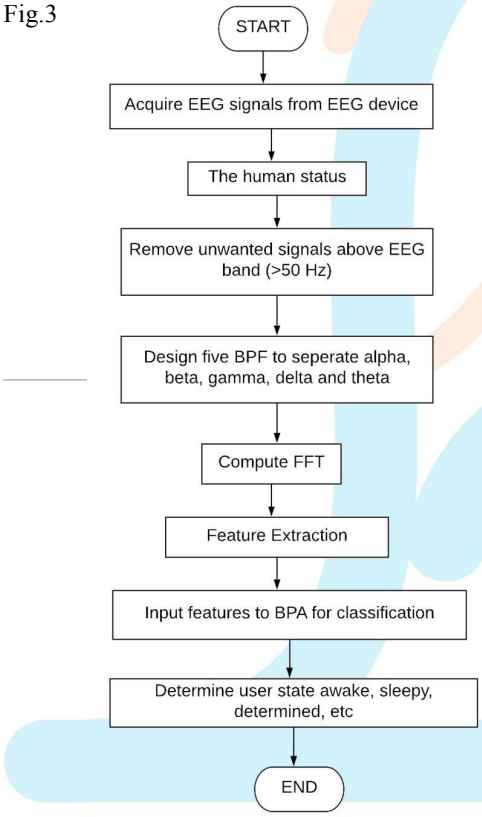
Figure 2.depicts the proposed block diagram, where the sensor output is a raw digital data which contains the different brainwave signals captured from human brain.

The FPGA board contains a MATLAB algorithm which is used to separate the main five frequency bands of brainwaves viz.; Delta waves, Theta waves, Alpha waves, Beta waves, and Gamma waves.

It is also used to amplify the signals to sufficient level and to reduce noise. It is then given to computer for monitoring and display.

b) Proposed Experimentation:

Flow-Chart for the proposed work is as shown in Fig.3



After acquiring EEG signals in MATLAB (PC) from EEG device; unwanted signals with frequency greater than 50 and power line interference signals are removed using low pass filter and notch filter. Then the signal is passed through 5 band of band pass filters to filter signal contents in the range of 14-30 Hz, 9-18 Hz, below 4 Hz, 4-8 Hz & above. Then FFT is applied these individual signals and the statistical features such as mean, standard deviation, variance etc. will be found and used as inputs to a classifier to classify the human status.

IV. Advantages

Advantages of this system would be in a) On-the-go Brainwave capturing, b) Ease of detection, monitoring and identification of brain state.

V. Conclusion

This project is intended to serve the growing need of portable bio-electronics applications for both medical and research applications. It is easy to develop and program the algorithm and it is suitable for using brainwaves for monitoring as well as for brain computer interface.

VI. Future Scope

Future scope is to implement the proposed method for capturing, feature extraction and classification for finding human activity. Also study the proposed system using array of electrodes to capture the waves with more precision.

VII. Technology And Impact

The brain generates minute Electromagnetic Waves (EM) activities according to state and using electrodes this activity is converted into waves and the waves are then analyze to find the current mental state. Emotion Recognition using different modalities is a rising area of research from many years. EEG images and speech signals can be the powerful modalities for designing Robust Emotion Recognition. Frequency domain methods may not provide high quality performance for some EEG signals. In contrast Time frequency methods (a) Has good performance. (b) May not provide detailed information on EEG analysis as much as frequency domain methods.

VIII. References

[1] Marco Paleari, RyadChellali, "Feature of Multi-model Emotion recognition-An extensive study" 978-1-4244-1674-5/08, IEEE 2010.

[2] Madhu Sudha.M, Literature Survey about Brainwave Test, International Journal of Emerging Trends in Science and Technology.

[3] Marco Paleari, RyadChellali, "Feature of Multi-model Emotion recognition-An extensive study" 978-1-4244-1674-5/08, IEEE 2010. 4-5/08,IEEE 2010. http://shodhganga.inflibnet.ac.in/bitstream/10603/74950/11/11_chapter2.pdf

[4] Literature review about Brainwave Test, 2014 http://ijetst.in/article /v1-i7/31%20 ijetst.pdf

[5] Literature review about Brainwave Test, 2014 http://ijetst.in/article /v1-i7/31%20 ijetst.pdf

[6] Brainwave information https://brainworksneurotherapy.com/what-arebrainwaves&grqid=6vbN2kEq&s=1&h1=enIN&geid=1042, 2014

[7] Brainwave interfacing and programming https://www.pantechsolutions.net/brain-computerinterface&grqid=FBVYjgZ1&s=1&h1=enIN&g eid=1042, 2011

[8] Hacking Your Brain Waves: