Scalable NOC Architecture for BMI Applications using Field Programmable Gate Array

P. Arun Prasath, M V Pavan Kumar, R. Sarathy, Pinjala Sai Kiran, G. Priya

ABSTRACT---The communication that links the brain and the computer is provided with the help of a Brain-Machine interface. In our project, deep learning algorithm is developed in VLSI architecture. The benefits of the deep learning algorithm enable the network on chip design with accurate data detection and processing. This helps us to understand the machine learning process. So that signals from the brain can control the machines. The output from post-process is translated to specific commands which will control the devices. To make this better we are using FPGA based system control which will reduce the time taken for the process.

I. INTRODUCTION

The ultimate aim of a Brain-Computer Interface is to artificially produce environmental control for the handicapped people. With the help of a Virtual Reality (VR) system, an electroencephalogram (EEG) based BCI was connected according to the user's requirements. These technologies pass-around the human body's ordinary ways. We know that diverse behaviour of neural communication in our brain leads to the various stages of human brain. Due to dynamic amplitude and frequency, it results in the unique patterns. As we all know when every neuron interacts with each other, it builds a minute electrical charge. The brain produces the signals which are captured and processed by EEG sensors which are labelled as packets. The information is transferred via Bluetooth which is basically comes under wireless communication. The MATLAB helps in converting the raw brain information into particular category of signal.

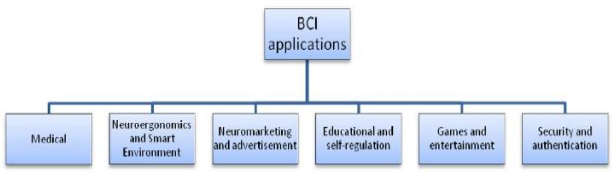

Figure 1.1 BCI Application Fields

The elements like tube light are handled when those signals are sent to the home section. Depending upon the movements of small muscular changes in the brain helps the system in the operation of materialistic elements. The architecture of a system mainly consists of three main components as shown in Figure 1.1. An interface circuit has been designed which consists of sensors as input devices and lamp (220v) as an output device which represents the controlled devices. BCI is interfaced with FPGA. According to Brain sensing, signals are sent to FPGA. A receiver unit will receive these commands from Brain wave Sensor those are given to FPGA. With respect to that, the required fan and motor will be enabled. According to blinking level and meditation level that home automation section can be controlled.

Revised Manuscript Received on May 29, 2019.

P. Arun Prasath, Students, Department of ECE, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India.

M V Pavan Kumar, Students, Department of ECE, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India.

R. Sarathy, Students, Department of ECE, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India.

Pinjala Sai Kiran, Students, Department of ECE, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India.

G. Priya, Guide, Department of ECE, SRM Institute of Science and Technology, Chennai, Tamil Nadu, India.

II. BCI FUNCTIONS:

Brain-Computer Interface has applications based on the functionality of observing the user state or the user to convey the ideas. The brain wave will be recorded by the BCI system and transfers the data to the processing unit to perform the planned task. The mediated signals are processed and applied to demonstrate a thought.

BCI plays an important role in providing the bond between mind and machines. It deals with transmitting the information from cerebrums, helping to express its idea. BCIs can likewise encourage an individual to control machines without involving body parts. It conveys the simplicity and supports the individuals through mind-controlling of machines. So no muscle involved actions are eliminated entirely. This enables them to use only a few sets of commands with their brain signals. BCI assistive robots can offer help for handicapped clients in every day and expert life, expanding their participation in the structure of their community.

III. RELATED WORKS:

Reference [1]

The need for BMI has been increased nowadays for research on neuroscience. The BMI is made to achieve accurate results in the operations. A physically impaired individual can utilize it to operate gadgets. This paves way for an open-source BMI platform, named `Open BMI'. It plays a role in processing the signal from the human brain. It also involves the analytic part of its operations. It basically deals with the captured data from the human brain. It uses a particular algorithm which comes under the Neural Networks technologies. The possible result expected is the commands

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

used to control the machines. The process involves a customized algorithm that is produced completely based on the data acquired with the help of the BMI system. The final stage is the O-BMI future development plan is introduced.

IV. DESIGN METHODOLOGY:

(a) Proposed Design

Design and implementation of Brain-machine interface oriented FPGA based system control is proposed here. BCI signals are more useful nowadays to analyze and control various factors through software and online. BCI signals are extracted from the traditional way of sensors using Brain wave sensors connected in a scalp. Here the collection of numerous brain wave datasets through different subjects. Brain signals are pre-trained using RTL architecture based Neural network design. The trained values we call as Feature vectors are stored in the Database. The RTL architecture is pre-modelled by Configurable Network on the chip. The network on a chip is a platform in which the controls are configured and Connected through Exact hardware in FPGA development kit. The proposed design achieves better accuracy and fast performance rate when comparing other embedded systems since the design of FPGA works with the frequency of > 100 MHZ.

(b) Objective of the Proposed System

- To design and implement a highly powerful Network on chip configuration through Brain-Machine Interface Controls.

(c) Module Description: -

Module 1 Design of Pre-processing

- This module is used to extract the useful info from the Brain wave datasets collected from the Test Peoples.
- The info vectors are extracted through DWT filters.
- The extraction of Alpha Beta Theta Delta Gamma waves are extracted separately.
- The frequency of the waves also determined by a Cymometer designed inside.

Module 2: The design of Neural Network Configuration

This block is used to design a Neural network platform used to analyze the input vectors with the pre-trained vectors of the database. The input vectors are compared with the trained vectors. By doing this, it will find what the incoming inputs want to do actually.

Module 3: Node configuration

We know that Deep learning algorithm is used to learn the machine language. Similarly, we are using the same algorithm here to create an Artificial Neural Network (ANN). Each artificial neuron is considered as node and the node configuration block is used to find the shortest path to the output.

Module 4: Design of FPGA Configurations

This module focuses on configuring the network on chip system with the matched vectors to process the data for controlling the available machines. The Machines are normally connected with the FPGA board in parallel manner. The Configured bits are further used for the control of machineries and other control applications.

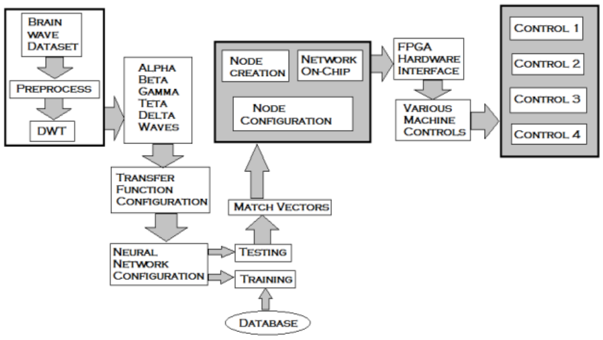

Figure 4.1 Block Diagram

V. BRAIN WAVE PATTERNS:

Brain waves are nothing butcommunication between neurons in our brain. The EEG is a type of rhythmic activity. Based on the frequency, the brain wave is divided into 5 types. The different types of wave patterns are shown in Figure 5.1. All types of brain waves are discussed below.

DeltaWaves

The frequency of Delta wave ranges up to 4 Hz depicted in Figure 5.1. It is the slowest wave and its amplitude is the highest among other waves. It may occur in the general distribution with deep midline lesions, diffuse lesions and focally with sub-cortical lesions.

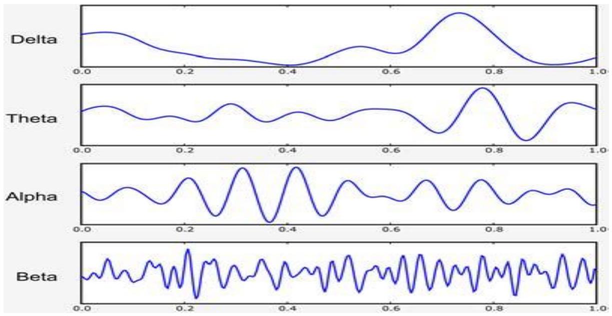

Figure 5.1:Brain waves

Theta Waves

The frequency of the theta wave ranges from 4 Hz to 7 Hz depicted in Figure 5.1. This wave is mostly seen in the person in meditation and adults in tiredness. Theta brainwaves happen regularly in rest but on the other hand, are overwhelming in profound contemplation.

Alpha Waves

The frequency of alpha waves ranges between 8 Hz and 12 Hz depicted in Figure 5.1. Hans Berger, who is a well known German psychiatrist, was the one who invented the study of rhythmic activity and he mentioned it as "alpha wave". This wave has a frequency range of 8–12 Hz and it could be observed on the dorsal sides of the brain and higher in amplitude on the dominant side. The main situation of this activity is closing the eyes and relaxation. The frequency seems to be less than 8Hz in small kids.

Beta Waves

The frequency of beta wave lies between 13 Hz to 38 Hz and is depicted in Figure 5.1. Beta wave occurs during motor behaviour. Energetic, Active and restless reasoning

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

are the main reasons for this activity. Sometimes rhythmic beta related to drug effects. Beta is the overwhelming beat in adults who are restless might be decreased.

Mu rhythms

Mu rhythm is otherwise called Mu waves. Alpha frequency range is depicted in Figure 5.2. It occurs in the motor strips. It has been categorised into synchronous and asynchronous activities.

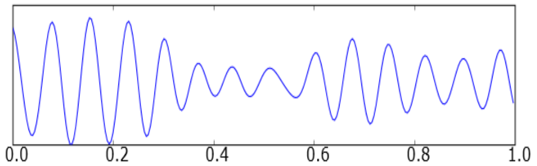

Figure 5.2: Mu rhythms

Gamma Waves

The frequency of the Gamma wave ranges approximately from 30-100HZ is depicted in Figure 5.3. Gamma rhythms are thought to attenuate with sudden motor sensory stimuli.

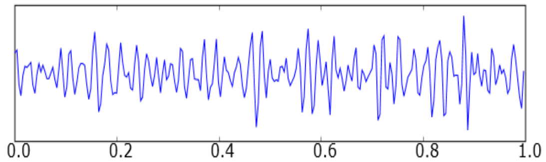

Figure 5.3:Gamma waves

Out of these wave patterns, we will be using the Mu rhythms and beta in the proposed system. Because while thinking of movement such as left, right, hand movements and leg movements, these signals are produced in the brain.

Preprocessing

Pre-processing involves getting the raw data, compressing it and rounding off to remove the floating values. Finally, the data are filtered using a Discrete Wavelet Transform (DWT). The output from pre-processor will be eligible for the further process.

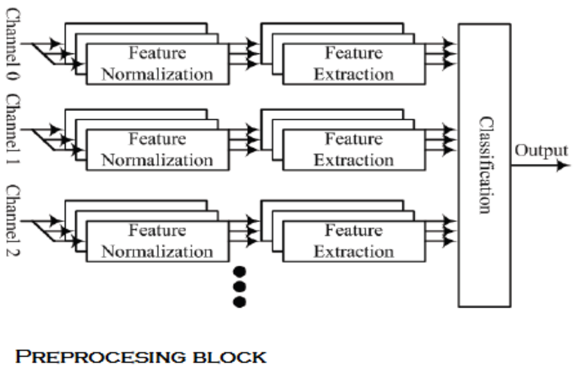

Figure 5.4:Pre-Processing Block

VI. FEATURE EXTRACTION:

At the point when the ultrasonic test signals received in a kind of digitized data are pre-processed, we need to choose features from the raw signal by the utilization of digital processing techniques. This procedure is called 'Feature extraction'. It is a remarkable kind of dimensionality decrease. Feature extraction consolidates improving the measure of assets required to describe an expansive set of data precisely. Since not all features that can be pulled out from ultrasonic signs for a given classification issue should be utilized, because of their repetition, a further procedure is required for excess decrease with the help of holding just an informative subset of them. This phase of handling is called 'feature selection'.

VII. FEATURES EXTRACTION USING DWT

Discrete Wavelet Transform (DWT) is utilized to remove qualities from a signal on various scales continuing by a dynamic high pass and low pass filtering. The wavelet coefficients are the detail coefficient which is obtained after the progressive continuation of the estimation. The fundamental feature extraction procedure comprises of

1. Disintegrating or Breaking down the signal by utilizing DWT into N levels using filtering and using decimation to get the estimate and point by point coefficients.
2. Removing the features from the DWT coefficients.
3. The features separated from the above coefficient of sample signals are viewed as valuable characteristics for contribution to distributors because of their viable characteristics with respect to time rendering of motionless signals.

ALGORITHM

Feature Extraction Algorithm

At first, it is confirmed that the digitized imperfection data are available in the powers of 2 for making the effective decomposition. The steps involved are as follows:

Step (i): Using Discrete Wavelet Transform (DWT) the ultrasonic flaw information are decomposed as four sub-bands. These sub-bands are named as low-frequency signals andalso consists of high-frequency signals.

Step (ii): The approximation coefficients are further subjected to decomposition using DWT because we need to extract localized data or information. This is classified into four different categories using bio orthogonal wavelet.

Step (iii): All the coefficients are taken for further analyzing and handling techniques.

Step (iv): The vector in terms of frequency (in radians/sample) is pulled out for four detail sub-bands using MATLAB (Periodogram function).

Step (v): The features are registered either by utilizing sentence structure or by executing the formulae. They are minimum energy, maximum energy, minimum amplitude, maximum amplitude, mean, variance, mean of energy, mid frequency, average frequency, minimum frequency, maximum frequency and a half point of the function.

Step (vi): At long last, the separated features for the six classes of defects are organized and examined for classification.

VIII. DEEP LEARNING ALGORITHM:

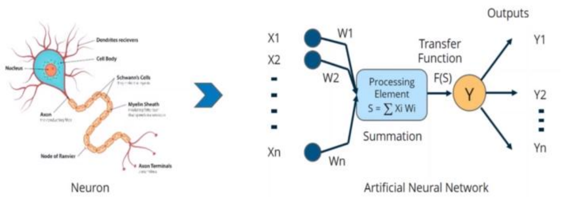

Figure 7.1: Artificial Neuron

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

We know that actual neuron in our brain looks like the one which is displayed on the left side of the Figure 7.1. The neurons are nothing but “Brain cells”. We have Dendrites here, which is used to get input to the neuron. As we can see we have multiple dendrites, so this much dendrites will get input from many neurons at once. Inside the neuron, we have the cell body which performs a function. After that, the output will be travelled through the Axon and finally, the output is fired out from the Axon terminals.

On the right side of the figure 7.1, we have an artificial neuron. Similar to neurons we have multiples inputs here (x1,x2…xn). Now, these elements are provided to the processing element (like our cell body). Inside the processing element, it performs the function as it is. For example, here we have the summation of all inputs [xn] * weights [wn]. So the output generated from the processing element will be in the transfer function [F(s)]. After that comes the concept called activation element [Y] which is used to fire out the output to other neurons. We can use the Step function as the activation function. So multiple neurons connected to each other will form an Artificial Neural Network [ANN]. Now the activation element will check the output [y1, y2…yn]. If this output is not equal to the desired output then it will compare the output with the desired output and we will find the dissimilarity between the present output and the expected output. By utilizing that difference again we are going to update the weights. This process will keep on repeating until we get our desired output. So this is how Artificial Neural Network [ANN] works.

IX. CONCLUSION:

This mainly focuses on the deep learning algorithm. The hardware requirement is minimized which eliminates the cost factor. The efficiency of this system mainly revolves around the algorithm used. The proposed deep learning algorithm and FPGA achieves 83% saving in design time. The proposed FPGA based system control will reduce the time taken for the process, increase the capacity and it can be reconfigurable.

REFERENCE:

1. Min-Ho Lee; Siamac Fazli; Keun-Tae Kim ; Seong-Whan Lee “Development of an open source platform for brain-machine interface: open BMI” *IEEE xplore* [2016].
2. Y. Su, S. Routhu, K. S. Moon, S. Q. Lee, W. Youm, and Y. Ozturk, “A wireless 32-channel implantable bidirectional brain machine interface,” Sensors, vol. 16, no. 10, p. 1582, 2016.
3. P. Bogdan, “A cyber-physical systems approach to personalized medicine: Challenges and opportunities for NoC-based multicore platforms,” in Proc. Design Autom. Test Eur. Conf. Exhib. (DATE), Mar. 2015, pp. 253–258.
4. J. W. Lichtman, H. Pfister, and N. Shavit, “The big data challenges of connectomics,” Nature Neurosci., vol. 17, pp. 1448–1454, Oct. 2014.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication