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Brain Computer Interface Based Real Time Control of Wheelchair using Electroencephalogram

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Abstract: In this study, eight electrodes were to capture Electroencephalogram (EEG) from the brain to build a brain computer interface (BCI) based real time control for wheelchair to help the severely handicapped persons. To achieve this goal Wavelet Packet Transform (WPT) was used for feature extraction of the relevant frequency bands from EEG signals. Radial Basis Function network was used to classify the pre defined movements such as rest, forward, backward, left and right of the wheelchair. The experiment results confirmed that this system can provide a convenient manner to real time control a wheelchair.

Index Terms: Electroencephalogram (EEG), Wavelet Packet Transform (WPT), Radial Basis Function neural network (RBFNN), Brain computer interface (BCI), Rehabilitation, and Wheelchair Controller.

I. INTRODUCTION

A BCI is a communication system which allows a subject to act on his environment only by means of his thoughts, without using the brain's normal output pathways of peripheral nerves and muscles. The last two decades have witnessed the importance of innovative BCI with voice, vision and a combination of these, as a communication platform. Effective attempts have been made to achieve successful BCI systems based on analysis of bioelectric signals. They were mainly to help the subjects with various neuromuscular disorders by providing them a way of communication to the world, through extracting information about their intensions [1-4]. Like any communication system a BCI has inputs (electrophysiological signals that result from brain activity monitoring) outputs (device actions), elements that transform inputs into outputs, and a protocol that determines its operation [5-6]. The subject controls the active device by performing mental tasks which are associated with actions that are dependent on the BCI application. Literature survey shows existing systems such as Chin controller is inconvenient to use, ultrasonic non-contact head controller has relatively low accuracy and voice controller gives delayed response to voice command hence not useful in noisy environment. Recently, a number of biological signals such as electromyogram (EMG), Electroencephalogram (EEG) and Electrocculogram (E.O.G) have been employed as hands-free interface to machines [7-13].

Paper introduces the working prototype of a Brain Computer interface based Wheelchair that can navigate inside a typical office and hospital environment with minimum structural modification. It is safe and relatively low cost and provides optimal interaction between the user and wheelchair within the constraints of brain computer interface.

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II. DATA ACQUISTION

EEG Data used in this study was recorded on a Grass Telefactor EEG Twin3 Machine(as shown in figure1) available at Deptt. of Neurology, Sir Ganga Ram Hospital, New Delhi. EEG recording for four right-handed healthy male subjects having no sign of any motor- neuron diseases was selected for the study. A pro-forma was filled in with detail of their age & education level. The participants were student volunteers for their availability and interest in the study. EEG data was collected after taking written consent for participation. Full explanation of the experiment was provided to each of the participants.

Fig :-1 EEG Machine

Data was recorded for 10 sec during each task and each task was repeated five times per session per day. EEG was recorded using eight standard positions C3, C4, P3, P4, O1 O2, and F3, F4 by placing Ag-Agcl silver electrodes on scalp, as per the international standard 10-20 system of electrode placement as shown in figure 2. The reference electrodes were placed on ear lobes and ground electrode on forehead. EEG signals are filtered in the 1-35 Hz

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frequency band, i.e. the effective EEG frequency support. The settings used for data collection were: low pass filter 1Hz, high pass filter 35 Hz, sensitivity 150 micro volts/mm and sampling frequency fixed at 500 Hz.

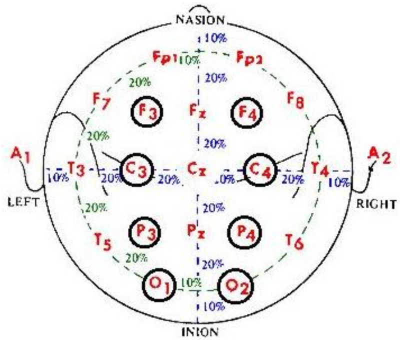

Fig:-2 Montage for Electrode Placement

As power line and other electromagnetic noise sources have frequency supports beyond 35 Hz such filtering removes most of this noise. Eye blink artifacts are very common in EEG data; they produce low-frequency high-amplitude signals that can be quite greater than EEG signals of interest. Indeed, while regular EEG amplitudes are in the range of -50 to 50 microvolts eye blink artifacts have amplitudes up to 100 microvolts.

Ocular artifacts have large amplitudes their spectral content is mainly concentrated in the theta band and is more prominent at frontal pole electrodes, i.e. Fp1 and Fp2. Time-frequency representation of a signal containing a series of ocular artifacts exhibits an abnormal concentration of the power in the theta band when ocular artifacts appear.

Muscular artifacts have amplitudes in the order of that of regular EEG but their spectral content is concentrated in the beta band. These artifacts are more noticeable in central, temporal and parietal electrodes, i.e. electrodes T3, T4, T5, P3, P4 and T6. Time-frequency representation of a signal containing a muscular artifact reveals the presence of the artifact by exhibiting an abnormal concentration of the power in the beta band.

EOG (Electooculargram) being a artifact, was derived from two electrodes placed on outer canthus of left and right eye in order to detect and eliminate eye movement artifact.The artifacts are detected and special actions are generated to indicate to the subject whether an ocular or muscular artifact was detected. Thus, the subject can auto-regulate the artifacts he produces. Following mental tasks are considered to control the wheelchair.

- Movement Imagination:-The subject was asked to plan movement of the right hand.

- Geometric Figure Rotation:-The subject was given 30 seconds to see a complex three dimensional object, after which the object was removed. The subject was instructed to visualize the object being rotated about an axis.

- Arithmetic Task:-The subject was asked to perform trivial and nontrivial multiplication. An example of a trivial calculation is to multiply 2 by 3 and nontrivial task is to multiply 49 by 78. The subject was instructed not to vocalize or make movements while solving the problem.

- Relaxed: - The subject was asked to relax with eyes closed. No mental or physical task to be performed at this stage.

III. THE PROPOSED STRUCTURE& HARDWARE IMPLEMENTATION

Conceptual block diagram of EEG based power wheelchair system is shown in figure3. Eight standard positions C3, C4, P3, P4, O1 O2, and F3, F4 by placing Ag-Agcl silver electrodes on scalp, as per the international standard 10-20 system of electrode placement.

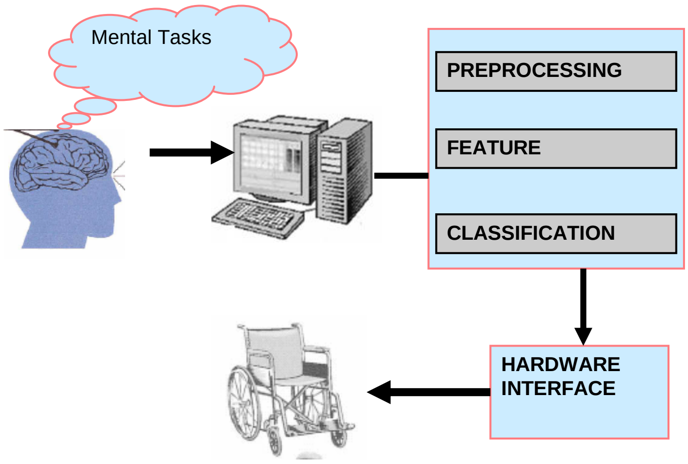

Fig:- 3 Conceptual block diagram of EEG based wheelchair control system

The frequency spectrum of the signal was first analyzed through Fast Fourier Transform (FFT) method [14-18]. The FFT plots of signals from all the electrode pairs were observed and maximum average change in EEG amplitude was noted. At this stage, the FFT output could have also been used for feeding into the classifier structure but the data size being too large. The data is preprocessed using Wavelet packet transform to extract the most relevant information from the whole signal [19-20]. By applying Wavelet packet transform on the original signal wavelet coefficients in the (8-13Hz) frequency band at the 5^{th} level node (5, 3) were obtained. Twenty one coefficients have been obtained from one second of EEG data. These coefficients are scaled and used as the best fitting input vector for classifiers. Subsequently the signal was reconstructed at node (5, 3). For classification, Radial Basis Function Neural Network (RBFNN) classifier was employed [21-23]. A two layer network was implemented with 21 input vectors, a hidden layer with Gaussian activation function consisting as many as hidden neurons as input vectors and five neuron in the output layer.

After the classification of five mental tasks namely movement imagery, trivial multiplication, geometrical figure rotation, nontrivial multiplication and relax, the output of the classifier was interfaced with the motor using parallel port.

Each direction (left, forward, right, backward and stop) of the wheelchair corresponded to five mental tasks (movement imagery, trivial multiplication, geometrical figure rotation, non -trivial multiplication and relax).

Using parallel port, Motor driver IC (IC L293) was interfaced with computer as shown in Circuit Diagram (figure 4) for the wheelchair controller. In the circuit, P1 acts to enable the chip and combination of P2 and P3 were used to control direction of wheelchair. The truth table for the above logic is shown in table 1 with polarities of motor of M1and M2. All five direction of wheelchair movement were properly controlled by this designed circuit.

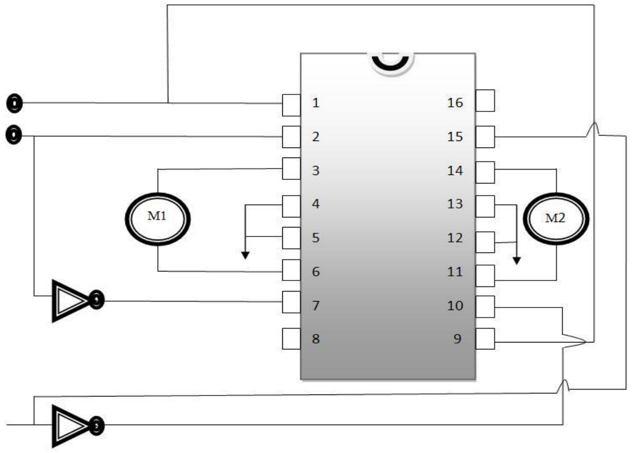

Fig-4: - Circuit Diagram for wheelchair controller

Table 1.Truth TABLE OF HARDWARE DESIGN

P1	P2	P3	*M1*		*M2*		TASKS
1	0	0	0	1	1	0	LEFT (L)
1	1	0	1	0	1	0	FORWARD(F)
1	1	1	1	0	0	1	RIGHT (R)
1	0	1	0	1	0	1	BACKWARD(B)
0	X	X	-	-	-	-	STOP(S)

The polarities of the motors M1 and M2 are shown in the truth table. State diagram for wheel chair movement in different direction is shown in figure 5. For movement imagery task, the output of parallel port would be [1 0 0]. Due to opposite polarities, M2 motor would move forward and M1motor backward which would be lead to left movement of the wheelchair. For trivial multiplication task, the output of parallel port would be [1 1 0]. Due to same polarities, both motors M1and M2 move forward resulting forward movement of the wheelchair. For geometrical figure rotation task, the output of parallel port would be [1 1 1]. Due to opposite polarities, M1 motor moves forward and M2 motor backward resulting right movement of the wheelchair. For nontrivial multiplication, the output of parallel port would be [1 0 1]. Due to same polarities, both motors M1and M2 move backward resulting backward movement of the wheelchair. Similarly, for stop tasks output of parallel port would be [0 x x] and the wheelchair would be control by different polarities at the motors.

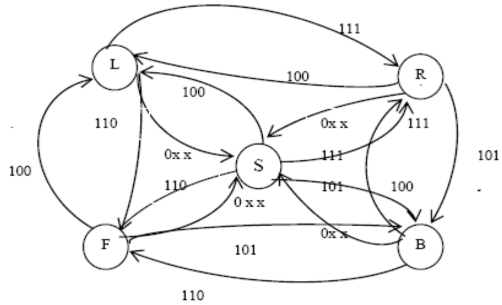

Fig 5:- State diagram for Wheelchair Movement

IV. RESULT & DISCUSSION

Prototype of wheelchair control using based on BCI as shown in the figure (6). Earlier researchers had established the most prominent areas in brain for domain of information during various mental tasks as shown in table 2[15-18]. In the present study, maximum average change in EEG amplitude has been observed. The study had led to following observations [24 25].

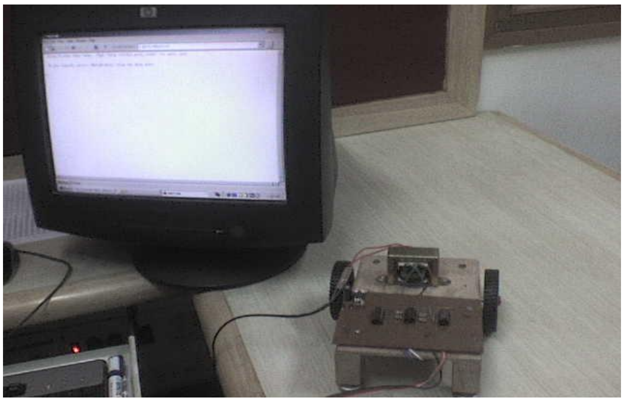

Fig 6:-prototype of wheelchair control

For movement imagery task, the amplitude of the power spectrum for alpha frequency range (8-13Hz) had attenuation in contralateral area.

For geometrical figure rotation task, the amplitude of the power spectrum increases in the right occipital region for alpha frequency range (8-13Hz).

For trivial multiplication task, the amplitude of the power spectrum increases in the left frontal region for alpha frequency range (8-13Hz).

For nontrivial multiplication task, the amplitude of the power spectrum increases in the left parietal region for alpha frequency range (8-13Hz).

In this study, Wavelet Packet Transform (WPT) method was successfully used for feature extraction of mental tasks from eight channel EEG signals. Original signal were decomposed at the 5^{th} level node (5, 3).WPT coefficients give the best discrimination between the directions of wheelchair in the relevant frequency band. The WPT coefficients were used as the best fitting input vector for classifier. Radial Basis Function network was used to classify the signals. Classification of five mental tasks using Radial basis function neural network shown in the table2.

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Figure 7(a-d) associated with table 3 show four experiments conducted on four right-handed male subjects. The subjects were asked to mentally drive the wheelchair from the starting point to a goal by executing the five different mental tasks namely Movement Imagery (MI), Trivial Multiplication(TM), Geometrical Figure Rotation (GFR), Non Trivial Multiplication (NTM) and Relax (R) to control direction of the power wheelchair. To complete task from staring point to goal, the subject performed sequence of the mental tasks as shown in table 3. Experiment has been successfully completed with 100% accuracy by all four subjects.

Table 2. CLASSIFICATION OF FOUR MENTAL TASKS

Tasks	classifications
Movement Imagery	10000
Trivial Multiplication	01000
Geometric Figure Rotation	00100
Nontrivial Multiplication	00010
Relax	00001

Table 3. Matrix of mental tasks and direction of wheelchair

Path a	TM/ Forward	GFR/ Left	GFR/Left	GFR/ Left	R/ Stop
Path b	TM/ Forward	MI/ Right	MI/ Right	MI/ Right	R/ Stop
Path c	TM/ Forward	GFR/ Left	GFR/Left	GFR/ Left	R/ Stop
Path d	TM/ Forward	MI/ Right	GFR/Left	GFR/ Left	R/ Stop

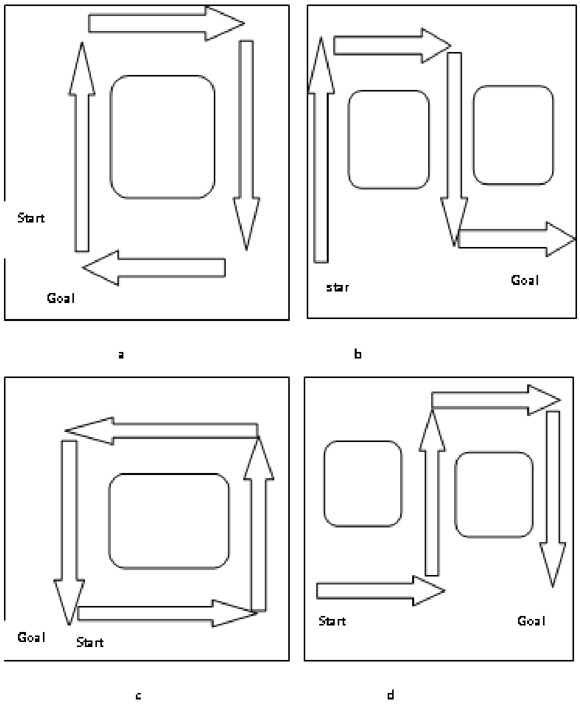

Fig 7(a-d): Top view of random path

V. CONCLUSION

The key is to take BCI technology beyond the demonstration stage to the real world applications, so that the quality of life for paralyzed patients is improved. We detected the changes in the EEG patterns due to mental tasks. In this study we investigated the controlling of a power wheelchair by mental tasks (EEG signals). This was an attempt to control direction of wheelchair via brain signals. Each direction (left, forward, right, backward and stop) of the wheelchair corresponded to five mental tasks (movement imagery, trivial multiplication, geometrical figure rotation, non -trivial multiplication and relax). To differentiate five mental tasks, wavelet packet transform was employed for feature extraction and Radial basis function neural network was used for classification. The experimental result showed 100% accuracy.

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