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Human Robot Cooperative System Based on Non-invasive Brain Computer Interface

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ABSTRACT: In this paper a human robot cooperative approach to reliable planning and execution is presented. We provide a comprehensive review of the system which represents limit types of user's intention patterns based on EEG signals with insufficient decoding accuracy and time delay. BCI's provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity in to commands in real time. With these commands the human robot system (or mobile robot) can be controlled. The pattern of interaction between the neurons in brain is represented as thoughts and emotional states. This pattern will change according to the human thoughts which in turn produce different electrical waves. In this paper a brain wave sensor is used for sensing the signals in the brain and it is converted to control commands which further transmitted to the robot module for processing. By using the entire system, the human robot can be moved as per the human thoughts which can serve as a powerful aid for severely disabled persons in their daily life especially to help them move voluntarily. We conclude this paper with a discussion of the current challenges and future research directions.

KEYWORDS: Brain Computer Interface, Electroencephalography

I.INTRODUCTION

Independent mobility reduces dependence on caregivers and family members, promotes feelings of self-reliance and enhances quality of life. Important as it is, some wheelchair users find existing manual or powered wheelchairs difficult or impossible to operate. For example, persons with diagnoses of muscular atrophy, spinal cord injury (SCI), amyotrophic lateral sclerosis (ALS), or brainstem stroke, they have one or more symptoms such as weakness, visual field loss, and spasticity. Traditional neuromuscular based joystick or keyboard operation is impossible for them, even voice activation or visual stimuli in some cases cannot be relied on. As the disease usually does not impair thinking or cognitive abilities, direct intention decoding through using a brain-computer interface (BCI) system provides an alternative communication pathway for those users. For practical application, non-invasive electroencephalography (EEG) based BCI has been adopted to interpret user's intention.

Between 40 and 50 million people in the United States report some kind of disability. A brain computer interface, which does not require any muscle activity for device manipulation, is also a feasible control mechanism for this population a brain computer interface (BCI) is a real time communication system designed to allow users to voluntarily send messages or commands without sending them through the brain's normal output pathways. A BCI device allows people to communicate without movement. People can send information simply by thinking. Everybody can imagine how useful would be a system that could know accurately what the user desires to do just by reading his scalp potentials. There are two main BCI approaches: the invasive one that is based on ElectroCorticoGraphic (ECoG) data or single neuron recording and the non-invasive one that is based on EEG data. In the invasive way, the signal is much cleaner of noise and the potentials locations are more evident since the electrodes are placed on the region of interest. On the one hand, the non-invasive approach is more susceptible of noise interferences and their potentials have less spatial resolution than the invasive way, on the other hand it is less traumatic and risky. Therefore the non-invasive BCI have been preferred by several implementations and it is referred as BCI on this manuscript from now on.

In this paper, it proposes computer system based on the mapping of brain waves with the help of an Electroencephalograph (EEG). These waveforms can be isolated and used for interfacing the human brain with the

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computer and help in controlling it just by thought process alone. For generations, humans have fantasized about the ability to communicate and interact with machines through thought alone or to create devices that can peer into a person's thoughts. These ideas have captures the imagination of humankind in the form of ancient myths and modern science fiction stories. However only in recent decades have advances in neuroscience and brain sensing technologies which allow us to monitor the physical processes within the brain that correspond with certain forms of thought. Modern brain sensing technologies provide a variety of methods for detecting specific forms of brain activity. This phase of the project deals with conducting an intensive literature survey on the various teams doing research in this field around the world. Several papers have been written on recognizing EEG signal differences during different mental calculations. These papers suggest that different parts of the brain are active during different types of mental calculation, and if these different tasks may be accurately recognized, they could be used in a BCI.

II.BRAIN COMPUTER INTERFACE

BCI system provides a direct communication pathway a human or animal brain and an external device. The design of BCI is divided into three modules:

1) Amplification
2) Data processing
3) Electrical isolation and shielding.

A. Single Channel Amplifier: The amplification may be fine-adjusted to the appropriate voltage level for the data capture microcontroller's analog-to-digital converters (ADC).

1) Interface: The interface begins at the surface electrode locations. Each electrode is attached to the skin using a conductive electrode cream to lower electrode-skin impedance. The electrode material is chosen such that it will not interact chemically with electrolytes of the skin. The electrodes are connected to a shielded cable that carries their signal into one channel of the electrophysiological amplifier. Depending on the montage, configuration each electrode measurement is referenced to one relatively bio-electrically isolated electrode (monopolar) or each electrode is referenced to another electrode within the montage (bipolar). For each channel, the reference electrode voltage is subtracted from the signal electrode voltage using a precision instrumentation amplifier. This interface amplifier must have a high input impedance, gain, common mode rejection ratio, low offset voltage, and very small bias current. To facilitate this design, the amplifier required low operating voltage range and an output referenced to an internal ground.

2) Filtering*:* The signal from the interface stage was notch filtered to remove the 60-Hz mains noise and then low pass filtered with a 50-Hz second order Butterworth filter. These filters were implemented using passive resistor capacitor elements.

3) Amplification: The interface amplifier was specified with a very low offset voltage; however, this still may result in a non-zero output from common-mode input and high amplification. To compensate for this offset, a zero-trim stage may be included, or if the electrical specifications permit, then the signal may be AC coupled. The signal was amplified to a peak-to-peak voltage and level shifted within the range of the analog-to-digital (ADC) converter in the next stage

B. Data Processing and Storage: Two primary goals of this ambulatory BCI system were data collection using non-volatile storage, and on-line real time processing and control. A single processing unit could be used; however, employing a parallel processing configuration enabled the system to be more flexible in design and programming with less computationally powerful microcontrollers.

C. Electrical Isolation & Shielding Requirements: For this type of research application, electronic device standards require the isolation of the subject from the supply mains. The connection of the subject to a data acquisition system that is powered directly or indirectly by the mains without proper consideration has the potential of harming the subject. Electrical isolation may be achieved by incorporating electro-optical isolation components. In addition to the safety considerations, there are significant shielding and grounding considerations for a device that must

1) measure signals in the mV range with respect to an external reference
2) amplify and shift the signal with respect to an internal floating reference

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3) output an isolated signal that is referenced to ground .

III. SYSTEM ARCHITECTURE

A. Human Robot System Architecture:

The system architecture for human robot cooperation with EEG based BCI is shown in fig.1.

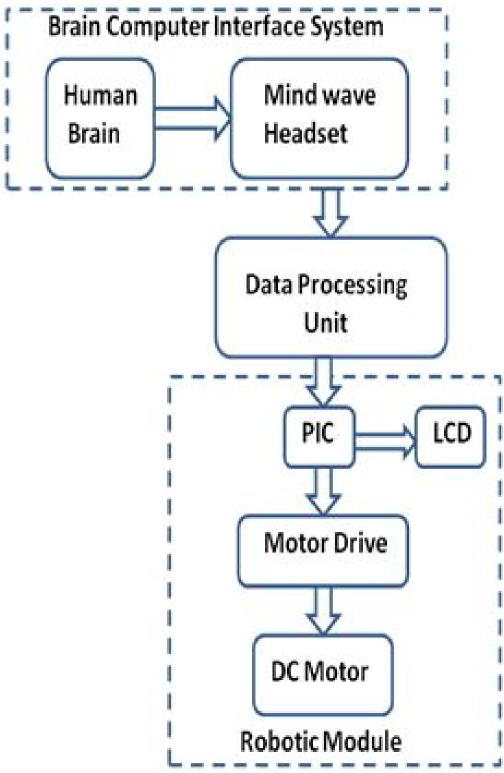

Fig.1 System architecture of human robot cooperation with EEG-BCI

The system consists of brain computer interfacing system, data processing unit and a robotic module. The brain computer interfacing system consists of human user with a mind sensing headset. The user generates task and makes decision on execution according to the protocol. The task is performed by the wheel chair robot when it receives commands from BCI. The human-robot cooperative strategy is the core of the robot system. It generates driving instructions based on the map and user intention. These instructions are then sent to the driving system of the robot to implement the actual movements. This paper focuses on the human-robot cooperative strategy in achieving accurate navigation and positioning.

The brain computer interfacing unit consist of a mind sensing headset which tracks the brain response/signals. The signal converted to digital data and send to Controller (PIC) through wireless connection. Controller collects the data and takes decision with respect to the received data / signals. The controller sends data to the motor driver corresponding to the received signals from EEG Headset. The motor driver drives the two motors with respect to the data from the controller. Then the robot can move in any direction. LED is status LED. Initially the LED will be in off state. When data is received LED will light. Therefore the Robot moves in any direction.

B. EEG Signal:

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EEG stands for Electroencephalography. It is the neurophysiologic measurement, via the use of electrodes on the scalp, of the electrical activity of the brain. The electrodes are carefully placed on certain areas of the brain in order to collect voltages. The resulting traces of voltages from the brain are called an electroencephalogram. The process of the EEG is non-invasive. Before electrodes are placed on the scalp, a conductive gel is usually applied to the skin to reduce impedance. Normally, each pair of electrodes is connected to the input of a differential amplifier which allows for amplification of about 60-100 dB of voltage gain. The resulting voltage signal is then passed through high-pass and low-pass filters, which are normally set at 0.5 Hz and 35-70 Hz, respectively. Electro galvanic signals are filtered out by the high-pass filter while electromyography signals are filtered out by the low-pass filter. The final signal is then displayed on a computer screen or oscilloscope. Although it a very powerful method of collecting brain activity, EEG also a has several limitations. Scalp electrodes are not sensitive enough to pick up individual action potentials. Instead, they actually pick up the activity of large groups of neurons. This is because the large groups of neurons emit larger voltage values that an individual neuron. Another limitation of EEG is the fact that it has limited anatomical specificity. Also, EEG is also the only method to directly measure electrical activity. Major advantage of EEG signal is it has high resolution. Another advantage, which leads to our decision to use EEG, is its relative scalability.

IV.CONTROL STRATEGY

According to the control strategy the navigation and positioning of the system can be done using attention and eye blink. The sensor placed in the scalp of the head touches the contact in the forehead and the reference point that located in the ear clip. The sensor collects the brain wave signals and process to digital signals in the on-board chip. Attention, meditation and eye blink rate can be calculated by using the mind wave headset. In this paper we are taking only the attention and the eye blink rate. In case of attention two values are set in the program by the user. If signals tracked by the brain are below than the lowest rate then the robot will move in backward direction. If it is greater than the highest value then movement will be forward. (Table no.1) The value in between these rates will make the robot at stand still. Similarly for the eye blink the robot move to right or left.

V. SIMULATION & RESULTS

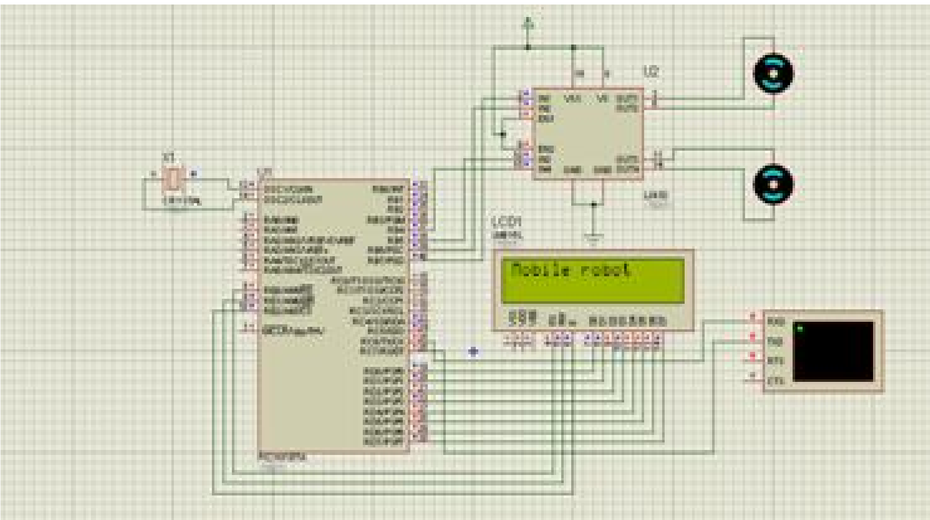

Fig.2 Simulation Diagram

The result of simulation is that the motor rotates in both clockwise and anticlockwise direction. If the value of attention is less than a particular value (say 40), letter 'S' is transmitted. Then both the motor rotates in anticlockwise direction that is backward motion of the robot. The word 'Move Backward' will be displayed on the LCD. If the value of attention is greater than 80, letter 'W' is transmitted. Then both the motor rotates in clockwise direction that is forward motion of the mobile robot. If the value of eye blink is less than 40, letter 'D' is transmitted. Now only one motor (left

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side connected motor) rotates and the other motor will be in standstill condition that is, left motion. The word 'Turn Left' will be displayed. If the value of eye blink is greater than 60 letter 'A' is transmitted then only one motor is rotate (right side connected motor). This indicates the right movement of the robot. The content on LCD is 'Turn Right'.

Attention<40	Transmit S	Backward
Attention>80	Transmit W	Forward
Eye Blink>60	Transmit A	Right
Eye Blink<40	Transmit D	Left

Table no: 1 Control mode

The navigation and positioning of the system using BCI can be done in three ways. They are attention, eye blink and meditation. In this paper we are selecting attention and eye blink rates using mind sensing headset. A graph is plotted which represent the attention and eye blink rate. In the fig.3, it shows the graph of eye blink and attention values at different time instants.

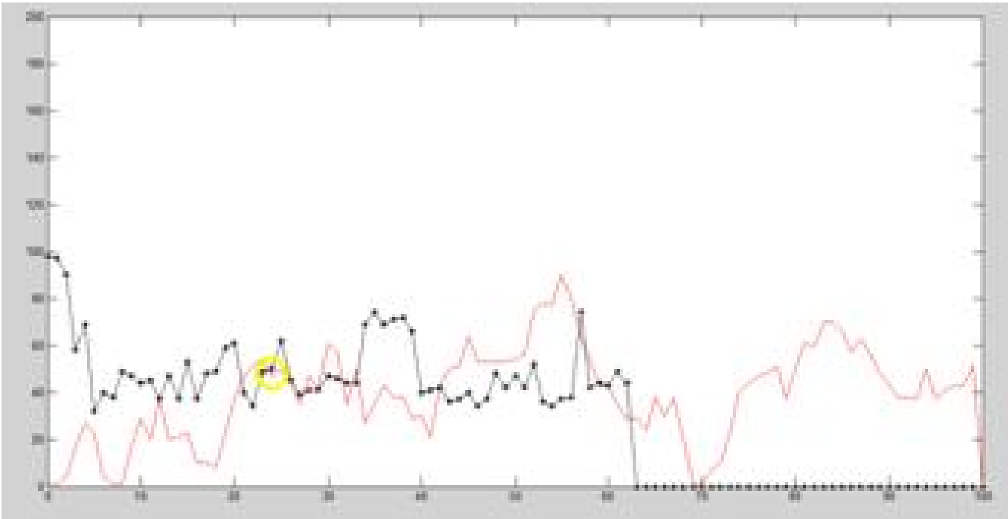

Fig.3 Time Vs Amplitude of attention and eye blink

VI. HARDWARE

The brain signal is acquired by the sensor called Mind wave head set. The mind wave headset sensor placed at the human scalp acquires the brain signal. The sensor is also act as the transmitter and which transmit the brain signal by converting as a digital pulses. It contains a dongle device act as the receiver. The dongle device receives the transmitted signal by using a zig-bee pair and applied to a microcontroller. The microcontroller interfaced with dc gear motors. Depending upon the brain signal strength from the sensor the microcontroller control the rotation of dc gear motor by forward or backward motion. The dc gear motors are connected with a toy car and the motion of the toy car controlled by rotation of the dc gear motor.

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Fig.4 Mind sensing robot

VII.CONCLUSION

The research and development of brain controlled mobile robot have received a great deal of attention because they can help bring mobility back to people with devastating neuromuscular disorders and thus improve their quality of life. The major difference between brain-controlled mobile robots and other brain-controlled devices is that these mobile robots require higher safety because they are used to transport disabled people. Many researchers have developed various brain controlled mobile robots using different BCI techniques as well as other techniques such as intelligence techniques (in sensing situations, localization, and path planning) and shared control techniques so as to make these robots safer. Brain computer interfaces intended to translate ‘‘thought into action’’ with brain activity only. BCI research stimulates long-held hope and expectation of thought and emotion detection and translation from brain states. In the present study, we proposed an EEG based BCI system with EEG sensors for sensing EEG signal and a microcontroller for processing EEG signal and controlling devices. In addition, we try to demonstrate its use by an EEG-based vehicle movement control system. Thus, to ensure the proposed brain-controlled mobile robots to be usable by the targeted disabled population, they need to be designed for and tested by the targeted population.

Research on brain-controlled robot systems has achieved many significant accomplishments. Further work and success of this research would lead to the development of robotic systems that can be used by disabled users, and thus improve their mobility, independence, and quality of life.

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