Design and implementation of brain controlled wheelchair

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Abstract

Traditionally the brain has been under constant research and the source of numerous technologies. One such technology, brain machine interface, is the extraction of brain signals and their use in real time applications. The brain consists of three main regions of which the cerebellum is focused on by this technology. This technology uses electrodes to extract signals from corresponding regions of the brain and use these signals to operate devices. This paper does progressive work and continues in the lines of research done presently in this field and their applications. The concentration is given to a wheelchair that has been designed to work on the extracted brain signals. Extraction of brain signals from various regions of the brain using both invasive and non-invasive techniques and the use of this signal in real time applications has been shown in this paper with the development of brain controlled wheel (BCW) chair, a device for persons with total neural failure and other degenerative neural disorders. The model for BCW has been simulated with necessary algorithms and programs. Finally the unbound applications of this technology in futuristic applications have been shown in this paper.

Keywords: BCW, CCU, Electroencephalography, quadriplegic

1. Introduction

The brain is the major organ of the central nervous system [1] and the control centre for all the body’s voluntary and involuntary activities. One of the major parts of the brain is cerebellum whose main functions are the maintenance of posture and the coordination of body movements.

In the human body there are several parts and all having their separate motion. Each area of the cerebellum has its separate significance in the body movements.

To control movement the brain has several parallel systems of muscle control. The motor system controls voluntary muscle movement, aided by the motor cortex cerebellum, and the basal ganglia. The picture below shows the cerebellum with clear labelling showing at which part, signals are generated for controlling, which body parts.

In brain machine interface technology the electrical signals from the brain are extracted and processed to run various applications. Fig 1 shows the pictorial representation of interfacing brain and device and Fig. 2 shows the various regions of the cerebellum from which signals are extracted.

In this paper more focus is given on signal extraction from cerebellum, the region responsible for motion. The BCW uses the signal which has been extracted from the brain region responsible for leg movement, using electrodes. This extracted signal is translated using translation algorithms [2] and given to a microcontroller. The microcontroller performs the predefined operation like rotating the wheelchair motor or turning the wheels based on the electrical level of the signal.

Fig. 1. Brain-Device Interface
2. Existing System
Presently research is going on in the field of signal extraction from the brain. This extracted signal is being experimented with various applications like artificial arm, artificial eye, artificial ear etc. This paper has focused on one similar application in the form of a wheel chair, which will be useful for persons with total neural failure and other degenerative neural disorders, with an experimental setup to simulate the extraction of brain signal.

3. Motivation
Ron Nuzzie a salesman was paralyzed neck below in a major car accident. The doctors in the intensive care unit were able to save his life but he was declared a quadriplegic [3]. No current available technologies could give him full solace. This spurred us to think of the brain-controlled wheel chair, a major application of brain machine interface technology.

4. Proposed system
4.1 Extraction of Brain Signals
The data-out BMI [4][5][6] consists of multi-neuron population recordings in motor cortex, the output of which is electronically decoded. The neural implants typically consist of a four by four millimeter multi-electrode (25-100+ electrode) array that is implanted into the area of motor cortex that is most active during the motor task of interest (such as moving an arm). Data-out BMIs are a recent phenomenon because they involve several technological feats that are of recent origin: predicting (via FRMI) where the motor activity of interest occurs, the ability permanently implant single cell recording devices into the motor cortex, and the ability to make mathematical and mechanical sense of the neural output in the short time period necessary for such control. Newer, blunt-tipped, flexible, Teflon-coated stainless steel microwires produce very little damage and allow permanent implantation.

Permanent implantation is necessary for complex testing because the interface has to be tuned specifically for each subject and for each implantation. After neural outputs are obtained, additional machinery decodes the neural signals using algorithms (that are based upon the output associations that the system acquired during training) that derive the intended motor output of the system. Although decoding technology is currently customized for each application, the platforms have several characteristics in common. The hardware mechanisms allow for parallel, real-time processing based on the parallel data that was used to create the decoding algorithms [2][7]. These mathematical algorithms derive a mechanical signal from the brain output and are adjusted by higher order algorithms to compensate for variations caused by the animal feedback learning. That is, the algorithms are sensitive to the fact that the subject's realizes that its thoughts are producing external cues, and the algorithms adjust in real time to compensate for this subject adjustment. Due to limited understanding of the information represented by neuronal discharges [8] and the sparse sampling, no model can reconstruct exactly the intended motion from the neural activity recorded. Current microelectrode arrays gather enough data to predict two-dimensional or three-dimensional hand coordinates with an average correlation coefficient of about 0.65–0.8. If position is predicted, the decoded output resembles the monkey’s arm trajectory with noise added. The unsteadiness of the output trajectory makes dexterous manipulation very difficult. Although a low pass filter may be used to reject some of the noise, such a filter results in a delayed response and loss of the ability to make quick movements. Using integrated circuits (ICs), several stages of signal conditioning can be moved onto a chip and implanted subcutaneously [9]. Data can then be collected from the implanted system using a wireless link. A possible system realization is a device that collects and transmits waveforms, including interspike samples. Such a device would not be affected by neuron firing rates because interspike samples are not discriminated from spike-related samples.

4.2 Brain controlled wheel Chair
The application designed in this paper using brain machine interface is Brain Controlled Wheel Chair. The signal is extracted and processed and given to the microcontroller. BCW capitalizes on the fact that motor cortex activity occurs approximately 300ms before its associated motor response. Therefore, BCW that is to mimic a natural motor system has this period of time to create motor output while allowing the subject to maintain the experience of natural motor processing.
4.2.1 Layout of BCW

Fig. 3 shows the layout of BCW. Signals from all regions associated with physical movement are taken out using the headband that uses the above said methods for signal extraction, and this feed is given to the unit at the back of the wheelchair, which is its Central Control Unit (CCU). The feed from all other units is also given to this unit and processed here. The CCU contains the necessary microcontrollers, sensor circuitry, converters, signal translators, attenuation removers and all other allied circuitry that are required for BCW. The CCU receives extracted brain signals through the headband. The received signals obtained from the brain are processed so that they are real time and noise free enough to operate devices as seen above and as seen in other researches. The microcontroller recognizes and recognizes these signals and based on the definition of these signals using predefined algorithm (like the example in the working model) the microcontroller makes the corresponding unit perform the required operation. For parallel operations multiple microcontrollers are used.

The BCW contains larger back wheels, which can rotate both backward and forward and smaller front wheels, which can rotate angularly so that the combined movement of both the wheels provides more mobility to the wheel chair. Both the wheels are controlled by the microcontroller. Coherent motion is produced as follows. When the brain generates signals corresponding to forward movement of the legs, the signal after translation into corresponding signal recognized by the microcontroller, is given to the microcontroller. The microcontroller recognizes the signal based on the predefined algorithms would be producing so many rotation of the back wheels so as to move the same distance that the leg movement would have moved. In usual body movements responsible for turn, corresponding muscles are pulled that make the ankle or leg turn. The brain signals that are responsible for these muscle pulls are extracted and processed and given to the microcontroller. The microcontroller based on the predefined algorithm rotates the smaller wheels in whichever direction the person should move. Thus their combination provides fluid movements corresponding to the actual leg movements. Since motor activity occurs approximately 300ms before its associated motor response the wheel chair operations are not time lapsed. Thus they give the paralyzed person the feel of natural processing such that after a period of time he forgets that he is using a prosthetic. These wheels have anti-roll mechanism built into them for user safety so that any motor failure on an up slope causes any danger to the person.

The CCU also recognizes operations that can’t be performed and skips them, operations like jumping. This is done by using a device that defines a threshold and signals only within this threshold are given to the microcontroller and the unrecognized signals are dropped. Purposeful human movements range from approximately 0.01 Hz (posture) to about 10 Hz (physiologic tremor). Previous lab experiments have already found out the electrical signal value for each movement. These values are used to define the threshold.

Sensors and other optical or sonar sensors are placed at strategic locations depending on the need and situation. The backrest and leg rest are electrically controlled. The cushions are such designed that they maintain a constant blood flow thus avoiding sores that may arise because of long hours of use of the wheel chair. The BCW uses heavy-duty motors, which have high starting momentum and turning torque. The batteries are lightweight rechargeable solid-state batteries that eliminate the dangers of acid batteries and do not need acid replacements. The wheelchair features a small display to display details like battery level, motor temperature etc and can be extended to upload details like doctor appointment timings from a computer through a data cable. A lot of safety features are built into the wheel chair since it contains a live human on it. This BCW provides more flexibility to patients with muscular dystrophy, quadriplegic patients etc. As BCI technology progresses many more features can be built into BCW like a wireless phone controlled by brain, personal computer controlled by brain etc. As technology progressed the scope for developing BCW as multiutility vehicle is unbound, thus giving people with severe paralysis a fresh lease of life.

5. Working model

Fig. 4 shows block diagram of the working model. In this, a scaled down implementation has been done. Inputs in the form of voltage are given to operate stepper motor and LED’s, which are controlled by a microcontroller. Three inputs are given to the microcontroller. But in real time applications parallel processes require multiple microcontrollers but in this design one microcontroller performs three different operations sequentially but gives an image of parallel operation. The input (voltage) responsible for leg movement is given to an A/D converter also.

![Fig. 4. Block diagram of the working model](image)

The A/D converter outputs a digital value corresponding to this voltage, which is also inputted to the microcontroller. The microcontroller, based on the input signals which is given to various ports, glows the LED’s (which represent the hand and eyes) or rotates the stepper motor. The speed of the stepper motor is determined by the microcontroller based on the digital input from the A/D converter. The microcontroller is reset by external signal to its reset pin. An 8051 microcontroller is used. Voltage is given as inputs using an external voltage source to three input ports. To the output ports of the microcontroller LED’s and standard stepper motor are connected (stepper motor board used) using 26pin FRC interface cord. The output of the A/D converter is given to the microcontroller and the corresponding program is
loaded into the microcontroller. Fig. 5 shows the experimental setup.

Fig. 5. Experimental Setup

6. Implementation details
The voltage input is given to the 8051 microcontroller [10] and for leg case it is given to the A/D converter also. Based on the voltage given, the A/D converter gives a corresponding digital value, which is given as an interrupt to the microcontroller. The following is the program loaded in the microcontroller. The program checks whether there is a input in the port p2.0, if the bit is not set the control goes to the next, otherwise the control is transferred to the hand routine. There it sets the port p3.0, which enables the output device connected, and then the control returns. Here it checks for the input in port p2.1, if the bit is not set the control flow goes to the next, otherwise the control is transferred to the eye routine. There it sets the port p3.1, which enables the external device connected, and then the control returns. Fig. 6. Shows the flow chart.

Now it checks for the input in port p2.2, if the bit is not set the control transfers to the start, otherwise it sets the port p3.3 which glows the led and then the control waits till an interrupt is raised by the A/D converter. After getting the digital value the corresponding rotational value in the lookup table is loaded in the register. Now the control transfers to the motor routine, where it transfers the port address to the register dptr from pa, which is defined in the top of program. Then a constant value ox88 (control word) is moved to the accumulator, then program compares this value with a constant value ox11, if it is true the value is reset to 0x88, if it is false the accumulator value is rotated and it is given to the port whose address is stored in the dptr through dptr. The stepper motor is rotated until the count in the register r0 becomes zero, which is simulated as the motor, for the movement of a wheel chair.

7. Futuristic Applications
One possible frightening application of brain machine interface technology is data interpretation were a persons brain contents can be interpreted by interfacing the brain to computers. This has practical applications were police could use this technology to extract secrets from criminals. Direct control of vehicles, computers, phones etc can be done using brain interface without use of our hands and exertion of energy. Futuristic warfare where the soldiers can operate the war weapons and vehicles sitting in some place thousands of miles from the actual place of war. This technology is so futuristic that a person can actually carry out businesses, travel etc without as much as twitching a muscle.

8. Conclusion
Brain machine interface is an emerging technology that is undergoing through a sea of research. It extracts signals directly from the brain thus circumventing the spinal cord and thereby giving spinally injured persons a go at normal life. In this paper the technology has been taken a step further with the design of the BCW that provides mobility to persons with motor immobility. Like any major technology, brain interface has its drawbacks, shortcomings and dangers but it is a technology for the future.

Reference
[1] Gytton & Hall, A textbook of Psychology
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