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NEURAL NETWORKS BRAIN CONTROLLED ARTIFICIAL LEGS

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Abstract: This paper describes a brain controlled robotic leg which is designed to perform the normal operations of a human leg. After implanting this leg in a human, the leg can be controlled with the help of user's brain signals alone. This leg behaves similar to a normal human leg and it can perform operation like walking, running, climbing stairs etc. The entire system is controlled with the help of advanced microcontrollers and digital signal processors. The signals are taken out from the human brain with the help of electroencephalography technique. The person can perform operations like walking, running etc. just by their thought. This system will be very much suitable for those who lost their legs in accidents and the proposed system is hundred percentage feasible in the real time environment with the currently available technology. The Brain Controlled Artificial Legs are very much cost effective when compared to the commonly used artificial legs which are available in the market. The reduction in cost of the proposed system is found to be above 80% when compared to the existing system. Moreover, the user can have full control over the artificial legs which is not possible in the existing system.

I. INTRODUCTION

A brain-computer interface (BCI), sometimes called a direct neural interface or a brain-machine interface, is a direct communication pathway between a human or animal brain and an external device. In this definition, the word brain means the brain or nervous system of an organic life form rather than the mind. Computer means any processing or computational device, from simple circuits to the complex microprocessors and microcontrollers.

An interesting question for the development of a BCI is how to handle two learning systems: The machine should learn to discriminate between different patterns of brain activity as accurate as possible and the user of the BCI should learn to perform different mental tasks in order to produce distinct brain signals. BCI research makes high demands on the system and software used. Parameter extraction, pattern recognition and classification are the main tasks to be performed in a brain signals. In this paper it is assumed that the user of this system has one leg which is functioning fully and the system is designed accordingly.

This system can be extended for both the legs and it is not limited to the basic operation of human legs such as walking, running, climbing stairs etc. It can also perform operations like cycling, hopping etc.

II. BRAIN WAVES

Electrical activity emanating from the brain is displayed in the form of brainwaves. There are four categories of these brainwaves ranging from the most activity to the least activity. When the brain is aroused and actively engaged in mental activities, it generates beta waves. These beta waves are of relatively low amplitude, and are the fastest of the four different brainwaves. The frequency of beta waves ranges from 15 to 40 cycles a second.

The next brainwave category in order of frequency is Alpha. Where beta represented arousal, alpha represents non-arousal. Alpha brainwaves are slower and higher in amplitude. Their frequency ranges from 9 to 14 cycles per second. The next state, theta brainwaves, is typically of even greater amplitude and slower frequency. This frequency range is normally between 5 and 8 cycles a second. A person who has taken time off from a task and begins to daydream is often in a theta brainwave state. The final brainwave state is delta. Here the brainwaves are of the greatest amplitude and slowest frequency. They typically centre on a range of 1.5 to 4 cycles per second. They never go down to zero because that would mean that you were brain dead. But, deep dreamless sleep would take you down to the lowest frequency. Typically, 2 to 3 cycles a second.

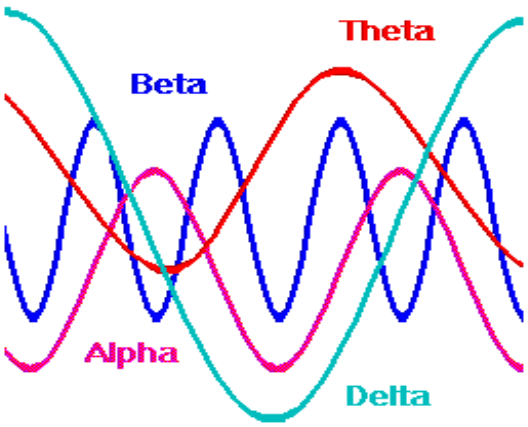

Fig 1:Different Types of Brain Waves

In the proposed system alpha waves and beta waves are used from the brain for signal processing. It is assumed that the person is in alpha state and beta state (which is the case normally) and these waves are taken out from the human brain and converted into electrical signals with the help of electrode caps. The following figure shows the different types of waves and also the mental state of the

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person. Those waves usually vary from a frequency of 1Hz to 40 HZ

III. GENERAL BLOCK DIAGRAM OF THE SYSTEM

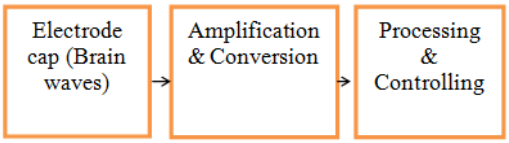

Fig 2. General block diagram of the proposed system

The above fig shows the general block diagram of the proposed system. Electrode cap is placed in the scalp of the person. The signals taken out from the human brain will be in the range of mV and µV. Hence they are fed to an amplifier. Then it is sent to an Analog to Digital Converter to convert the analog brain signals in to digital form. Then it is sent to a signal processor where parameter extraction, pattern classification and pattern identification are done. These digital signals are fed as inputs to microcontroller Unit are placed inside the artificial Leg. The output of the microcontroller unit is fed to the driving circuit. Let us see about these blocks in detail.

IV. ELECTRODE CAP

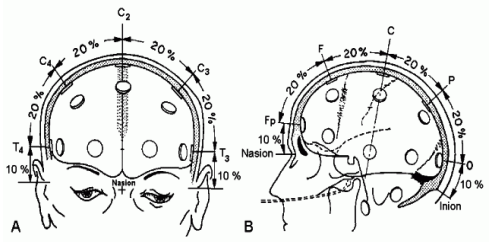

Fig 3 .Diagram of 10-20 electrode cap system

Fig 3: shows person wearing an electrode cap. These electrode caps contains electrodes which are placed on the skull in an arrangement called 10-20 system, a placement scheme devised by the international federation of societies of EEG. In most applications 19 electrodes are placed in the scalp. Additional electrodes can be added to the standard set-up when a clinical or research application demands increased spatial resolution for a particular area of the brain. High-density arrays (typically via cap or net) can contain up to 256 electrodes more-or-less evenly spaced around the scalp. The main function of the electrode cap is to take the brain signals in the form of electrical signals. The signals taken out from the Electrode cap are fed to an amplifier. Fig 3: Placement of electrodes in 10-20 system

V. AMPLIFIER

The output signal from the electrode cap will be in the range of mV and µV. So, these signals will not be suitable for signal processing. Hence these signals are fed to an amplifier. Each electrode is connected to one input of a differential amplifier (one amplifier per pair of electrodes); a common system reference electrode is connected to the other input of each differential amplifier. These amplifiers amplify the voltage between the active electrode and the reference (typically 1,000–100,000 times, or 60–100 dB of voltage gain).

VI. ANALOG TO DIGITAL CONVERTOR

The output signals from the amplifier are analog in nature. They also contain some unwanted signals. Hence the output signals are filtered using high pass and low pass filters. The high-pass filter typically filters out slow artifact whereas the low-pass filter filters out high-frequency artifacts. After the signal is filtered they cannot be directly fed to a digital signal processors and microcontroller unit as they are in analog form. Hence these signals are sent to an Analog to Digital converter to convert the incoming analog signals in to digital signals.

VII. SIGNAL PROCESSOR

Output signal from the A/D converter are fed to a Fast Fourier Transform Unit. This is done to simplify the calculations. An FFT algorithm computes the result in O (N log N) operations instead of O (N^2) operations. Then by parameter extraction, pattern classification and pattern identification, current brain waves are compared with reference signals corresponding signals are created. Then the output signals from the signal processor are fed to a Microcontroller unit.

VIII. MICROCONTOLLER UNIT

The output signals from the signal processor are fed to a microcontroller unit. This microcontroller unit performs the robotic operation with the help of a stepper motor. It will control the operations such as walking, running, etc. depending upon the input signal. For different patterns of input signals it will be pre-programmed to do a specific operation. The reference signal will be already stored in the microcontroller memory in digital form. Usually an 8 bit or a 16 bit microcontroller is preferred depending upon the number of operations to be performed. The complexity of the microcontroller programming increases with the number of operations which has to be performed.

IX. PRINCIPLE OF OPERATION OF PROPOSED SYSTEM:

For every human activity the brain waves changes its pattern. For example, if a person moves his/her hands then a specific pattern of brain wave is obtained and if the same person moves his/her legs then a different pattern of brain wave is obtained. Even if a person thinks of moving his/her legs a brain wave of specific pattern is produced and it is sent to the legs and then the operation of moving the legs is performed. The same brain waves are produced even for a person who is not having his/her legs. But the operation of moving the legs will not be performed due to the absence of legs. So, just by thinking of moving the legs, a brain wave which is capable of performing a specific operation is generated in the brain. Due to the lack of the appropriate system, the activity will not be performed successfully.

In the proposed system, the brain waves are pre-recorded for each operation to be performed and these waves are used as reference signals. These signals are stored in the microcontroller memory. For each reference signal in the microcontroller memory, the robotic leg is pre-

programmed to do a specific operation. When the reference signal matches with the actual signal from the user's brain, the robotic leg will do the pre-programmed operation with the help of the microcontroller.

For example, let us say that the user is thinking of walking. So a brain wave will be produced. These waves are processed and then it is converted in to digital signals. These signals are compared with the pre-recorded reference signals and a match in the signal pattern will be found in the microcontroller. The operation for this particular pre-recorded signal will be pre-programmed in the microcontroller circuit i.e. walking and thus the microcontroller will send the control signal to the artificial robotic leg and the robotic leg will perform the required operation.

Usually a stepper motor controlled robotic leg is used for this purpose. Similarly to walking, other operations can also be performed using the artificial leg. This system is very user friendly and the system can be designed according to the user's requirements i.e. the number of operations required for the user can be fixed by him and the system can be designed accordingly. So the number of operations that has to be performed by the leg can be increased or decreased and the complexity of the design varies accordingly.

This idea can be extended for both the legs and both the legs can be made to do operations like walk, run etc. simultaneously. Thus the system is versatile. This system is hundred percentages feasible in the real time environment and it can be implanted to any human irrespective of their age.

X. POWER SUPPLY

These artificial legs are powered by a small improved lithium-polymer/ion battery which has to be charged once in a week. Lithium-ion batteries have very high charge density (i.e. a light battery will store a lot of energy). They are of ultra-slim design and hence they occupy very less space. Moreover their life time will be longer when compared to other batteries. Hence they are preferred when compared to other batteries. Moreover they have longer life time when compared to other batteries.

XI. COMMONLY USED ARTIFICIAL LEGS

Commonly used Artificial Legs, available in the market, is very costly. They use a group of sensors and a complex algorithm for their operation which makes the existing system very costly. This disadvantage has been overcome in the Brain Controlled Artificial Legs as they don't use any sensors for their operation. Moreover the commonly used artificial legs are 100% dynamic in operation. Hence the chance of occurrence of an error is more in those systems. External appearance and output of both the legs are same. But the method of operation is different. Hence the Brain Controlled Artificial Legs are cost effective.

XII. CONCLUSION

Newton said. "Leg sockets were made out of wood, offering the equivalent of a door hinge at the knee". But with the recent advancement in the technology, BCI Artificial leg can be made as a reality. The performance of the proposed system will be better than the existing artificial legs as the user has full control over the Brain Controlled Artificial Legs. Hence it behaves like a normal human leg. The built-in battery can support a full day's activity. The recharge can be performed overnight or while traveling in a car via cigarette lighter adapter.

The cost of the proposed system is found to be very less when compared to the existing ones. So it is affordable even for middle class people. With this system life can be made easier for the handicapped persons and they can also do their day-to-day activities normally without any difficulties. Even for senior citizen it can be modified to work in a wheel chair. Less cost and also effective.

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