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 operations like walking, running and climbing stairs. The entire system is controlled with the help of advanced digital signal processors. The signals are taken out from the human brain with the help of electroencephalography technique. The person can perform activities (like walking and running) just by a thought. This system will be very much suitable for those who lost their legs in accidents and the proposed system is hundred percent feasible in the real time environment with the currently available technology.

Keywords-Robotic leg, Brain signal, Electroencephalography, Walking.

1.Introduction

A Brain-Computer interface (BCI), sometimes called a direct neural interface or a brain-machine interface, is a direct communication pathway between the brain and an external device. In this definition, the word "brain" means the physical brain or the nervous system of an organic life form rather than the mind. Computer means any processing or computational device, from simple digital circuits to the sophisticated 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 with great accuracy 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 restricted to the basic operations of human legs such as walking, running or climbing stairs. It can also perform challenging operations like cycling, swimming and hopping.

2.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 active to the least active. When the brain is aroused and engaged in vigorous mental activities (like solving arithmetic problems), 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 per 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 lower frequency. This frequency range is normally between 5 and 8 cycles per second. A person who has taken time off a task and into daydreaming is often in a theta brainwave state. The final brainwave state is delta. Here the brainwaves are of the greatest amplitude and least frequency. They typically range from 1.5 to 4 cycles per second. The brain waves never tend to go to zero because when it does, it would mean that the brain is dead. But, deep dreamless sleep would take you down to the lowest frequency. Typically, 2 to 3 cycles a second.

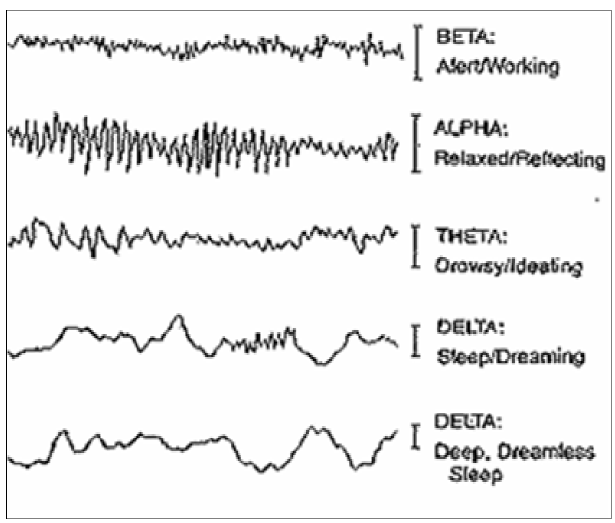


Figure 1 Different types of Brain waves

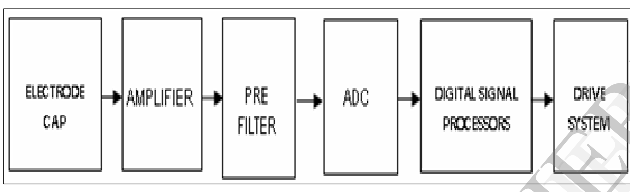
In the proposed system alpha waves and beta waves signals are processed for the operation of the artificial legs. It is assumed that the person is in alpha state and beta state (which is the case normally) and these waves are taken out from the human brain and converted to electrical signals with the help of electrode caps. Fig.1 shows the different types of waves and also the mental state of the person. Those waves usually vary from 1Hz to 40 HZ.

3.General Block Diagram Of The System

Fig.2 shows the general block diagram of the proposed system. Electrode cap is placed on the scalp of the person. The signals taken out from the human brain will be in the range of mV or µV. Hence they need to be amplified by an amplifier. The amplified signal it is sent to a filter to filter out the artifacts (bio-noises). Then it is fed to an Analog to Digital Converter to convert the analog brain signals in to

digital form. It is then sent to a Digital Signal Processor where parameter extraction, pattern classification and pattern identification are done. Another function of the Digital Signal Processor is to control the driving circuit. A stepper motor is used to control the positions and movements of the leg. Let us see about these blocks in detail.

Figure 2 General block diagram of the proposed system



4.Electrode Cap

Figure 3 A person wearing electrode cap

Fig 3 shows a person wearing an electrode cap. This electrode cap 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 function of the electrode cap is to detect the brain signals (from the scalp) and convert it to electrical parameters.

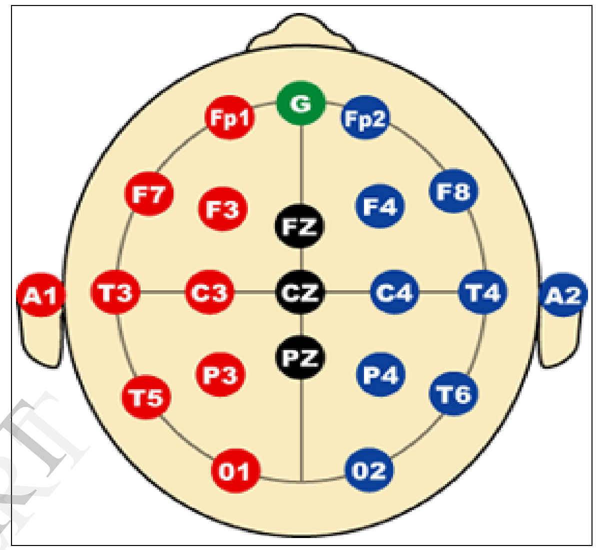


Figure 4 Placement of Electrodes in a 10-20 System

5.Amplifier

The output signal from the electrode cap will be in the range of mV or µV. So, the voltage of 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 to 100,000 times, or 60 to 100 dB of voltage gain).

6.Filter

The output brain signals from the amplifier will contain noise signals. These noise signals are filtered with the help of filter. A high pass and low pass filters are used for this purpose. The high-pass filter typically filters out low-frequency artifacts and the low-pass filter filters out high-frequency artifacts.

7.Analog to Digital Convertor

The output signals from filter are analog in nature. After the signal is filtered they cannot be directly fed to a digital signal processor 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.

8.Digital Signal Processor

Using the output signal from the A/D converter, parameter extraction, pattern classification and pattern identification are done. This is the main part of the proposed system. Once the pattern is identified it is compared with the signal stored in the digital memory. If the digitized brain signal matches the pre-recorded pattern, then the required operation is performed.

The Digital Signal processor performs the robotic operation with the help of a stepper motor. It will control the operations such as walking and running 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 Digital Signal Processor memory. Usually an 8 bit or a 16 bit Digital Signal Processor is preferred depending upon the resolution of the operations to be performed. The complexity of the DSP programming increases with the number of operations which has to be performed.

9.Working of the 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 DSP memory. For each reference signal in the DSP 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 Digital Signal Processor.

Figure 5 Proposed model of the artificial leg

For example, let us assume that the user thinks about 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 Digital Signal Processor. The operation for this particular pre-recorded signal will be pre-programmed in the Digital Signal Processor i.e. walking and thus the Digital Signal Processor will send the control signal to the artificial robotic leg and the robotic leg will perform the required operation.

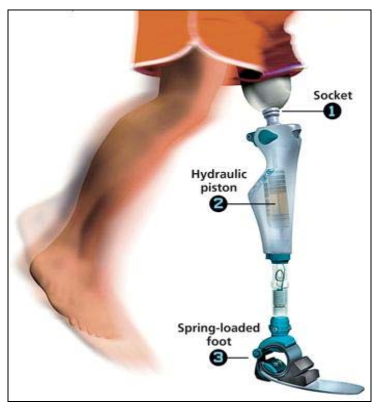


Figure 6 Internal apperance of the artificial leg

Usually a stepper motor controlled robotic leg is used for this purpose. Similar 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.

Figure 7 Climbing down the stairs using artificial legs

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

Figure 8 Walking with artificial legs

Figure 9 Artificial legs fitted to both the limbs

Note: Fig 8,9 shows the existing normal artificial legs which are currently available in the market.

10.Power Supply

These artificial legs are powered by a small lithium-ion battery which has to be charged once in two days. Lithium-ion batteries have very highcharge 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.

11.Normal Artificial Legs

Normal Artificial Legs, that are commercially available, is very expensive. 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 normal 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.

12.Difference between Brain controlled artificial legs and normal artificial legs

Brain Controlled Artificial Legs	**Normal Artificial Legs**
1. Ease of Construction	1. Complex in construction
2. Cost is very less.	2. Cost is about $80,000-$90,000(Rs.35,00,000 to Rs.40,00,000)
3. User can have full control over the artificial leg.	3. User cannot have full control over the artificial leg.
4. Semi-Automatic	4. Fully Automatic
5. Sensors are not required	5.Sensors are required
6. Requires simple control unit.	6. Requires complex control unit.

13.Conclusion

Forty years ago, the technology was so basic. 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, Brain Controlled 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 lasts anywhere from 25 to 40 hours so it can support a full day's activity. The recharge can be performed overnight or while traveling in a car via a cigarette lighter adapter.

The cost of the proposed system is found to be very less when compared to the existing ones. So, even the middle class people who cannot purchase the existing artificial legs can make use of this proposed system.Moreover, the user can have a full control over the artificial legs which is not possible in the existing system. 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.

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