Wireless Assistive Technology for Severely Disabled Persons: An Overview

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Abstract–Assistive technology plays very important role in the life of the people who are severely disabled due to quadriplegia, spinal cord injuries, central nervous system disorders or traumatic brain. Assistive technologies help them to lead a self supportive independent life. This paper provides the brief description about the various assistive technologies which has been developed until now for the severely disabled persons and its limitation. Further Tongue Drive System incorporating wireless assistive technology, which can overcome the limitation of previous related technologies, is discussed. Tongue Drive System is a tongue operated non-invasive or minimal invasive, unobtrusive and effective technology to control many devices in their environment. It helps users with the ability to drive power wheelchairs and access computers using their unconstrained tongue motion.

Keywords – Assistive technologies (ATs), magnetic sensors, spinal cord injuries, wheelchair movement control.

I. INTRODUCTION

The number of people severely disabled due to spinal cord injuries, quadriplegia or repetitive strain injuries (RSIs) is continually increasing. It becomes tedious for such person to carry out their work in day to day life without continuous assistance. Power wheelchair plays the key role in severely disabled person's life as they completely depend on the wheelchair for moving around in home, office and outdoor environment. Normally, the movement of wheelchair is controlled by operating the joystick, but for doing so upper limbs should have certain level of physical movement, which people with severe disabilities may not have. Hence researcher developed some assistive technology which enabled user to operate or control the devices that they were previously unable to operate or find hard to operate, by providing changing method of interacting with device depending on the remaining abilities in the user like head movement, eye position, muscular activities or neural signals. A number of assistive technologies have been developed to access personal computer, telephone, television or for driving power wheelchair. With the use of assistive technology the user will leave self determine life and can do some kind of official work. Also the work load of family member and dedicated caretaker will get reduce as the user with the help of assistive technology can do most of the work. Lots of improvement has been done in the power wheelchair depending upon the different type of disabilities in the people but there is a great scope of improvement for developing the wheelchair which can be totally operated without body movement.

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II. VARIOUS ASSISTIVE TECHNOLOGIES

Though people suffering from spinal cord injuries, quadriplegia or repetitive strain injuries cannot move there limbs, yet they have certain remaining abilities in them like muscular activities, diaphragm control, eye positions, voice or brain waves. By making study of the patterns of the remaining abilities in the user researchers had developed various assistive technologies. In all such technologies, computer works as an interface between the user and device to be operated.

A. Diaphragm Controlled Assistive Technology

The assistive technology that works on the principle of diaphragm control has been developed. It sends a signal to a device using air pressure by inhaling and exhaling through a straw or tube. Control typically consists of four different inputs from the user depending upon hard or soft inhaling and exhaling. It is one of the most popular, inexpensive and simple technology, but the person who continuously use ventilator may avail of this technology. The limitation of this technology is that we cannot assign more than four commands; moreover it is slow and awkward. Also the straw or tube which is used for inhaling and exhaling needs to be frequently cleaned.

B. Head Mounted assistive technology

The head mounted assistive technology is developed for such a person who is suffering from quadriplegia but has retained certain kind of neck or shoulder movements. This technology is mainly used to make devices that imitate computer mouse using head movement. In one of the approach, an infrared beam emitted or reflected from a transmitter or reflector attached to user's cap, glasses or headband is tracked, for controlling the movement of cursor. In one of the system tilt sensors are used to move the cursor in vertical and horizontal direction on computer screen. To detect the tilt from the gravity vector, the tilt sensor generally makes use of inertia [8]. As the user move the head in some direction the angle between a sensing axis and a reference vector that is earth's magnetic field is detected by sensor and depending upon the angle cursor movement will take place. One more system known as "Camera Mouse" has been developed to control the movement of cursor. This system consist of a video camera in front of the user, which continuously track the head or nose movement and proportionally moves the mouse pointer on the computer [10]. The main drawback of these systems is that it constantly requires neck or shoulder movement which is tiring and uncomfortable for the user.

The head of the user should always be in the range of sensor otherwise the user cannot be able to control the movement of cursor. Also the design limits the allowable commands to be generated.

C. Eye Gaze System

Another technology to assist the individual for driving power wheelchair is an eye gaze system. In this technology corneal reflection and pupil position act as an input. System takes the decision based on the movement of pupils or reflection coming from the cornea. In earlier systems, eye gaze trackers require physical contact with the user body like attaching a number of electrodes around the eye or placing a reflective dot directly onto the eye [7]. This system has two major drawbacks that, it has to be calibrated for each user individually and the users have to keep their head still since they have low tolerance for head movement that is very difficult for the user. To overcome these limitations eye gaze system which is based on visual feedback captured by video cameras has been developed. This is more promising system than previous eye gaze system because it provides the non-invasive way to develop the system. This system has the limitation that the sight of the user may get block due to the camera or display, which is always there for the visual feedback. Also eye is a part of sensory cortex and not of motor cortex therefore extra eye movements affects the normal visual activities of the user like reading and watching. Hence, when the user looks at some point system is not able to assign a particular command to the device, this problem is still unsolved.

D. Neural Interface System

Recent advancement in neuro-technology has helped the users who cannot benefit from mechanical movement of any body organs by developing the series of devices known as Brain Computer Interfaces (BCI) or Neural Interface System (NSI). This system control the external devices by detecting user's intention by utilising electric signal originated from brain waves [4]. The interface between the computer and brain become possible for the researcher due to noticeable progress in mathematical modelling for decoding of neural signal, detail understanding of the cortical region of the brain and development of new implantable microelectrode array. Brain computer Interface can be classified into invasive and non invasive system. The majority of the human Brain Computer Interfaces are invasive depend on the sensing of field potential signals recorded on the scalp using electroencephalography (EEG) or electrocorticography (ECoG) signals directly from the cortical surface for e.g. BrainGate is an invasive technology using intra-cortical electrodes [1]. Another type of BCI uses non-invasive technology for e.g. Cyberlink is a non-invasive interface using electrodes attached to the forehead [1]. In invasive system for making good electrode contact with the cortical region considerable amount of time is required because if good contact is not possible the electrode is removed and cleaned each and every time until we create good electrode contact. Hence it set up time is more. Also this system is prone to high error rate as the signal generated by the EEG has very small amplitude. The system can give unwanted command to the device due to interference of signals resulted from other activities such as talking and muscle contractions. To overcome such problem heavy signal processing and complex computational algorithm can be used, but it will increase the cost and delay. In addition, such a highly invasive technology may not be preferred by the potential users.

E. Voice Controlled Assistive Technology

Voice controlled mechanism can also be used to operate power wheelchair by the individual who can produce consistent and distinguishable voice. This technology makes use of speech recognition system for taking voice of the user as the input signal. Before this speech recognition system is used for actual control of the wheelchair it has to be trained. The set of command spoken by the user will be saved by this system. During operation the user speaks a command into the microphone; the speech recognition system will compare the spoken command with the saved command and will transmit the computer code associated with it. In this way we can operate the wheelchair. The advantage of this technology is that, users don't have to physically operate the wheelchair and it is also easy to learn [6]. It is unreliable because sometime it may fail to recognise user command which may lead to collision. It has been proven suitable for operating other assistive technologies such as computer and environmental control systems but is yet to become a viable wheelchair control method because it is difficult to operate in noisy and crowded environment. The user cannot do the frequent changes in the position of wheelchair in the crowded environment due to slow signal processing. We can improve its reliability by making use of sophisticated signal processing, but it is a costlier solution [4].

Out of all these assistive technologies which were developed, very few assistive technologies has been proved successful in outer environment rather than in research laboratories. There are various technical and psychophysical factors which affect the acceptance rate of an assistive technology which are as follows

- it should be easy and convenient to operate
- device should require less time to learn
- it should be cosmetically suitable
- device should be portable, unobtrusive, minimum or non-invasive [1]

Tongue Drive System is using tongue to operate the system because unlike hands and feet, which are controlled by the brain through spinal cord, the tongue is directly connected to the brain by a cranial nerve that generally escapes damages in severe spinal cord injuries or neuromuscular diseases [1]. Some amount of sensory and motor cortex in the human brain is occupied by tongue and mouth which shows equality in the ability with that of the fingers and hands [1]. Therefore tongue movement is fast, accurate and do not require much thinking, concentration or efforts. Also there is similarity between tongue muscle and heart muscle hence it does not fatigue easily [2]. Therefore a tongue based device can be used continuously for several hours. The tongue can be comfortably moved by the user at the resting position hence this system is advantageous for such people who are not able to sit for long time as they can operate device at resting position also.

Tongue Drive system consists of the arrangement of Hall Effect magnetic sensors and permanent magnet. Permanent magnet is held on the tongue using tissue adhesives or tongue piercing [2].

A Hall Effect sensor is a transducer that varies its output voltage in response to changes in magnetic field. In its simplest form, the sensor operates as an analogue transducer, directly returning a voltage. The magnetic field generated by the magnet will vary around the mouth as a result of tongue movement.

These variations are sensed by an array of magnetic sensors mounted on the headset outside the mouth [2]. Analog outputs generated by sensors are digitized, modulated, multiplexed and given to wireless transmitter .Wireless transmitter will transmit the signal in air. Wireless receiver will receive the signal, demodulate and de-multiplex it to extract the individual sensor output [1]. By processing these outputs, the motion of the permanent magnet and consequently the tongue within the oral cavity is determined [1]. Assigning a certain control function to each particular tongue movement is done in software and can be easily customized for each individual user. These customized control functions may then be used to operate powered wheelchair. The basic block diagram of Tongue Driven system is shown below:

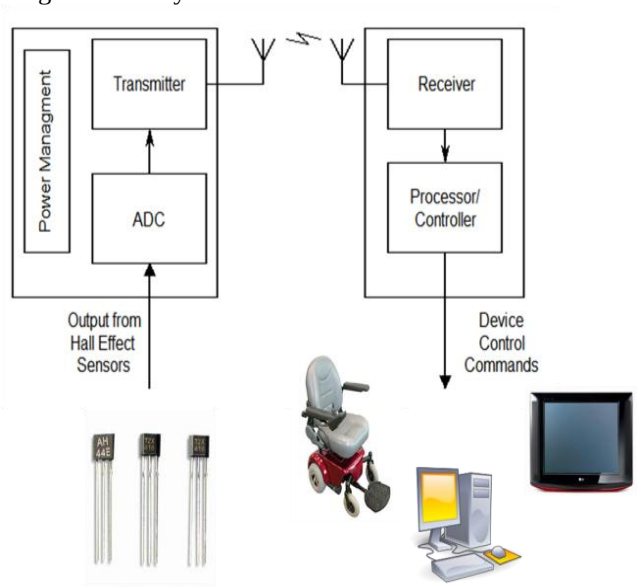

Figure 1. Basic block diagram for the Tongue Drive System

Depending upon this methodology few systems were developed. In one approach M. Ghovanloo and G. Krishnamurthy has developed a prototype Tongue Drive System. This system consists of four Hall Effect sensors which provide linear voltage output proportional to the vertical magnetic field. They have used cavities created in a Shock Doctor Max mouth guard for installing four Allegro A1321 ratiometric linear Hall Effect sensors with 5mV/G sensitivity along with 0.1 μF surface mount decoupling capacitors. The motive of this system was to move the cursor on computer screen based on the position of the permanent magnet relative to the four Hall Effect magnetic sensors, to judge the viability and performance of the approach in developing assistive devices. Of the four sensors arranged in parallelogram geometry the two front aligned sensors controlled the movements along X-axis while the remaining two rear sensors controlled the Y- direction. They designed the GUI and defined two modes of operation. First one is proximity mode, in which cursor movement would be controlled by that sensor to which magnet is closer. If the tongue is at resting position then no sensor has the control over the cursor movement. Second mode is Motion Detection in which system looks for movement of the magnet along with its position relative to the sensor. If the magnet is held steady there will be no cursor movement even if magnet is much closer to the sensor. [1]

In another approach, J. Kim, X. Huo et al used the iPhone as a wireless interface between Tongue Drive System and power wheelchair. The prototype system consists of an adjustable headgear with four 3–axial magneto-resistive sensors (HMC1043) two on each side, held near the user cheeks by the pair of goosenecks. A titanium tongue barbell with a magnet on it was pierced on the tongue. The magnetic field generated due to barbell changes as the user move the tongue. The changes were traced by the four 3-axial magnetic sensors and provide continuous real time analog outputs. The magnetic sensor outputs were sampled and digitized by the control unit which is mounted on the headset. Then wireless transmitter transmits the unprocessed data frames to the iPhone. In this system, sensor signal processing algorithm was used which will not only suppresses the EMI in the incoming data and also translate them into user defined commands. The command was also displayed on the iPhone screen for providing visual feedback to the user. [3]

III. CONCLUSION

In this paper, various types of assistive technology are discussed. The approach of every assistive technology was based, to the large extent, on the level of disabled person incapacity. A new communication and control technology using tongue has been discussed that can provide faster, smoother, and more convenient relative control than that of many existing technologies. Also it is low cost, minimal invasive, low power consuming and easy to learn assistive technology.

REFERENCES

1. G. Krishnamurthy and M. Ghovanloo, “Tongue Drive: A tongue operated magnetic sensor based wireless assistive technology for people with severe disabilities”, in Proc. IEEE Int. Symp. Circuits Syst., May 2006, pp. 5551–5554.
2. X. Huo, J. Wang, M. Ghovanloo, “A Magneto-Inductive Sensor Based Wireless Tongue-Computer Interface”, in IEEE Transactions on Neural Systems and Rehabilitation Engineering,Vol.16, No.5, October 2008, pp.497–504.
3. J. Kim, X. Huo, M. Ghovanloo, J. Minocha, A. Laumann, “Evaluation of a Smartphone Platform as a Wireless Interface Between Tongue Drive System and Electric-Powered Wheelchairs”, in IEEE Transactions on Biomedical Engineering, Vol. 59, No. 6, June 2012, pp.1786–1796.
4. X. Huo, M. Ghovanloo, “ Using Unconstrained Tongue Motion as an Alternative Control Mechanism for Wheeled Mobility”, in IEEE Transaction on Biomedical Engineering, Vol. 56, No.6, June 2009,pp.1719–1726.
5. R. Vaidyanathan, B. Chung, L. Gupta, S. Kota and J. West, “Tongue-Movement Communication and Control Concept for Hands-Free Human Machine Interfaces”, in IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans, Vol. 37, No. 4, July 2007, pp. 533–546.
6. R. Simpson, S. Levine, “Voice Control of Powered Wheelchair”, in IEEE Transaction on Neural Systems and Rehabilitation Engineering, Vol. 10, No.2, June 2002,pp. 122–126.
7. Z. Zhu and Q. Ji, “Novel Eye Gaze Tracking Techniques under Natural Head Movement”, in IEEE Transactions Biomedical Engineering, Vol. 54, No. 12, December 2007,pp. 2246–2260.

8. Y. Chen, “Application of Tilt Sensors in Human–Computer Mouse Interface for People with Disabilities”, in IEEE Transactions Neural Systems and Rehabilitation Engineering, Vol. 9, No. 3, September 2001, pp. 289–295.
9. S. Kim *et al*, “Point-and-Click Cursor Control with an Intracortical Neural Interface System by Humans with Tetraplegia”, IEEE Transactions on Neural Systems and Rehabilitation Engineering, Vol. 2, July 1995, pp. 193–203.
10. M. Betke, “The Camera Mouse: Visual Tracking of Body Features to Provide Computer Access for People With Severe Disabilities”, IEEE Transactions on Neural Systems and Rehabilitation Engineering, Vol. 10, No.1, March 2002, pp.1–10.

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Gaurav. B. Saboo received the B.E. degree in Electronics and Telecommunication Engineering from Shri Sant Gajanan Maharaj College of Engineering, Amravati University in 2009, and he is currently pursuing the M. Tech in Electronic System and Communication (ESC) at Government College of Engineering, Amravati**.**

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