WISION- Wireless Interface System for Interpretation of Ocular symbols from People with Neuromuscular Diseases

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***Abstract*— This paper proposes the design of a system that enables the severely disabled to communicate using their EOG, EMG and EEG signals. The typical approach is to modify the end devices to interpret these signals and to function accordingly [2-5]. But our system proposes an Interpreter System within which these signals are decoded and interfaced with the existing devices. The advantage is that the end devices need not be changed to suit the user, because the logic required for interpretation is within the Interpreter System. Therefore it acts as an interface through which the user can control multiple devices at the same time. Acquisition systems can capture and process EOG, EMG and EEG signals and transmit them to the Interpreter System via the Bluetooth Low Energy module. A communication language using EOG works in combination with EEG and EMG to enable communication. This language will help the users to interface with multiple devices with a limited number of symbols.**

Keywords-EMG; EEG; Assistive technology; Communication Device; Motor Neuron Disease; ALS

I. Introduction

Various forms of motor neuron diseases, accidents and stroke can leave a person permanently paralyzed and unable to communicate in any conventional manner. However, they are left with active brains capable of expressing emotions, creativity and intelligence, and no way to communicate. Many systems using EEG, EOG, EMG and other means have been developed.

The brain activity produces electric signals, which can be measured using EEG to find out the information that the user wants to convey. But since this technology is not very accurate [5], it is not suitable to be used as the only method of communication. EMG can be measured from various locations like cheeks, forehead, jaws etc. but the amount of information that it can convey is less because of limited degrees of movement for people affected by neuromuscular diseases. Many of the degenerative diseases eventually weaken all the muscles and hence they cannot be used for communication. EOG is a good method of communication for such people because there is much evidence to support the fact that motor neuron diseases do not affect the eye muscles [1]. The movement of the eyes can be tracked using a limited number of electrodes and it offers more degrees of movement than EMG.

Much work has been done in this area using EOG [2][3], EMG [4], and EEG [5] signals, but all of these systems focus on changing the end devices to suit the user and have been developed for specific applications like navigating wheelchairs, human computer interface and so on. This work focuses on a general purpose system that can be used to communicate with and control a number of devices with a limited number of commands. Fig.1 shows an Interpreter System that monitors the various signals from the user, interprets and interfaces them with a number of other devices.

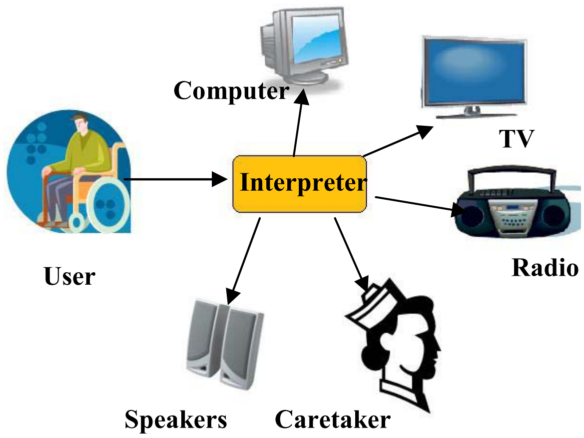

Figure 1. The Interpreter System interfaces with various devices

II. SYSTEM DESIGN

The system can be divided into two subsystems- The Acquisition and Interpreter systems. The Acquisition system is responsible for capturing, processing and transmitting the EOG, EMG or EEG signals using the Bluetooth Low Energy (BLE) module. This is received and decoded by the Interpreter system to act as an interface to various devices.

A. Acquisition system

Acquisition system acquires EOG, EMG and EEG signals as shown in Fig.2. The signal is acquired using capacitive type electrodes, since they can capture signals even through hair or clothes. Unlike the other electrodes, skin preparation is not necessary for capacitive electrodes. The signal thus acquired is passed through a preamplifier. This is then further processed using a differential amplifier in order to eliminate the DC offset. The frequencies of interest are separated using a Band Pass Filter. The Micro Controller Unit (MCU) converts the signal to digital format and then further processes it for extracting features of interest, in order to minimize the amount of data that has to be transmitted via the BLE module.

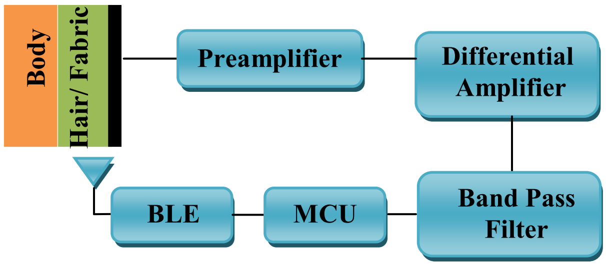

Figure 2. Acquisition system for EOG, EMG and EEG

B. *Interpreter System*

This system is designed to receive and interpret the signals from multiple Acquisition systems, in order to find out the symbol that the user is trying to communicate. Machine learning algorithms can be trained to accurately detect these symbols in a patient specific manner, because the Interpreter system is generally meant only for a single user.

Communication from EOG is established using a series of symbols. The eyes predominantly move in four directions, which labeled- Up (U), Down (D), Left (L) and Right (R). Various methods [7] [8] exist, to detect the direction of eye movement.

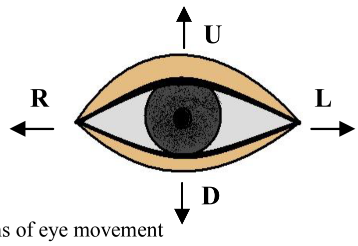

Figure 3. Directions of eye movement

Using formula 4Pr, different permutations of the 4 directions- U, D, L and R, produces unique symbols of length r, where r varies from 1 to 4. These are the symbols used for communication. A permutation of the 4 directions produces 24 symbols of length r=4. Another 24 symbols are produced when r=3, 12 symbols are produced when r=2 and 4 symbols when r=1. This implies that we get a total of 64 unique symbols, whose lengths vary from 1 to 4. These are the symbols which are used for the actual communication.

More symbols can be produced by considering the repetition of directions within a symbol, provided they show a transition in direction from one state to the next. Considering this, the permutation of 4 directions- 4x3x3x3 gives 108 symbols, 3 directions- 4x3x3 gives 36 symbols, 2 directions- 4x3 gives 12 and 1 direction gives 4 symbols. This gives a total of 160 symbols.

The difficulty in using the eyes for communication lies in the fact that it serves dual purposes for the user. The user requires the eyes for communication, as well as for observation. Therefore the Interpreter System needs to be alerted as to when the user is ready to start or stop communication.

The beginning of the communication cycle is marked by using a unique sequence of EMG signals. Once the start of the communication cycle is marked, the EMG Acquisition Systems can go into low power state. After each EOG symbol is communicated, it is terminated by signaling an end symbol sign, by bringing the eye back to its normal position and waiting for at least B_T eye blinks. This end symbol sign is essential to distinguish between symbols because the symbols of shorter length are subsets of the longer symbols. The next symbol can start immediately after this end symbol sign.

If the user remains in the end symbol position for more than B_E eye blinks, where $B_E > B_T$, without starting the next symbol, the Interpreter automatically stops the communication cycle. Further eye movements are not sensed and the EOG Acquisition Systems go into low power state. This automatically triggers the EMG Acquisition Systems into active state, until the next communication cycle starts. The parameters of B_T and B_E is set by the user.

If the user is not able to make any muscle movement at all, the EOG Systems need to continue monitoring the symbols, even after the communication cycle has ended. The start of the communication cycle can then be initiated with a rare combination of eye movements and blinks, in order to prevent the user from accidentally triggering the start of the communication cycle. So until the start symbol is encountered, the EOG Systems only monitor the symbols, without interfacing them with any of the devices.

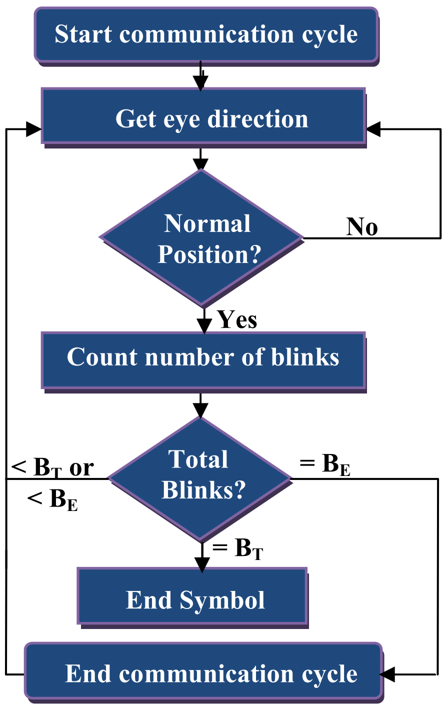

Figure 4. Flow chart of the communication cycle

The Interpreter System is used as an interface to a number of devices such as the computer, television, radio or air conditioner. It can even be used to communicate with other people. In order to enable this, some of the symbols are reserved only for selecting the Interface towards which the communication is intended, as shown in Fig. 7. The rest of the symbols can be reused for issuing different commands, depending on the device currently selected. For example, if there are 9 Interfaces to various devices- television, radio, air conditioner, caretaker, emotion interface, the computer mouse and keyboard, text to speech converter and an interface to the Interpreter itself, 9 unique symbols are allocated for the selection of each of these interfaces. The rest of the 55 symbols can be reused to issue different commands to these interfaces. This means that the same symbol would mean different things depending on the interface to which it is directed.

An overview of the hardware and software modules of the Interpreter System is given below.

Hardware modules of Interpreter

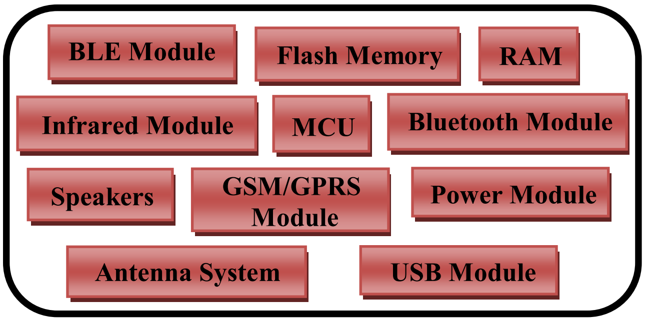

Figure 5. Hardware modules of Interpreter System

Software modules of Interpreter

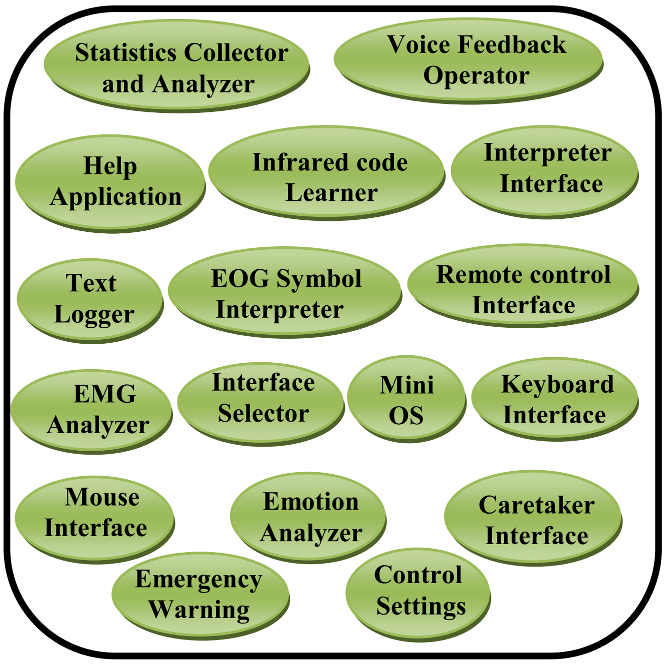

Figure 6. Software modules of Interpreter System

The EOG data sent by the Acquisition System is decoded by the EOG Symbol Interpreter and the symbol is passed on to the Interface selector. If the symbol is an Interface selection symbol, the EOG symbols following that, are passed on to that particular interface.

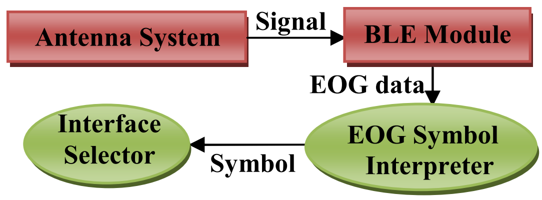

Figure 7. Block diagram of Interface selection

Computer Interfaces

The Interpreter interfaces with the computer via USB or Bluetooth module to work in mouse/keyboard mode. The mode is selected by the user using EOG symbols. A mouse/keyboard driver installation will be automatically initiated by the Interpreter System, on the computer, when it is first asked to connect to the computer in the mouse/keyboard mode. This driver is responsible translating the instructions from the Interpreter into mouse/keyboard commands.

When connected in the keyboard mode, the symbols are mapped to the keys of the keyboard and hence the user will be able to type with the help of EOG symbols.

When connected in the mouse mode, the mouse acts as an eye pointing device [9]. The user will be able to perform all the functionalities of a mouse with the help of the eyes. But to come out of this mode, the user will have to take the help of EMG signals since all eye movements are mapped to the mouse and the symbols are not being monitored anymore.

In case of inability to use EMG signals, a program can run in the background to detect the signaling of a particular EOG symbol to end the mouse mode. Alternatively, the mouse mode can run until the user manually selects the option to uninstall the mouse driver from the computer.

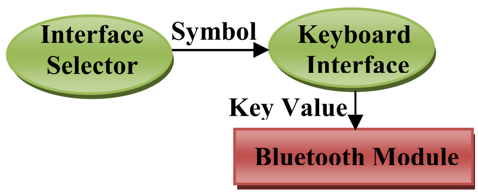

Figure 8. Block diagram of keyboard interface via Bluetooth

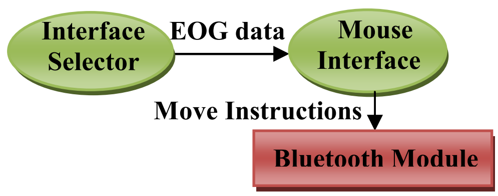

Figure 9. Block diagram of mouse interface via Bluetooth

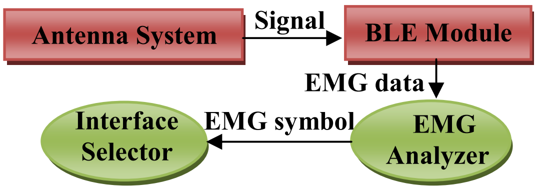

Figure 10. Block diagram of analysis of EMG data

Caretaker Interface

The user might want to communicate his/her basic needs via symbols, to the caretaker, such as food, water, discomforts and so on. If the caretaker is always at hand, it will be enough to issue voice messages through the speakers.

Emergency situations can occur where the user wants to immediately contact the caretaker. This can be accomplished via the GSM/GPRS module.

Since the Interpreter contains a flash memory card, it is used to collect and analyze vital statistics about the patient's physical and mental state. In such cases, emergency situations might also occur without the knowledge of the user. Then the Interpreter directly contacts the caretaker and might issue a warning to the user through the speakers.

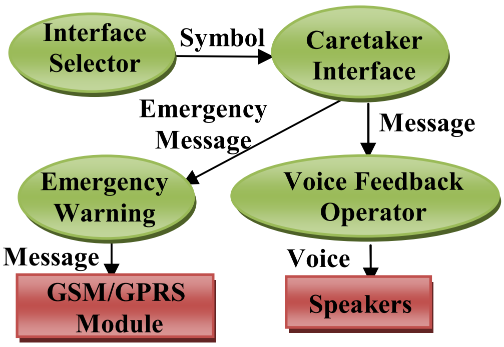

Figure 11. Block diagram of caretaker interface

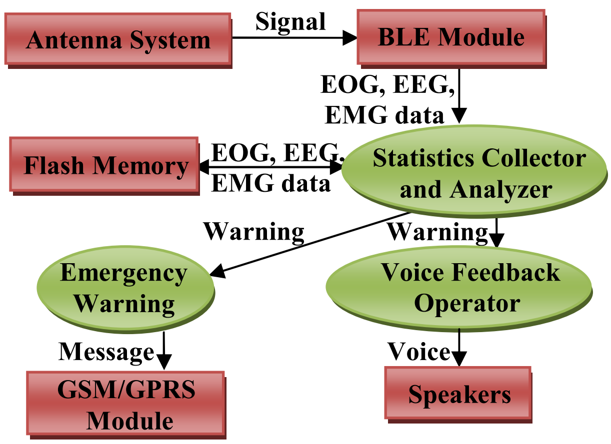

Figure 12. Block diagram of vital statistics collection and analysis

Text to Speech Interface

In cases where the preprogrammed symbols are unable to express the needs of the user to the caretaker or family members, the text to speech interface functions similar to the keyboard, where the user will be able to type text through symbols and this is then converted to speech and conveyed through the speakers.

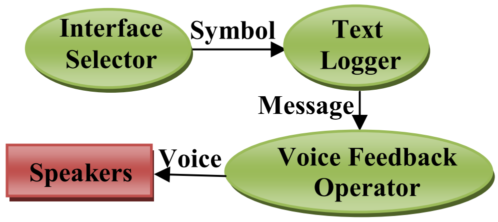

Figure 13. Block diagram of text to speech interface

Remote control interface for home appliances

The Interpreter interfaces with the home appliances via the Remote control interface. It interprets EOG commands from the user like on, off etc. and translates these into Infrared signals using the appliance manufacturers command codes. It is also given learning capabilities in order to make it easier for interfacing with devices from different manufacturers.

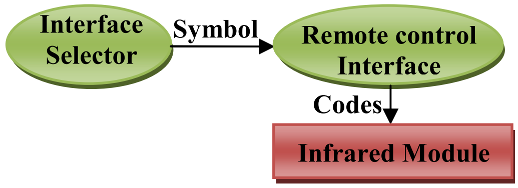

Figure 14. Block diagram of remote control interface

Emotion Interface

The EEG is a good indicator of the emotional state of a person [10]. But since all users might not be willing to expose their emotional state to others, they need to voluntarily approve the recording of this information. The user can voluntarily provide information about his/her emotional state by activating this interface using an EOG symbol. The emotional state can then be communicated through the speakers for attention.

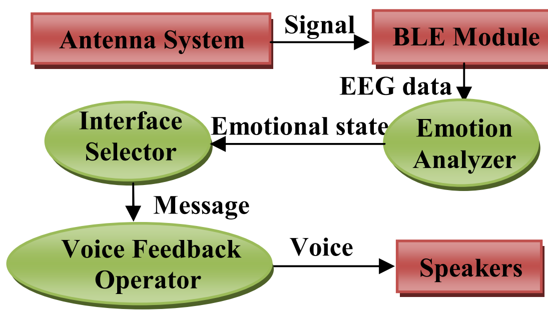

Figure 15. Block diagram of emotion interface

Interpreter Interface

The user might want to adjust the settings of the Interpreter itself. Parameters such as volume of the speakers, mapping of symbols to commands, value of B_T and B_E etc. is adjustable by the user. So the user can access these settings through commands to change it to suit his/her needs.

Since it is difficult for the user to memorize all the symbols, a help application is provided by the Interpreter. The user will be asked to select the device to be controlled, using the corresponding EOG symbol. Then he/she has to type in the keyword of the parameter that needs to be controlled. The application can be programmed to either speak out the symbol directions using the voice feedback operator, or to directly execute the selected command at the user's request. The advantage is that the user needs to only memorize the symbols to select the end device and the symbols for typing the alphabets.

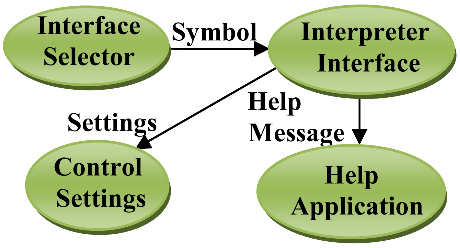

Figure 16. Block diagram of interpreter interface

It is very important for the Interpreter to constantly give feedback about its actions, to the user so that any misinterpreted/erroneous commands can be corrected. In order to do this, the Interpreter should constantly give voice feedback through the speakers to the user about its understanding of each of the commands. In case of any confusion, the interpreter is programmed to ask simple yes/no questions to the user. This will make the user more comfortable as mistakes can be identified immediately.

Since the Interpreter stores the vital statistics about the patient, this can be viewed by a physician periodically to ensure that the patient's health is in order.

The user's EEG will inform the Interpreter whether he/she is asleep or awake. During the user's sleep state, the Interpreter can function in low power mode, where it just periodically wakes up to check on the user.

III. SYMBOLS

There exists a variety of methods to generate more symbols. Any of these methods may be adopted to suit each user.

Different permutations of the symbols themselves will produce more symbols. But in order to avoid overlap with the existing symbols, the net length of the new symbols need to exceed the length of four directions.

The diagonal and normal eye level directions can also be considered while creating the symbols. So along with the 4 directions already considered, there will be 5 more directions to create a total of 9 directions.

Alternatively, EMG can be combined with EOG to produce more symbols. Whichever method is adopted, care should be taken in order to avoid increasing the complexity of the system, since patient training becomes difficult.

IV. CONCLUSION

The proposed method will greatly improve the quality of life of the users. Its advantages include the facts that a large number of functionalities can be performed with a limited number of symbols. It enables the users to lead active lives and be in control of many things, in spite of having disabilities. The system can accommodate different types of end devices that have a common interface with the Interpreter System. When new and better algorithms to process EOG, EMG and EEG signals are developed, the Interpreter System alone needs to be reprogrammed.

Its disadvantages include the fact that the system requires an initial training phase in which the users will be taught the basic symbols and their usage. The symbols need to be memorized for faster usage and this might be difficult for elderly people. The speed at which the symbols are conveyed may cause strain to the user's eyes. So they have to maintain moderate speed in order to avoid strain and remain in control.

Algorithms considering both EEG and EOG signals, for the decision making process, can improve the overall performance of the system.

REFERENCES

[1] Motor Neuron Disease: General Articles - Brain Disorders, Neurological Foundation of New Zealand http://www.neurological.org.nz/News/General-Articles/Article/Motor+Neuron+Disease/ , Last Access Date: 23-5-11..

[2] Päivi Majaranta and Kari-Jouko Räihä, "Twenty Years of Eye Typing: Systems and Design Issues," in IEEE Transactions on neural systems and rehabilitation engineering, vol. 10, no. 1, March 2002.

[3] Rafael Barea, Luciano Boquete, Manuel Mazo and Elena López, " System for Assisted Mobility Using Eye Movements Based on Electrooculography," ETRA2002, ACM, pp. 15-22, 2002.

[4] Md. R. Ahsan, Muhammad I. Ibrahimy, Othman O. Khalifa, "EMG Signal Classification for Human Computer Interaction: A Review," European Journal of Scientific Research, vol. 33, no. 3, pp. 480-501, 2009.

[5] Dr. Kristin Cobb, "The dawn of brain-machine interfaces" Biomedical Computation Review, Fall 2005.

[6] Yu M. Chi, Patrick Ng Eric Kang, Joseph Kang Jennifer Fang, "Wireless Non-contact Cardiac and Neural Monitoring," in WH'10, pp. 15-23, 2010.

[7] Manuel Merino, Octavio Rivera, Isabel Gómez, Alberto Molina, Enrique Dorronzoro, "A Method of EOG Signal Processing to Detect the Direction of Eye Movements," in First International Conference on Sensor Device Technologies and Applications, 2010.

[8] Lawrence Y. Deng, Chun-Liang Hsu, Tzu-Ching Lin, Jui-Sen Tuan, Yung-Hui Chen, "EOG-based signal detection and verification for HCI," in Proceedings of the Eighth International Conference on Machine Learning and Cybernetics, Baoding, July 2009.

[9] Yoshiaki Kuno, Tohru Yagi And Yoshiki Uchikawa, "Development of eye pointer with free head-motion," in IEEE Engineering in Medicine and Biology Society, vol. 20, no. 4,1998.

[10] M. Murugappan, M. Rizon, R. Nagarajan, S. Yaacob, D. Hazry and I. Zunaidi, "Time-frequency analysis of eeg signals for human emotion detection," IFMBE Proceedings, vol. 21, part 3, part 4, pp.262-265, 2008.

[11] Vocal Eyes Becker Communication System, http://www.jasonbeckerguitar.com/eye_scroll.swf, Last Access Date: 23-5-11.

[12] K. Grauman, M. Betke, J. Lombardi, J. Gips, G.R. Bradski, "Communication via eye blinks and eyebrow raises: video-based human-computer interfaces," Springer-Verlag 2003, October 2003.