DEVELOPMENT OF AN EOG BASED HUMAN MACHINE INTERFACE TO CONTROL A 3R ROBOT

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ABSTRACT

To improve the quality of life of persons with severe disabilities rehabilitation devices are been developed increasingly. This paper describes one such novel technique. Usually persons suffering from extreme disabilities have the ability to control their eye movements. Electrooculography (EOG) is a technology of sensing eye signals and is used efficiently and effectively in developing bio-based human to machine interface (HMI) and human computer interface (HCI). Human to machine interfaces have received more and more attention of researchers in recent years. The described paper explains a simple electrooculography (EOG) based eye-control method to control 3R Robot. Human to machine interfaces have received more and more attention of researchers in recent years. Four electrodes are used to capture the EOG signal: two to detect horizontal movement and two to detect vertical movement. The captured signal is processed using a cost effective signal conditioning circuitry and is given as an input to the microcontroller to produce different control signals. These controls signals are transmitted using RF transmitters after encoding to the application part (receiver part). Once the commands are received, then according to the received combination (RL, LR, RR, LL, BB) the microcontroller which is programmed to drive the two servo motors of the robotic arm in required fashion moves the robotic arm up, down, left, right. An accuracy of 90% and processing speed of 5actions/min is achieved. The results show that the EOG based eyerobot system has stable performance and can be a good assistive technique for people suffering from extremely limited peripheral mobility.

Keyword:- Elctro-oculogram (EOG), Corneal-retinal potential (CRP), Signal conditioning, Instrumentation amplifier, logical combination

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1. INTRODUCTION

A large number of people in our society suffer from severe disabilities due to brain damage, neurological disorders, accidents etc. These patients depend on their families or nurses for their day to day activities including communication, mobility, equipments like fan, light, ac etc. controlling etc. To improve their quality of life rehabilitation devices are being developed increasingly which enable the disable persons to communicate, study, play or control equipments independently.

In 1849 it is found that a relationship exists between the movement of eye and electrode potentials from the surface of the skin. It was proved by medical studies that the potential difference, commonly known as the resting potential, arises from hyperpolarisations and dehyperpolarisations between the retina and the cornea. These resting currents flow in a continuous manner in the direction from retina to cornea, creating an electric filed with retina acting a negative pole and cornea acting as positive pole. The orientation of this field changes with the rotation of eyeballs. Therefore, a human eyeball can also be compared to a spherical battery with cornea being positive and retina being negative. It is possible to consider that the eye socket is embedded with a battery like this which rotates in the around the torsional centre. The micro currents produced flow radially similar to that of a battery from the positive pole towards the negative pole in the orbit where conducting material being the conductive tissue. A standing potential is generated around the eye by these currents, and

these micro potentials (EOG) are detected with the use of skin electrodes which are pasted over the surface of canthus.[1]
Based on electrooculography (EOG) an embedded eye tracker was introduced by A Bulling, D. Roggen and G.Troster [2] introduced. They designed a self contained wearable device consisting of goggles having dry electrodes integrated into the frame and a small pocket worn component with a DSP for real time EOG signal processing. Data can be stored locally for long-term recordings in this system.
A Rajan, Shivakeshavan R G, and V Ramnath J. [3] designed a dual channel EOG acquisition system and processed it for controlling wheelchair incorporating neural networks. The neural network processor learns the eye patterns and helps in reducing the noise due to the user. Based on wheelchair's instantaneous velocity the intelligent judging of absolute direction is done.
T Pander, T Przybyla and R Czabanski (2008) [4] presented a new method based on detection function for eye blink detection. Eye blink parameters can be extracted from EOG signal are like amplitude, blink frequency (blinks/min) or duration. It was reported that blink latency i.e. the time interval between stimulus onset and blink onset was delayed by cognitive processes and motor responses. They used six electrodes to capture the EOG signal.
The design of EOG measurement system and its application was discussed by A. Bulent and S. Gurkan [5]. It was microcontroller based, with CMRR of 88 dB, an electronic noise of 0.6 =V (p-p), and a sampling rate of 176 Hz. To classify the signals nearest neighborhood algorithm has been used and the classification performance is 95%. In this paper, NN technique was used because EOG signals are acquired quite distinguishably in time series with less noise. Eye gaze position was given by EOG classification algorithms.
In 2007 a simple gesture recognition algorithm was presented by K Takahashi, T Nakauke, and M Hashimoto [6] to estimate the user's thinking from EOG and EMG signals. A hands free manipulation system is made by a control method that combined the results of EOG gesture and EMG gesture multi-modally. Algorithms to transform EOG signal into a rectangular signal of amplitude A, to recognize eye movement direction (left or right), to find wrinkles in the forehead (from EOG), and to find jaw gestures from the EMG signal have been discussed in this paper.
A B Usakli, S Gurkan, F Aloise, G Vecchiato, and F Babiloni (2010**)** [7] implemented a Human Computer Interface (HCI) system based on EOG. Five Ag/AgCl electrodes were used for EOG measurement. **B**y a classification algorithm EOG signals are digitized and processed which is based on the nearest neighborhood (NN) algorithm. The system is battery powered and system's initial circuitry can be used for EOG, EEG and EMG measurements. Typing with a speed of 5 letters/s25sec is achieved on a virtual keyboard.
A gaze-controlled robotic system based on electrooculography was designed and implemented by Yingxi Chen and W S Newman in 2004 [8] consisting of signal acquisition, pattern recognition, control strategy and robot motion modules. The eye gaze movements of the user are reconstructed from EOG signal and are recorded in real time from the face. The eye movement patterns like saccades, fixations and blinks are detected by a pattern recognition module from raw eye gaze movement data. The user's intention from the eye movement is interpreted by the control strategy module having predefined protocols. The robot motion module controlled the robot according to the user intention.

2. METHODOLOGY

2. 1 *Basic Components of the System*

Fig 1 shows the system block diagram, which consists of EOG acquisition system, EOG processing system, ADC, eye movement detection, valid command wireless transmission and application part. EOG acquisition circuit captures EOG signals from electrodes which are processed to remove noise and are converted into digital signal. Valid eye movement commands are transmitted to the application part wirelessly after. According to the pre-designed command combination table motion of 3R robot is controlled.

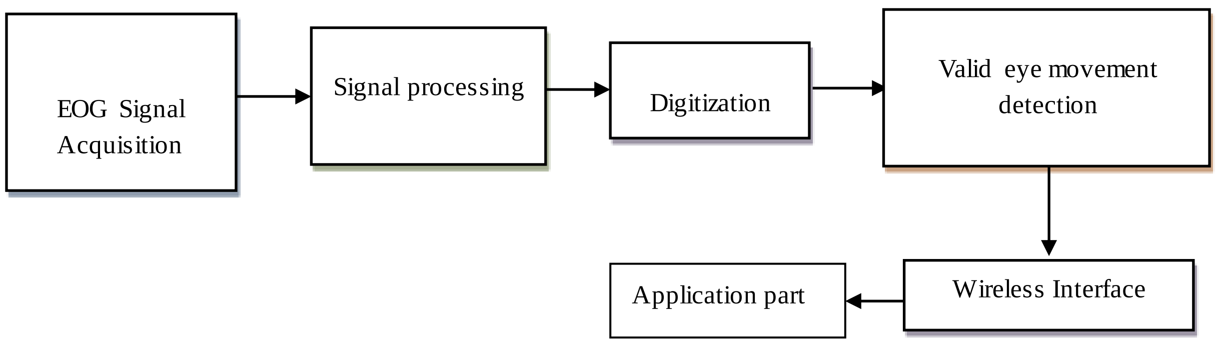


Fig-1: Eye movement detector and transmitter

2.2 *EOG Acquisition*

The EOG signal i.e. the potential difference between retina and cornea and the speed of the eye movement is acquired by the placement of electrodes around the eyes. Ag-AgCl electrodes are used for acquiring EOG signal which are placed at left Canthus of left eye and right Canthus of right eye. In our HMI system, 4 electrodes are employed to acquire the EOG signals. Fig 2 shows the electrode placement. 1 & 4 for detecting vertical movement i.e. up, down and blink movement 2 & 3 for detecting horizontal movement i.e. left and right.

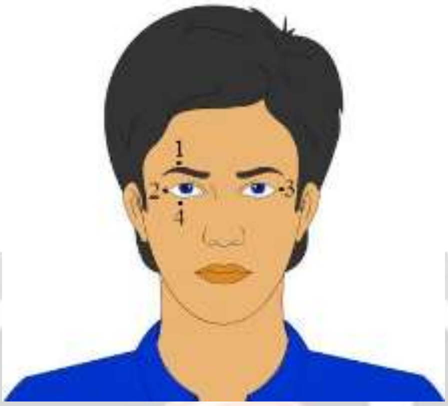


Fig-1: Electrodes placement

2.3 EOG Signal Processing

The bio-potentials captured by the electrodes from the body are very weak and very noisy. Thus a processing system is invariable needed. . The processing system comprises of precision instrumentation amplifier, band pass filter, active low filter, multiple gain block and dc shifting(or clamping) of signal followed by clipping to avoid any residual negative voltages for proper interfacing to ADC as shown in figure 3.
The bio-potential aquired by the electrodes are given to an instrumentation amplifier IA AD620 which is set for gain of 50. Output of instrumentation amplifier is applied to a band pass filter. A low pass filter and high pass filter together made the band pass filter. This produces signal with frequencies 0.5 to 4Hz at output. This signal is amplified by gain block 1 which has variable gain. Amplitude of the signal is increased to few mV after this stage. This amplified signal is given to one more gain block which is followed by active low pass filter that rejects all high frequency noises above 3Hz and also provides some gain if required at this stage. After this dc level shifter and clipper is used to ensure only positive voltages are going to ADC.

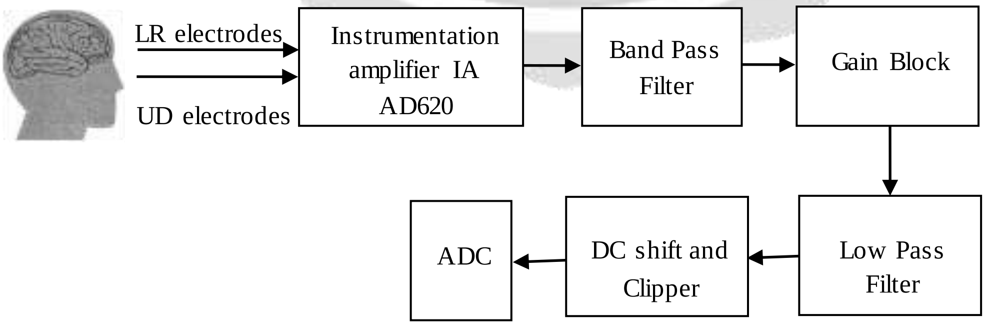


Fig-3: Block diagram of EOG Signal Acquisition and processing system

Similar circuit is there for up-down but only we have to adjust the again using variable resistor and dc level shift voltage. Both the final outputs are fed to I2C based 4 channel ADC PCF8591, left right signal is fed to ch0 and up-down signal is fed to ch1 as shown in figure 4.

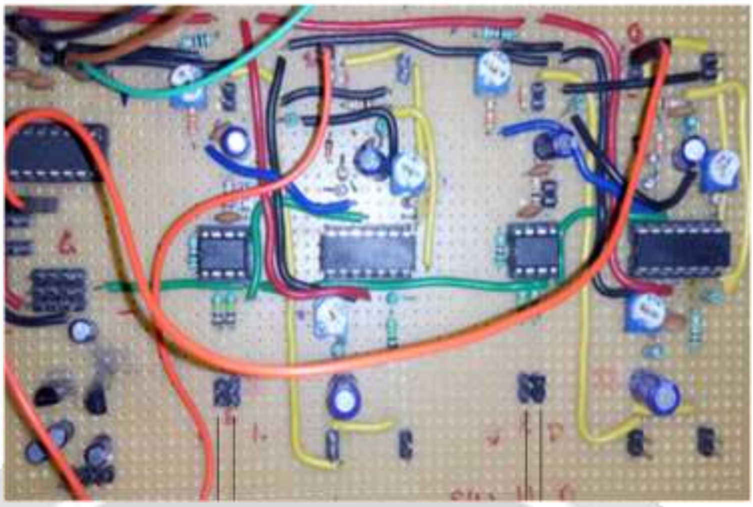


Fig-4: Circuit Diagram of EOG Acquisition System

2.4 Eye Movements Detection

The processed EOG signal from acquisition system is applied to I^2CBased 4 Channel ADC PCF859. This ADC is interfaced to Microcontroller P89V51RD2 having I^2C communication routines. The microcontroller reads the data sent by ADC using I2C protocol and starts processing the input EOG signals. Once data is processed and if any eye movement is detected then the microcontroller concludes which eye movement is made and decodes which command is given using eye. After decoding commands are send wirelessly to the receiver part. Once the codes are received the microcontroller P89V51RD2 starts conversion of codes in human readable format for debugging and display purposeAfter conversion of codes 8051 validates the code. Then according to the received combination microcontroller P89V51RD2 gives signal to ARDUINO which is programmed to drive the two servo motors in required fashion. For different combination of eye movement different signals are sent to ARDUNO from 8051 according to which direction of servo motors is controlled by ARDUINO. Flow chart for this is shown in figure 5 and table 1 gives the truth table for all 4 motions of the robot.

Table -1: Truth table for robot

Eye Movement combination	PA1	PA2	PA3	PA4	**Servo Motor 1**	**Servo Motor 2**	**Robot Motion**
LL	0	1	0	0	Clockwise	No movement	Left
RR	0	0	1	0	Anticlockwise	No movement	Right
LR	0	1	1	0	No movement	Clockwise	Down
RL	1	0	0	1	No movement	Anticlockwise	Up
BB	0	1	1	0	No movement	Clockwise	Down

If someone wants more operation then he can go for 3 movements instead of 2 movement combination. So just with 3 different eye movements and sequence of 3 movements 3^3 operations are possible.

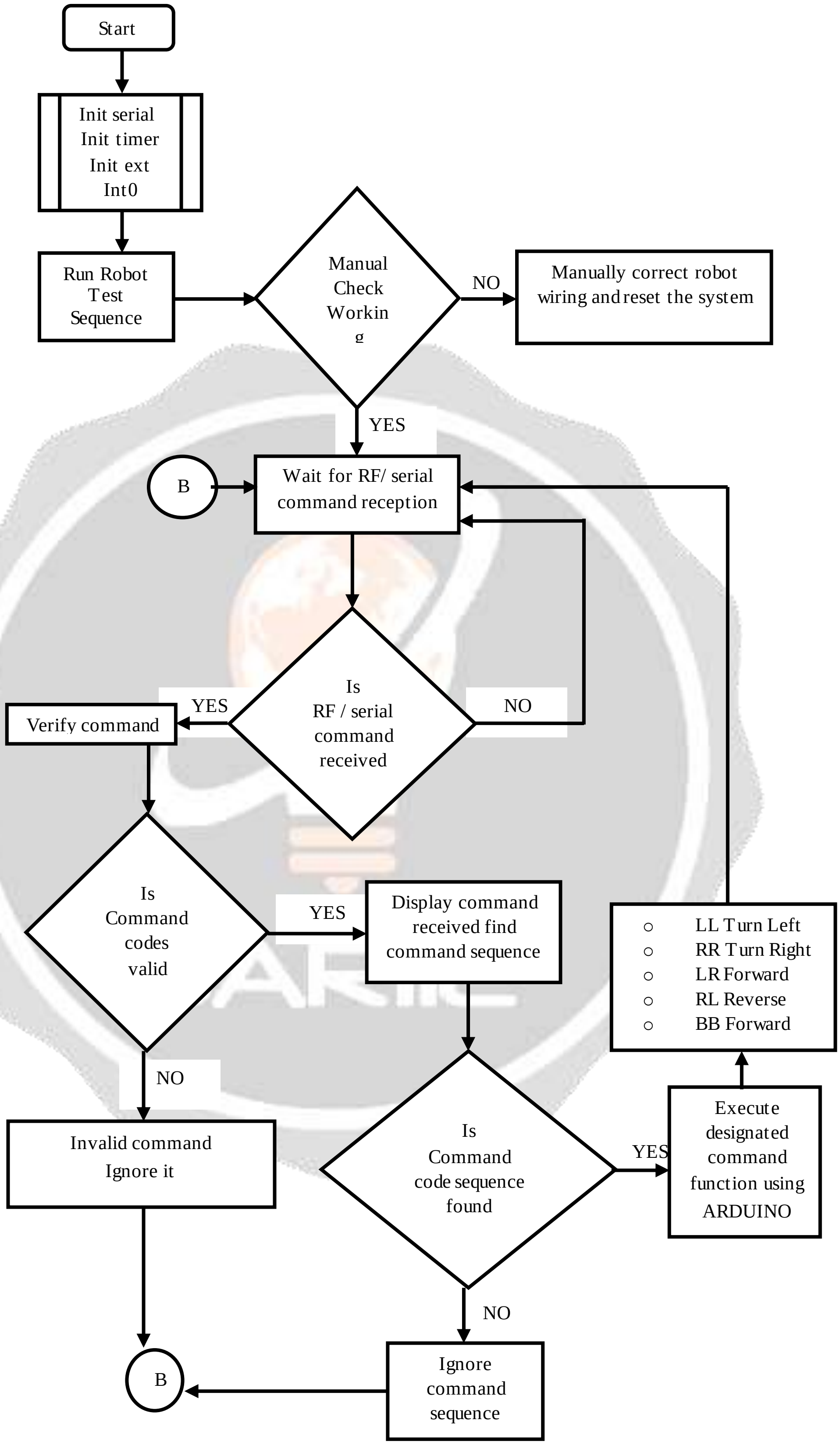
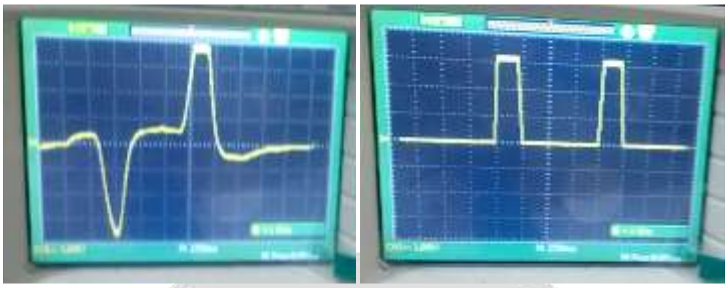


Fig-5: Flow chart for generating control commands

3. RESULT

Amplified and noise free EOG signals are acquired by the EOG acquisition and processing system and by using these amplified signals a 3R robotic arm is moved in 4 directions: left, right, up and down with an accuracy of 90% and speed of 5actions/min. The captured EOG signals for LR channel and UD channel is shown in fig 6



(a) (b)

Fig-6: EOG waveforms after processing (a) left-right signal
(b) Blink signal

4. CONCLUSION AND FUTURE WORK

An EOG acquisition system to control a 3R robot is successfully designed and implemented. For EOG classification and control signal generation an algorithm is also developed which requires less user training than other classification algorithms. Four outputs i.e. four different motions are generated by proper acquisition and processing of the EOG signal captured from electrodes using various logical combinations by interpreting the action. The results show that the EOG based eyerobot system has stable performance with an accuracy of 90% and processing speed of 5actions/min and can be a good assistive technique for people suffering from extremely limited peripheral mobility. As a whole, great prospects lie ahead for this project which can be implemented with some further modifications and the control signals generated can be used to control a motorised wheelchair and to control HCI systems or other communication devices Accuracy of the circuit can be improved by using electronic components with high precision and less tolerance.

5. ACKNOWLEDGMENT

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