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EOG Controlled Motorized Wheelchair for Disabled Persons

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***Abstract*—**Assistive robotics are playing a vital role in advancing the quality of life for disable people. There exist wide range of systems that can control and guide autonomous mobile robots. The objective of the control system is to guide an autonomous mobile robot using the movement of eyes by means of EOG signal. The EOG signal is acquired using Ag/AgCl electrodes and this signal is processed by a microcontroller unit to calculate the eye gaze direction. Then according to the guidance control strategy, the control commands of the wheelchair are sent. The classification of different eye movements allows us to generate simple code for controlling the wheelchair. This work was aimed towards developing a usable and low-cost assistive robotic wheel chair system for disabled people. To live more independent life, the system can be used by the handicapped people especially those with only eye-motor coordination.

***Keywords*—**Electrooculography, Microcontroller, Motors, Wheelchair .

I. INTRODUCTION

GAZE detection can be done using many techniques such as Infrared Video System (IRVS), Infrared oculography (IROG), Search Coil (SC), Optical type Eye Tracking System, Purkinje dual-Purkinje-image (DPI) and Electrooculography (EOG) to develop eye movement controlled HCI. EOG acquisition is considered to be the simplest method among all of the above mentioned methods. EOG is the biopotential generated around the eyes. The cornea of the eye is observed to be electrically positive with respect to the back of the eye, the retina. Since it is not affected by the presence or absence of light it can be treated as a resting potential. [1]. EOG has some drawbacks over other methods in determining eye movement. One of the drawbacks is that the corneo-retinal potential varies and may be affected by fatigue. Devices such as rehabilitation aids, computer control, robotic aids etc are being achieved using EOG signal. A simple biopotential amplifier was used for signal detection and C programming for data acquisition and display for its flexibility, which was a technique proposed for EOG cursor control [2].

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Reference [3] used a wearable EOG unit in recognition of reading activity in Transit. The objective was to develop an EOG based communication device for user with limited functionality based on pattern recognition algorithms. EOG plays an important role in rehabilitation aids by providing the control signal for some control devices. Controlling and guiding mobile robots by means of ocular position using EOG techniques were developed [4], [5]. EOG based inverse eye model was developed so that it is easy to detect where the user is looking by the saccadic eye movements. This control technique can be used to guide an autonomous wheel chair to assist the people with severe disabilities. The work was even extended in developing different techniques and, guidance strategies were then shown with their advantages and disadvantages. This control technique may be useful in communication aids for handicapped persons [6], [1]. Devices developed are built on a common platform for generating control signal through the saccadic eye movement. Thus controlling a dc motor, this in turn can be employed to control any device [7]. The outcome of this area of research is that the EOG based technology has been tried for the implementation of rehabilitative aids. Especially EOG based systems have been experimented to construct eye movement controlled wheelchairs so that severely paralyzed patients can lead their independent life [8]-[12]. Still there is a much to travel to make the work worthy. EOG guided wheel chair using microcontroller like PIC16F877 have been designed and developed, wherein it has low speed of conversion of the analog signal and low operation speed of PIC16F877 which is about 10 MHz [13]. Features like speed of conversion, classification of signals and generation of control signals are very important for these kind of control systems. And also the spontaneity and synchronization between the subject and the interface is very much essential. The present work was concentrated on all the above mentioned key features. The block diagram of the EOG based control system is shown in Fig. 1.

II. MATERIALS AND METHODS

A. EOG Amplifiers

EOG amplification is the first stage of the system. This stage consists of two channels namely Horizontal and Vertical channels. Horizontal channel contains EOG amplification unit that is used to amplify the EOG signal of right and left movements of eyes. Similarly, the vertical channel also contains EOG amplification unit of similar design that is used to amplify the EOG signal of up and down movements of eyes. The EOG signal is acquired through Ag/Agcl electrodes for amplification.

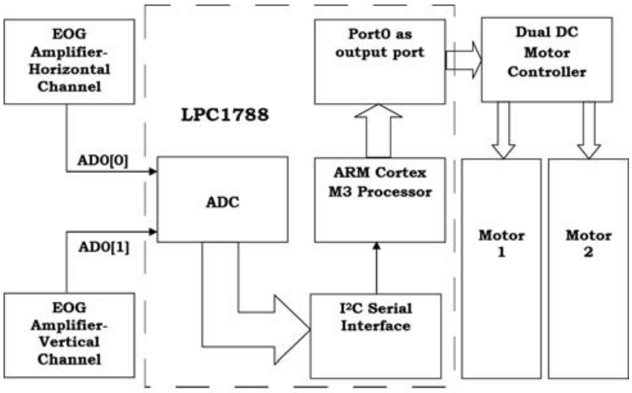

Fig. 1 Block diagram of EOG based control system for motorized wheelchair

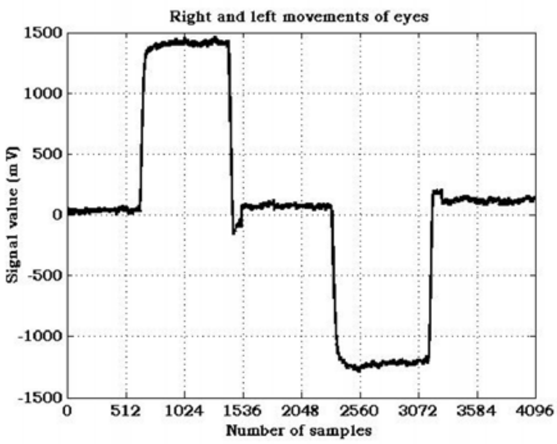

Fig. 2 EOG signal of horizontal movement of eyes

The amplitude of the EOG signal is around 16 μV per 1°. Therefore, the gain of the EOG amplifier is set as 1000. The range of frequencies needed for eye movement detection is 1-15 Hz and hence the bandwidth of the filter is 1-20 Hz. The baseline drift, power line interference and other artifacts are removed by proper signal conditioning. Fig. 2 shows the EOG signal of horizontal movement of eyes.

B. Analog to Digital Conversion

The second stage of the system is ADC unit. The amplified signals from the horizontal and vertical channels are fed to the ADC unit for converting them into digital signals. The ADC unit is inbuilt in LPC1788. This ADC unit has 12-bit successive approximation analog to digital converter. This unit has input multiplexing among 8 pins. Hence 2 pins are sufficient for our proposed system to feed the two analog signals from two channels for converting them into digital signals. The AD0 [0] and AD0 [1] pins are used as analog inputs. As discussing about the speed of conversion, this ADC converts the analog signal into 12-bit digital information at a speed of 400 KHz.

C. I^2C Serial Interface

The 12-bit digital output from the ADC unit is fed to the processor of LPC1788 through I^2C serial interface. The I^2C serial interface supports 1 MHz Fast Mode Plus, 400 kHz fast mode, and 100 kHz standard mode. The 400 KHz mode is set for the system to transmit the data serially to the processor. The programmable clock allows adjustment of I^2C transfer rates. The data can be transferred bidirectionally between masters and slaves.

D. ARM cortex M3 Processor

The serial data from the I^2C interface has to be processed to detect, classify and generate control signals for all the EOG signals of five basic distinct eye movements. This is done in this fourth stage of the system with ARM cortex M3 processor. Both the algorithms, one to detect horizontal movements of eyes and the other to detect vertical movements of eyes and blinks, are executed simultaneously and continuously. The LPC1788 microcontroller unit can be operated at up to a 120 MHz CPU frequency.

E. Port0 as Output Port

The generated control signals by the processor are fed to the dual dc motor controller through port0, the fifth stage of the system. The port0 of LPC1788 is configured in output mode. Port0 has totally 32 lines, out of which only 4 lines are utilized to transmit the generated control signals to dual dc motor controller. Out of 4 lines from port0, 2 lines (P0(0) and P0(1)) are connected to A and B inputs and the other 2 lines (P0(2) and P0(3)) to the C and D inputs of dc motor controller. Control signals are transmitted to these motors so as to rotate the shaft in clock wise or anticlockwise directions.

F. Dual DC Motor Controller

The dual dc motor controller is a quadruple half-h driver, SN754410. The pin configuration and how 2 motors can be connected to it is shown in Fig. 3. The motor controller receives input from port0 of LPC1788 microcontroller. SN754410 provides bidirectional drive currents up to 1A at voltages from 4.5 V to 36 V. Drivers of SN754410 are enabled in pairs. Drivers 1 and 2 are enabled by 1,2EN and drivers 3 and 4 are enabled by 3,4EN. The outputs of the respective drivers are enabled and are in phase with their inputs only when an enable input is high. When the enable input is low, those drivers are disabled and their outputs are off and in a high-impedance state.

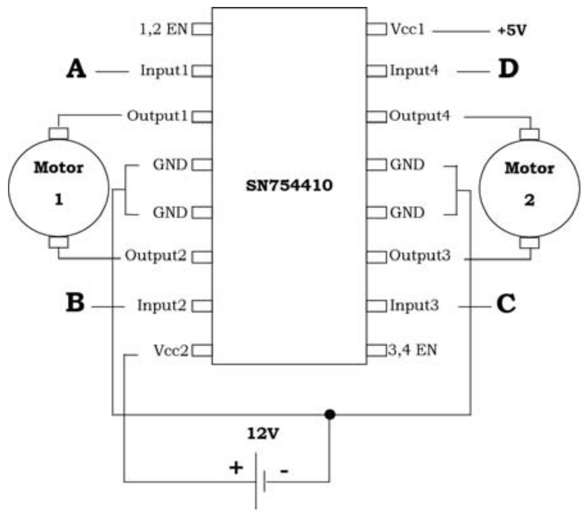

Fig. 3 Dual dc motor controller

By proper application of data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for motor applications.

G. Motors

This is the final stage of the system. Two high torque dc motors of 12V, 800 RPM are connected to the dual dc motor controller. The motors rotate Clockwise (CW) or Anti-Clockwise (ACW) according to the control signals received by SN754410.

The amplitude of the EOG signal for eye movement in right and left directions were found to be +1.4V and -1.4V. The amplitude of the signal stays high for duration of 500ms to 900ms for both right and left movement of eyes. In the same way, for up and down movements of eyes, the amplitudes were found to be +1.2V and -1.2V. Almost same duration was observed for up and down movements of eyes as for right and left movements. The EOG signal of up movement was found similar to the EOG signal of blink. The amplitude of the blink signal was between +1.2V and +1.5V which was slightly larger than the up signal's amplitude. And the duration of the blink is only 200 ms to 450 ms which is less when compared to up signal's duration.

III. EOG Signal Classification

As discussed about five basic distinct eye movements, each eye movement has its own unique pattern. There are various algorithms to classify these EOG signals. Most of the algorithms compare the EOG signal's amplitude with a predefined threshold. If the EOG signal amplitude crosses the threshold value, then a valid eye movement is detected. This approach becomes very simple for implementation and has its own disadvantages, because the EOG signal is very sensitive to head movements and minute displacements in electrode position. Therefore the algorithms produce errors due to above mentioned circumstances [13].

This problem can be overcome by calculating moving average values for the receiving samples of amplitude of the signal. And predefined threshold is set to detect the amplitudes for all the basic five distinct eye movements. The same algorithm can be modified to detect eye movements in up and down directions. The steps to detect blink is included with up movement detection. The algorithm for up, down and blink classification was applied to EOG signals of vertical channel and similarly, for classifying right and left movements, the algorithm was applied to horizontal channel. Both the algorithms were executed in parallel simultaneously.

IV. Generation of Control Signals

Vertical channel EOG signals and horizontal channel EOG signals were processed in parallel. Signal amplitudes were compared with the corresponding threshold values. If the amplitude of the EOG signal crosses the threshold value, the microcontroller generates control signal. For example, if the EOG signal amplitude of up movement of eyes from the vertical channel is 0.8V, the microcontroller generates necessary control signals to drive the motors as the amplitude is in between the threshold range 0.6V and 1.2V. If the amplitude of the EOG signal is less than 0.6V, the algorithm checks for the next sequence of samples. And moreover, if the amplitude crosses the 1.2V, the algorithm detects that it is a blink. The algorithm checks for 2 continuous blinks within one second so that the microcontroller passes necessary control signal to stop the motor. Similarly, according to the threshold values set, the algorithm to detect right and left movements of eyes generate control signals to drive the motor. These control signals can be used to control and guide rehabilitation aids. The present work uses these controls signals to guide a motorized wheelchair.

V. Controlling Motorized Wheelchair

Appropriate control signals should be issued to the motors, so that the wheelchair moves according to the ocular commands from the subject. Table I shows the direction of wheel chair to the direction of the eye movement. The two motors, left and right, are driven according to the inputs of the motor controller A, B, C and D. For example, if the direction of the eye movement is up, the microcontroller sends the data 1001 to the motor controller through port0. Then the two motors rotate in clockwise direction, which in turn moves the wheelchair in forward direction. If the subject wants to stop the mobility of wheelchair, the eyes must be blinked 2 times in one second, then the microcontroller sends the data 1111 to the motor controller. Hence, both the motors stop rotating and therefore the wheel chair does not move.

Fig. 4 shows the top view of the developed motorized wheelchair which can be controlled by EOG signals.

TABLE I
EYE MOVEMENT VS WHEELCHAIR'S DIRECTION

Eye Movement	Inputs of motor controller				Motor's Direction		Wheelchair's Direction
	A	B	C	D	Left-Motor 1	Right-Motor 2	
Up	1	0	0	1	CW	CW	Forward
Down	0	1	1	0	ACW	ACW	Backward
Right	1	0	0	0	CW	Stop	Right
Left	0	0	0	1	Stop	ACW	Left
Blinks	1	1	1	1	Stop	Stop	Stop

VI. RESULTS AND DISCUSSIONS

The EOG signals are synchronized with the microcontroller operation and therefore spontaneity between subject's eye movements and the wheelchair's directions is achieved. The subject or the user of EOG based control system uses only the eye movements to produce the control signals for the wheelchair. Eyes were getting tired due to continuous movements of eyes and therefore the control logic is set almost half the maximum value of amplitude of the EOG signal (except for blink detection). Of course, the threshold can be varied according to user's choice. If the threshold is not set as mentioned above, the motors were found driven even for normal eye movement of the user. This is due to continuous ON position of the system. The subject must be properly trained for effective utilization of the system.

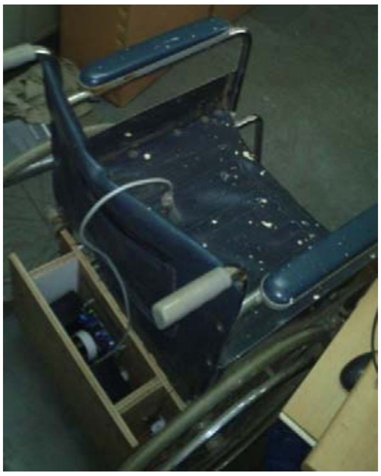

Fig. 4 Top view of the developed motorized wheelchair

VII. CONCLUSIONS

This research work is concentrated on the detection and classification of eye movements as well as controlling the motorized wheelchair with the help of eye movements by means of EOG signal. The eye movements are classified on the basis of amplitude of the EOG signal. The wheelchair motors has been driven with appropriate control signals from the microcontroller unit. The subject must be properly trained for effective utilization of the system. However, the technique presented in the work can be treated as a novel technique on the basis of utilization of upgraded circuit systems such as ARM cortex-M3 processor unit, high speed ADC unit etc and even the logic used in the algorithm of classification of EOG signals. The work can further be extended by implementation of wireless EOG acquisition system.

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