

HUMAN TO TELEVISION INTERFACE FOR DISABLED PEOPLE BASED ON EOG

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(Received: November 13, 2017; Accepted for Publication: February 22, 2018)

ABSTRACT

The objective of this paper is to design Human to Television Interface (HTI) system for disabled people, who cannot control their hands. The proposed HTI has a new feature in comparison with the most recent HTI systems. The user can control the basic operations of TV remote controller such as changing channels, controlling volume. Besides, two sequences of eye-movements are considered to allow the user to deactivate/activate the HTI system during watching TV. These two sequences are designed using finite state machine, and implemented in LabVIEW. In this paper, a new pulse detection method is developed to identify four eye-movements from the EOG signals such as looking up, down, right and left. In this new method, two techniques are considered to enhance the performance of HTI system. The First technique is based on using two AC-coupled channels to overcome the problem of baseline drifting in the EOG signals. Pulse Timer Block is the second technique which is used to reduce the false identification of the EOG pulses due to the effect of head movements. The performance of the HTI system was tested by three male and three female participants. The results show that the average performance is about HR=93.41%.

KEYWORDS: Electrooculogram (EOG), Human to Television Interface (HTI), Finite State-Machines (FSM)

1. INTRODUCTION

Developing Human to Machine Interfacing (HMI) is necessary for people with physical disabilities, who cannot manually control devices. Recently, there has been an effort toward designing and developing Bio-based HMI to assist these disabled people to control computer and wheel chair by themselves. Therefore, bio-signal like Electrooculogram (EOG) has been considered as the best candidate for HMI applications because it has the potential to replace the manual way to control devices with eye movements (Estrany, Fuster, Garcia, & Luo, 2009). EOG signal has been employed widely in HMI applications such as controlling computer and wheelchair because these two applications allow disabled people to move and to manage their computer applications (Aungsakun, Phinyomark, Phukpattaranont, & Limsakul, 2012; Lv, Wu, Li, & Zhang, 2010). On the other hand, Television is considered as an important source of entertainment for disabled people. However, very few papers have investigated the use of EOG to control home appliances like Television (Bissoli, Sime, &

Bastos-Filho, 2016; Hassan & Mansor, 2014). Most of the recent Human to Television Interface (HTI) designs has considered the basic operations commands of TV remote control such as changing channel, controlling volume or turn On/Off the TV (Bissoli, et al., 2016; Deng, Hsu, Lin, Tuan, & Chang, 2010; Hassan & Mansor, 2014). The problem with these designs is uncomfortable using specially during TV watching because these HTI designs are kept active all the time. As a result, unwanted remote control commands may be generated by the user due to the unconscious or involuntary eye movements. The objective of this research is to design adapted HTI system based on EOG signals for physically disabled people. The proposed HTI design has considered four eye movements (Looking Left, Right, Up and Down) to permit the disabled people to control the basic operations of TV such as changing channel, controlling volume. To make watching TV more comfortable, the user can be activated and deactivated HTI system through two different sequences of eye-movements. These two sequences were designed using two Finite State-Machines (FSM). In this paper, the EOG signals in AC-coupling mode are considered to overcome

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the problem of baseline drifting. The HTI system was implemented using EOG module KL-75003 and myRIO 1900. This paper is arranged as following: eye-movement detection methods, activate/deactivate sequences, results and discussion and conclusion.

1.1 Related works

(Hassan & Mansor, 2014) designed and developed a TV remote control based on EOG signals to turn on/off the TV only. The suggested EOG detection algorithm was based on couple of setting like the distance between the eye and TV remote control, and the position of the eye with respect to the TV remote control. The problem of this system is that only switching on/off the TV was considered. Moreover, the algorithm was designed based on specific settings. This may not be practical for real life application to set the settings every time the user wants to watch TV (Hassan & Mansor, 2014).

(Bissoli, et al., 2016) developed an intelligent interfacing for disable peoples to control devices

like turning lights, TV and fan. Two paradigms of HCI were designed. The first was based on surface electromyography (sEMG) and electrooculography (EOG), and the second was based on videooculography (VOG) to track eye movements. These two paradigms have considered the basic operation commands of TV remote control like changing channel, controlling volume and turning On/Off the TV (Bissoli, et al., 2016). However, this intelligent interfacing is not comfortable for users during TV watching because any involuntary eye movements may generate unwanted commands.

1.2 Foundation of EOG signals

Electrooculography is a technique for measuring the cornea-retinal standing potential that exists between the front and the back of the human eye. The presence of active nerves in the retina compared to the front of the eye causes a potential different of 10 to 30 mV as shown in figure 1 (Jose, 2013).

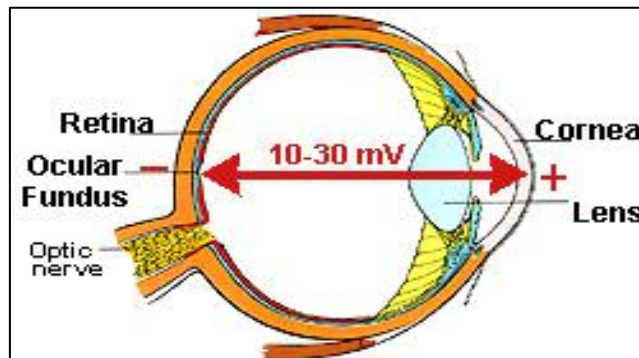


Fig. (1): The potential between Cornea and Retina (Jose, 2013)

This potential can be considered as an electrical dipole signal, where the negative pole at retina and a positive pole at the cornea (see figure 1) (Estrany, Fuster, Garcia, & Luo, 2008). The resulted signal is denoted as electrooculogram. The AC-coupled EOG signals (known as differential mode) are suggested to reduce the problem cause by baseline drifting and (Kim &

Yoon, 2013; Lv, et al., 2010; Merino, Rivera, Gómez, Molina, & Dorrnzoro, 2010). Typically, the EOG signals consist of two pulses. The first pulse represents the beginning of EOG signal, and the second pulse represents the end of the EOG signal (Merino, et al., 2010). The properties of EOG signals of different eye-movements in AC-coupling mode are located in table 1.

Table (1): Characteristics of eye movements (Merino, et al., 2010)

Eyeball movements	First Pulse	Second pulse	Pulse duration	Channel
Up	Positive	Negative	400-600 ms	Vertical Channel
Down	Negative	Positive	400-600 ms	Vertical Channel
Right	Positive	Negative	400-600 ms	Horizontal Channel
Left	Negative	Positive	400-600 ms	Horizontal Channel

When the eyeball is moving to the right or up direction and returning to the center, positive pulse and negative pulse are generated respectively in the horizontal or vertical channel (see figure 2). When the eyeball is moving to the

left or down direction and returning to the center, negative pulse and positive pulse are generated respectively in the horizontal or vertical channel (see figure 2) (Gandhi, Trikha, Santhosh, & Anand, 2010).

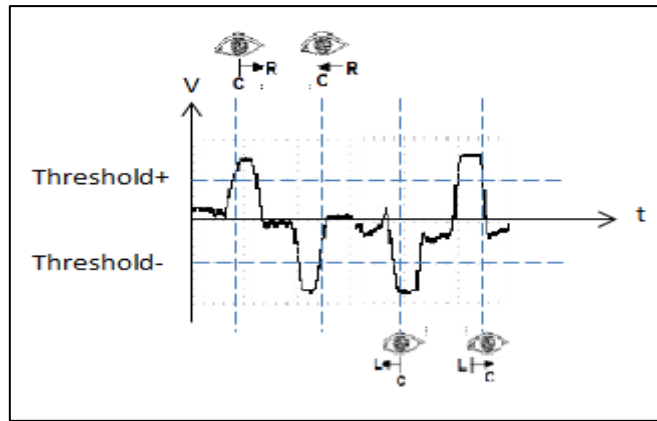


Fig. (2): Pulses of Right/Left eye movement (Gandhi, et al., 2010)

1.3 HTI System Description

The main advantage of the proposed HTI system is that the system can be deactivated during watching TV, and activated during controlling TV by the user. In this paper, pulse detection method is developed to identify four eye-movements up, down, right and left. These four eye-movements are considered to generate the following HTI commands as located in table 2.

Table (2): The proposed HTI Commands

HTI Commands	Eyeball movements
Next channel (CH+)	UP
Previous channel (CH-)	Down
Increasing Volume (VOL+)	Right

Decreasing Volume (VOL-)	Left
Deactivate Sequence (DS)	UP UP Down Down
Activate Sequence (AS)	Right Left Right Left

The proposed HTI system is designed using KL-75003 EOG Module, myRIO-1900 and Arduino Uno. Figure 3 shows the complete design of the HTI system. The data acquisition of the EOG signals is performed using KL-75003 EOG Module with myRIO. Then, the EOG signals are processed and classified using LabVIEW software. Arduino Uno is used to generate the TV remote commands to control the TV as shown in figure 3.

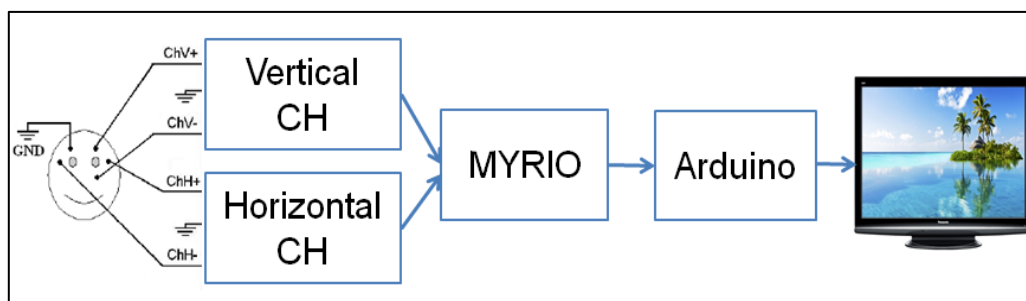


Fig. (3): Complete design of the proposed HTI system

2. EYE-MOVEMENT DETECTION METHOD

mode to reduce the effect of baseline drifting. This method consists of five stages (see figure 4). Each of these stages is explained in this section.

The suggested eye-movement detection method is based on EOG signal in AC coupling

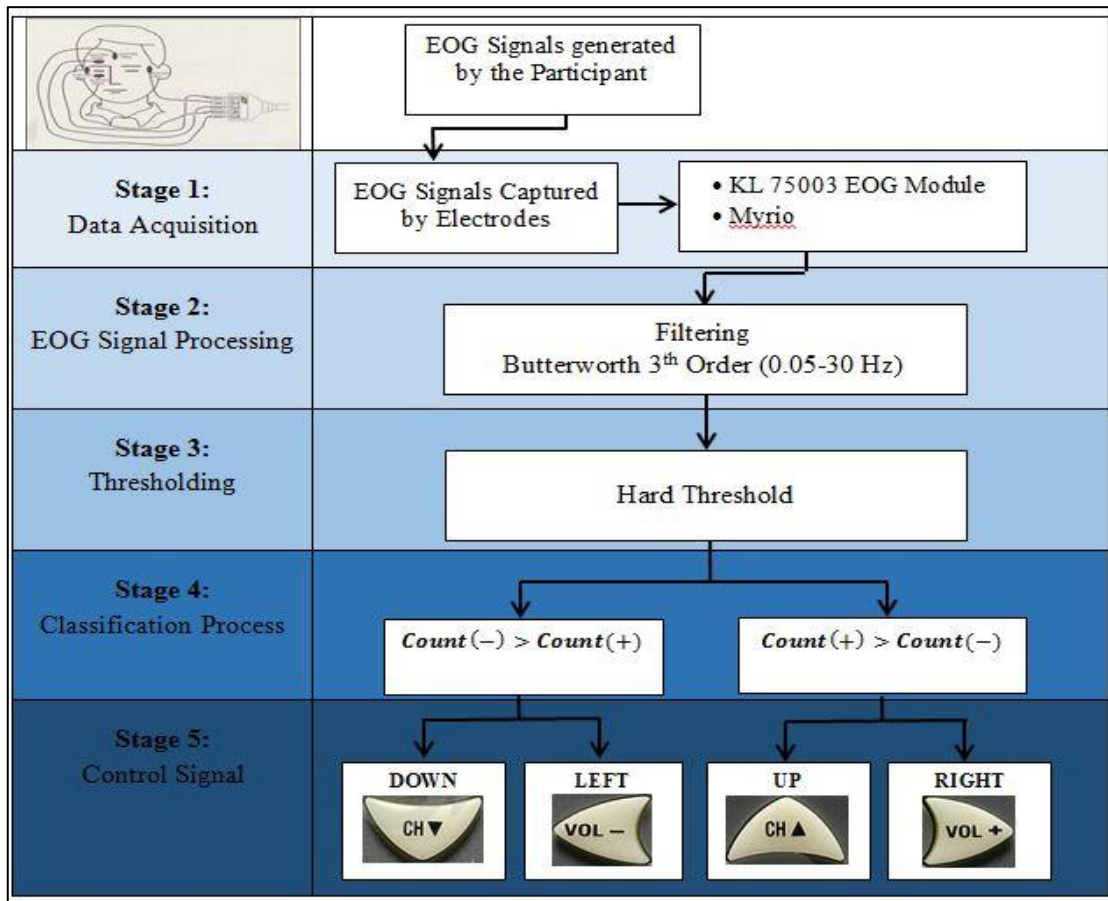


Fig. (4): Five stages of the proposed HTI system

2.1 Data acquisition

Five disposable Ag/AgCl electrodes are used to capture the EOG signals from the participants. These electrodes are placed on the participant as shown in figure 5.

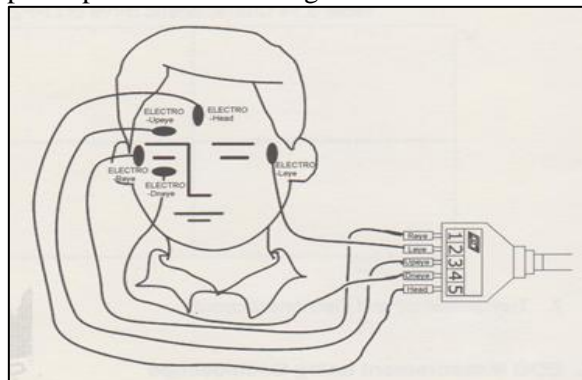


Fig. (5): Locations of Ag/AgCl electrodes around eyes

The electrode left and electrode right (see figure 5) are placed to capture the horizontal EOG signals. The electrode up and electrode down (see figure 5) are placed to capture the vertical EOG signals. KL-75003 Electrooculogram Module is used to amplify and to measure the EOG signals. This module consists of two stages of amplification, bandpass filter (0.05-30 Hz) and isolation circuit. The Audio input of myRIO-1900 is chosen to record the EOG signals. This audio input consists of two AC-coupled single-ended channels with normal amplitude range ± 2.5 V. The left audio input is used to record the

horizontal EOG signals, and the right audio input is used to record the vertical EOG signals. The eye-movement detection method is developed using LabVIEW software.

2.2 EOG Signal Processing and Thresholding

The EOG signals are acquired and processed with sampling rate of 10K samples/sec using timed loop (see figure 6). Then, the recorded EOG signals from the "Audio In" are passed through Butterworth bandpass filter (0.5-20 Hz) to smooth the EOG signals.

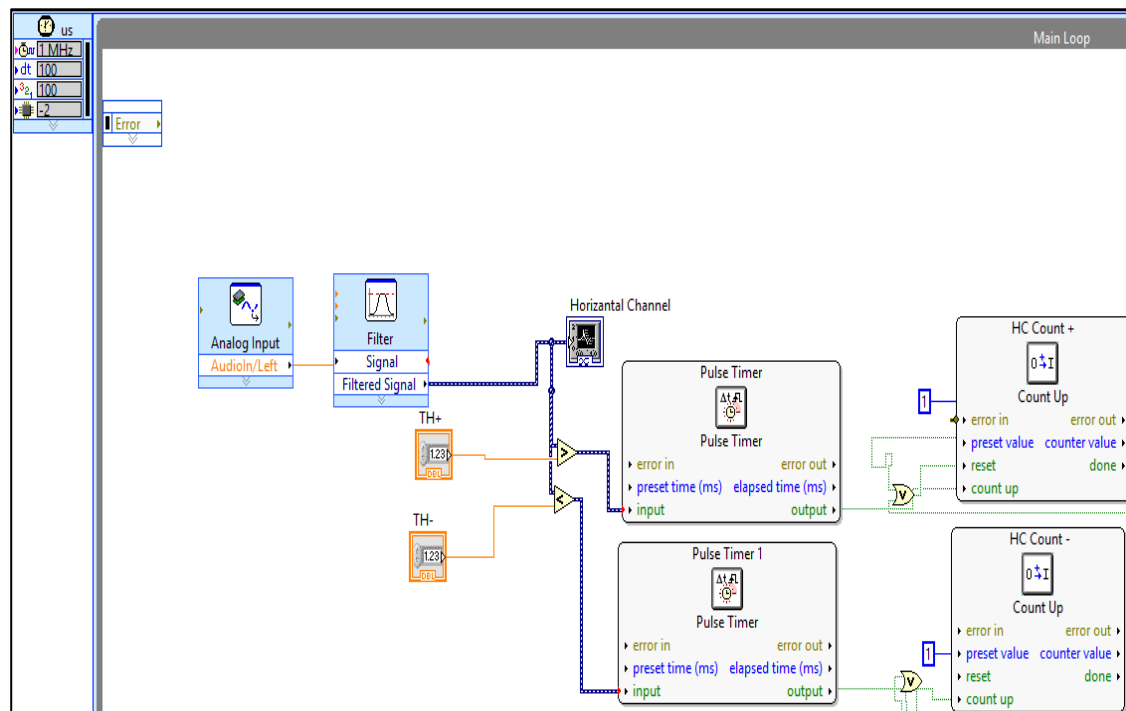


Fig. (6): EOG signals processing and thresholding using LabVIEW

Pulse detection method is considered to identify the polarity of pulses by using two predefined thresholds {TH+ and TH-}. The TH+ is used to identify the positive EOG pulses, and the TH- is used to identify the negative EOG pulses. Through analyzing the EOG pulses from six participants, it found that the maximum peak of the processed EOG pulses is approximately 0.4v for the positive pulses, and -0.4v for the

negative pulses. Therefore, the predefined thresholds TH+ and TH- are assigned to be ± 0.15 v. The suggested pulse detection method is simple and easy to implement. However, EOG signals are very sensitive and usually fluctuate regarding to any head movement. So, predefined thresholding may cause false identification of the EOG pulses. As shown in figure 7, two positive pulses will be recognized instead of one.

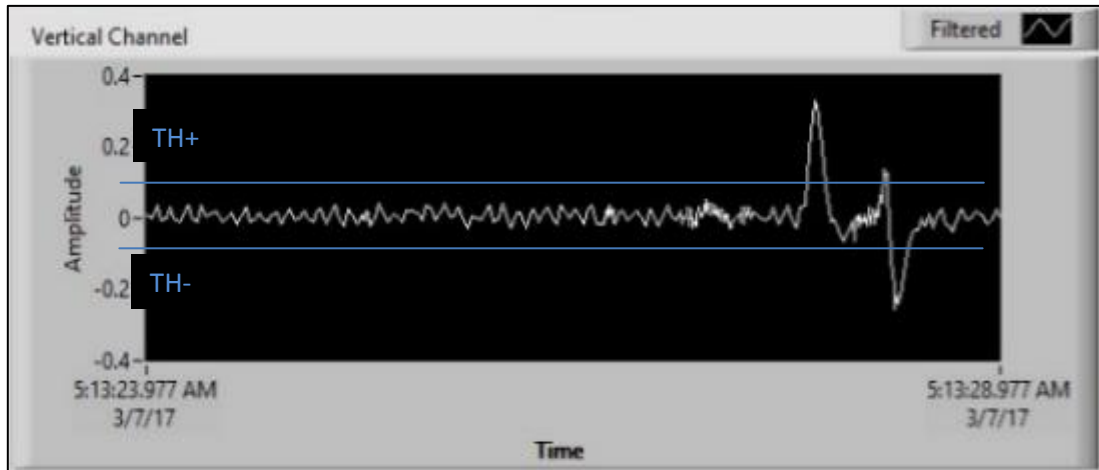


Fig. (7): False identification of EOG pulses

Pulse Timer block in LabVIEW is used to overcome the problem of false identification. This Pulse Timer generates output pulse triggered by the rising edge of the input signal, and does not respond to the rising edges of the input during the preset time as shown in figure 7. In this case, the

preset time is set to be 600 msec similar to the duration of EOG signals (see table 1) to neglect other pulses. Two Pulse Timers are used for positive pulses and negative pulses as shown in figure 8.

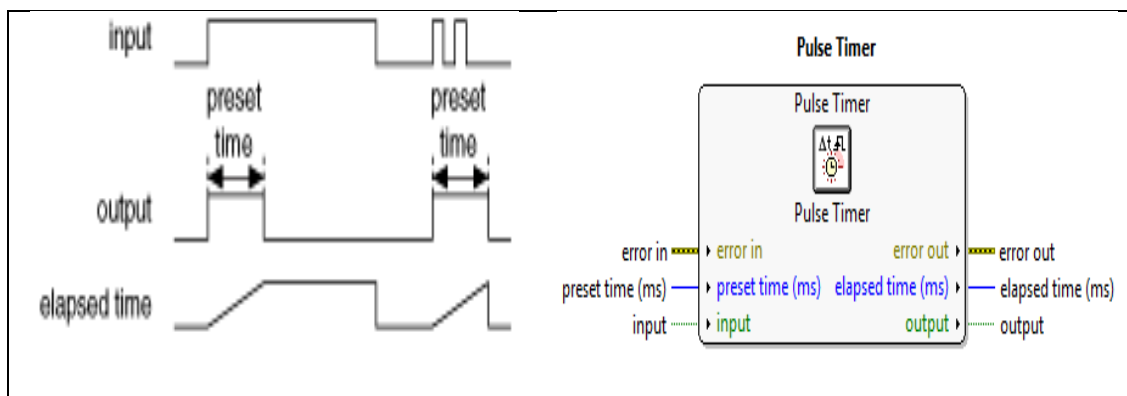


Fig. (8): Time diagram of the Pulse Timer Block

2.3 Classification Process

The classification process of different eye-movements is based on counting pulses and resetting counters. Symbols {HC+, HC-, VC+,

VC-} are positive/negative counters in the horizontal and vertical channel respectively. The following flow chart demonstrates the classification process.

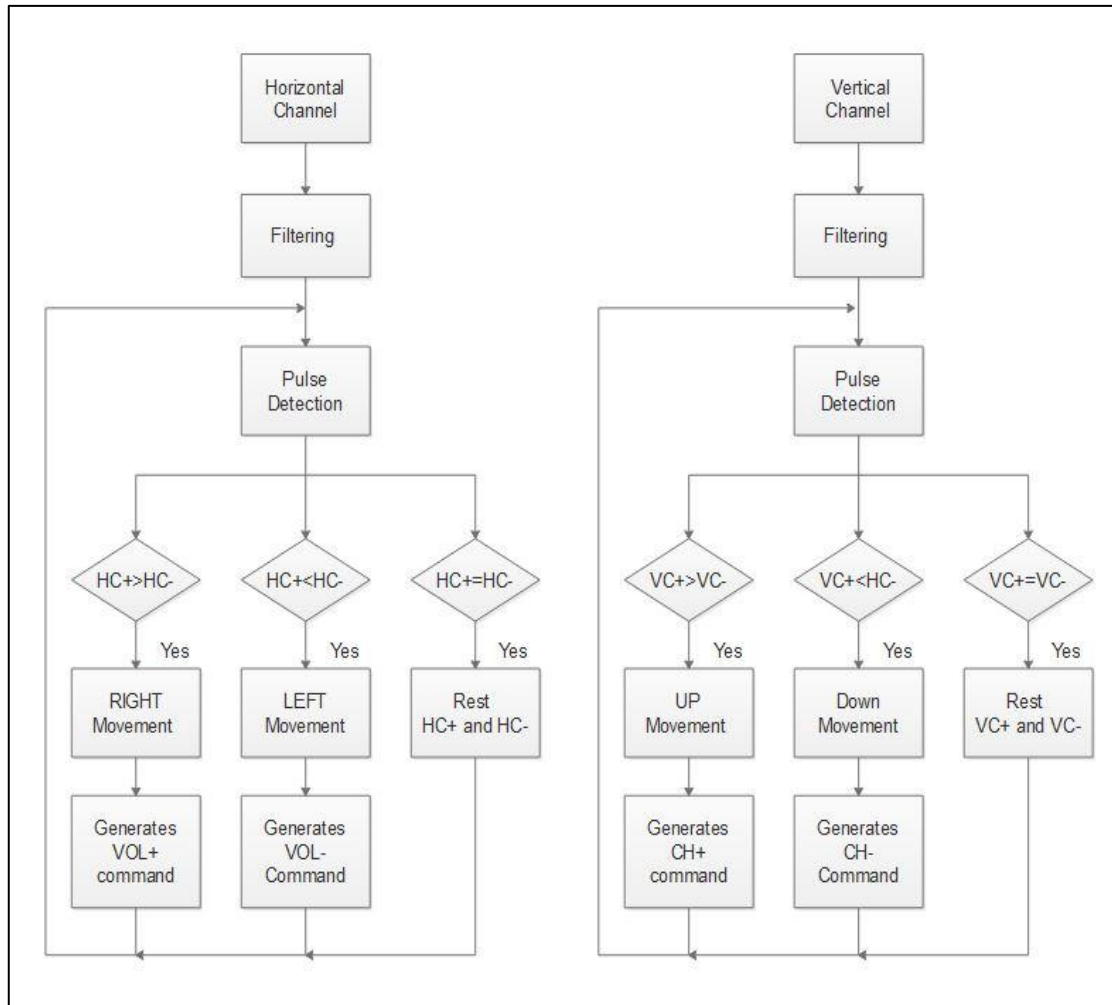


Fig. (9): Flow Chart of the proposed HTI system

In the both channel, when a positive pulse is detected, the HC+/VC+ counter will be increased. When a negative pulse is detected, the HC-/VC-counter will be increased. The rule of classification is demonstrated as shown below. This rule is considered for both vertical and horizontal channel.

IF ($HC+ > HC-$) (1)
eye – movement is RIGHT
ELSE IF ($HC+ < HC-$)
eye – movement is LEFT
ELSE IF ($HC+ = HC-$)
Reset $HC+$ and $HC-$

The classification process of different eye movements is shown in Figure 10. Figure 10a&b demonstrate the output signal of the horizontal counters (HC+ and HC-) in case of Right and Left eye-movement. Figure 10c&d show the output signal of the vertical counters (VC+ and VC-) in case of Up and Down eye-movement.

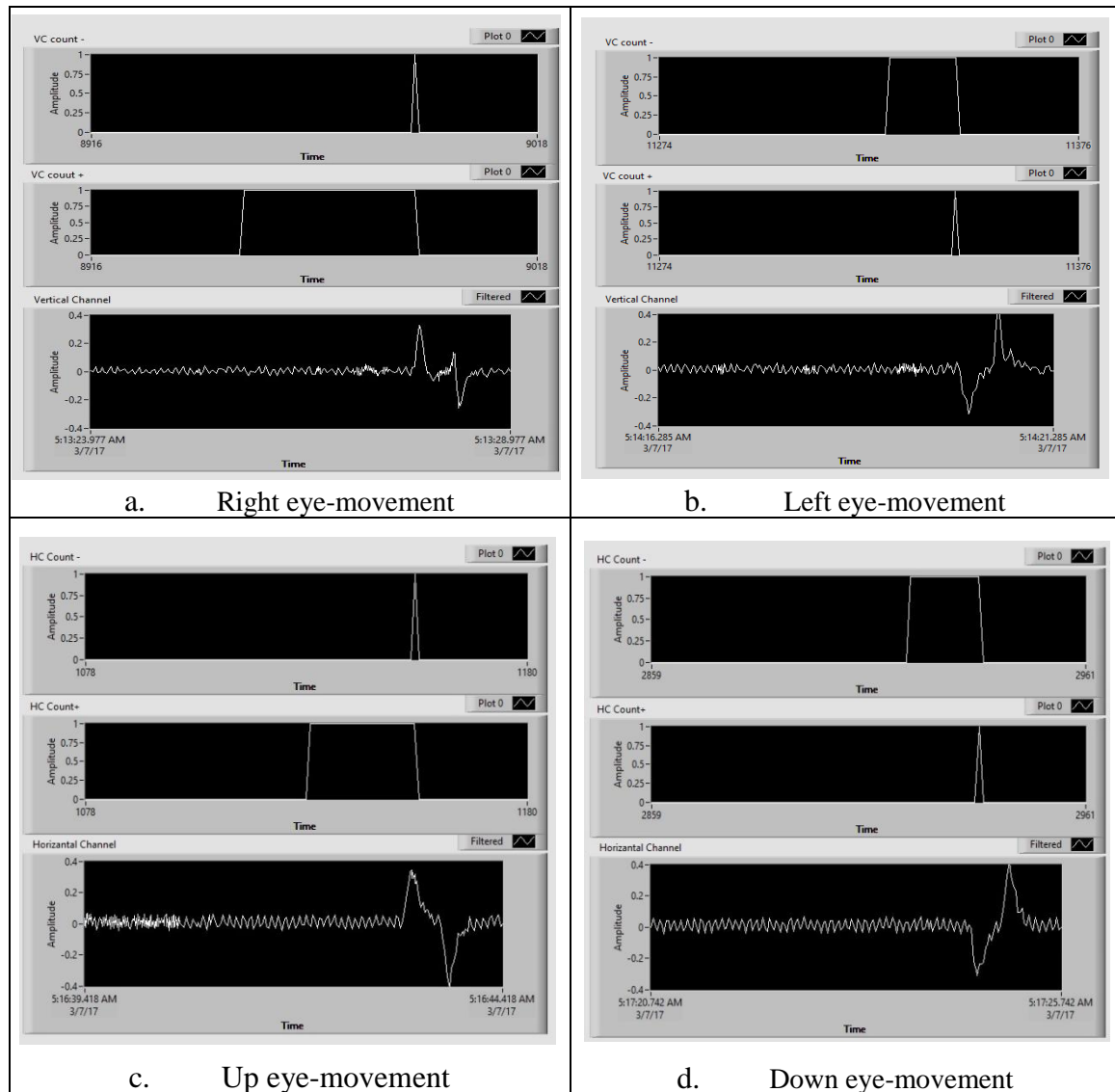


Fig. (10): Classification process of four eye-movements

2.4 Control signals

In this paper, the actual TV remote commands are generated as following. The code of each command is collected from the TV remote control using Arduino Uno with IR receiver. Then, these codes are retransmitted using Arduino Uno with IR transmitter. The interfacing between myRIO and Arduino is achieved by connecting four digital outputs of myRIO with four digital inputs of Arduino.

3. DESIGN ACTIVATE/DEACTIVATE COMMAND USING FSM

To make watching TV more comfortable, two commands are designed using Finite-state machine to activate the HTI system during

commanding session, and to deactivate the HTI system during watching TV. Each of these commands has a unique sequence of eye movements. The 'activate' and 'deactivate' command have the following sequence {Right, Left, Right, Left} and {Up, Up, Down, Down} respectively. The choice of the sequences was based on the probability of having these sequences during watching TV and commands session.

Finite-state machine FSM was used to design 'activate' sequence 'AS' and 'deactivate' sequence 'DS'. Moore Finite-state machine was used since the output is only function of the state. In each FSM model, there are four states. At the end of the fourth state, the sequence will be linked to the first state of the other sequence as shown in Figure 11.

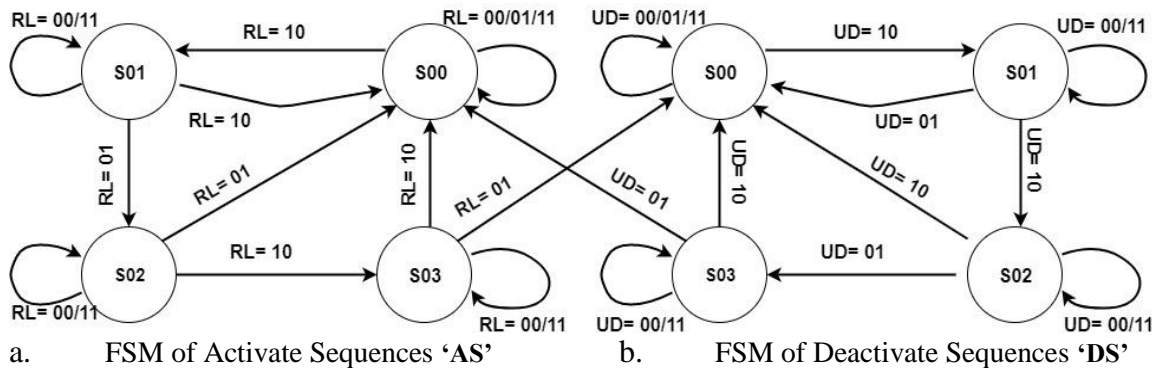


Fig. (11): FSM diagram of activate and deactivate commands

For each FSM model there are two logical inputs and one output. These input signals were derived from the vertical and horizontal channel. The FSM models were designed to rest to the initial state 'S00', when the two inputs are out of the proposed sequence.

In the first model (see figure 11a), the Right and Left signals were used as inputs to activate the commanding session. In case of the second model (see figure 11b), the Up and Down signals were used as inputs to deactivate the commanding session.

The performance of the proposed HTI system was tested by six participants. To ensure the reliability of the results, both gender (3 females and 3 males) participated in testing the system. Each of the participants was asked to repeat the test thirty times for every HTI commands to ensure the validity of the results. It was noticed that the users should train their eyes for at least 10 minutes in the first time before operating the HTI system. The performance of the HTI system was measured in terms of the Hit Rate percentage (HR%) (Samann, 2017). The results of HR% for each participant are located in table 3.

4. RESULTS AND DISCUSSION

$$HR\% = \frac{\text{no. of correct detection}}{\text{Total no. of test}} \times 100 \quad (2)$$

Table (3): The performance of HTI system

Participants	Eye movement Commands					
	Right 'VOL-'	Left 'VOL+'	RLRL 'AS'	Up 'CH+'	Down 'CH-'	UUDD 'DS'
	HR%	HR%	HR%	HR%	HR%	HR%
Participant 1 (F)	96.66%	100%	96.66%	93.33%	100%	96.66%
Participant 2 (F)	93.33%	93.33%	96.66%	90%	86.66%	93.33%
Participant 3 (F)	100%	100%	100%	90%	100%	90%
Participant 4 (M)	100%	96.66%	83.33%	90%	90%	86.66%
Participant 5 (M)	80%	93.33%	86.66%	90%	86.66%	90%
Participant 6 (M)	100%	96.66%	100%	93.33%	100%	83.33%

Table (4): Results comparison with other detection methods

Eye movements	Proposed System (HTI)	Short-time averaging Method (STA) (Samann, 2017)	De-noising using mathematical morphology (DMM) (Jiang & Zhou, 2013)
Right	94.99%	98.33%	86.50%
Left	96.66%	98.88%	93.49%
Up	91.11%	96.66%	91.94%
Down	93.88%	97.22%	97.56%

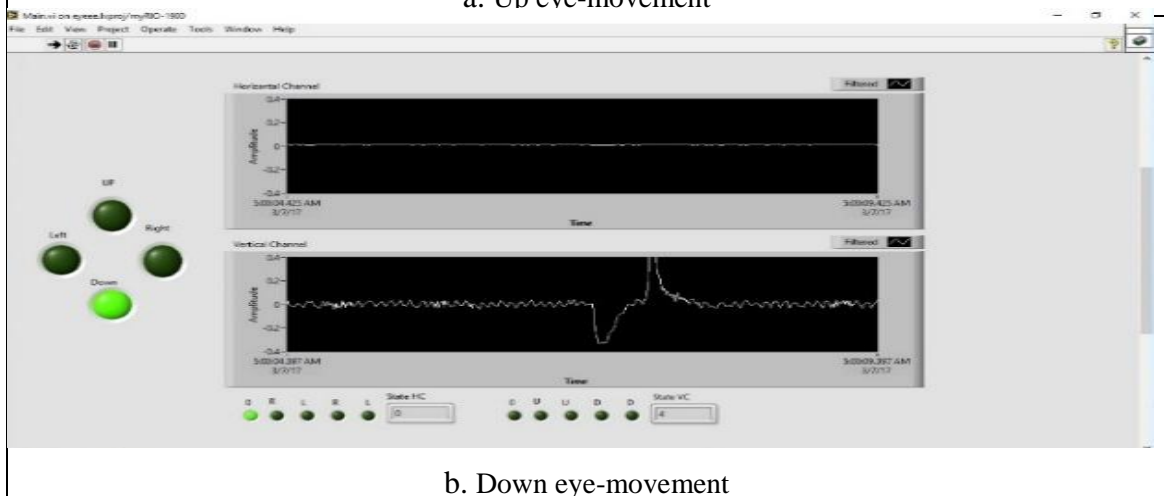
In term of average performance, the detection technique of HTI system has acceptable results comparing with STA and DMM methods (see table 4). The advantage of the proposed system is the ability to neglect the problem of any unwanted pulses using Pulse Timer, which cannot be achieved by other methods. In term of complexity, the proposed HTI system is very simple because it require only bandpass filter to reduce the noise

comparing with DMM and STA methods that require De-noising stage and moving average filter stage.

The interfacing of HTI system is designed using Graphical User Interface (GUI) of LabVIEW. This interface is considered to help the user in checking the status of the HTI system, and the state of the Active/Deactive sequence as shown in figure 12.



a. Up eye-movement



b. Down eye-movement

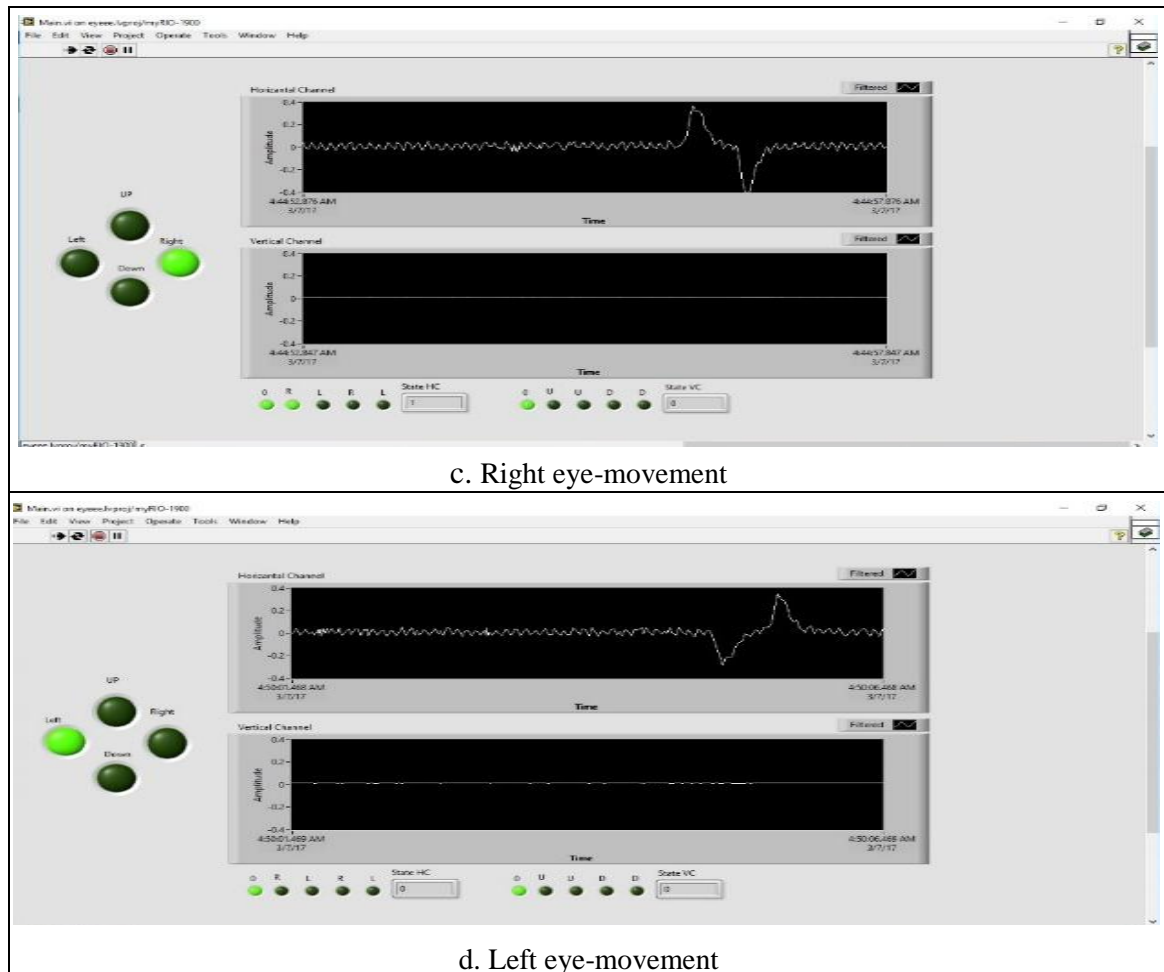


Fig. (12): User interface of HTI system

5. CONCLUSION

The proposed HTI in this paper was tested by six participants of both genders. The participants successfully controlled the TV using four eye movements. The advantage of the proposed HTI system is the activate and deactivate sequence, which are used to switch on and off the HTI system during watching TV. The possibility of activating the system during TV watching is very low due to the complexity of the sequence. The front interface of the system allows the user to check the status of the sequence and the state of the HTI system. For commercial uses, it is possible to replace the five electrodes with wireless electrodes attached to glasses.

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