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# EOG signal Modeling using Double Exponential Smoothing for Robot Arm Control System

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**Abstract:** ***This paper present a novel way of modeling EOG signal to use in a robot arm control system, two procedures implemented, offline procedure to measure and modeling EOG for building a pattern reference model ,and online procedure used to Control the robot arm. By comparing online measured EOG and the EOG pattern in reference model suitable manipulation instruction generated by the micro controller. The double exponential smoothing method used for building the pattern reference model, the accuracy of the reference model tested with main squire error (MSE) and main absolute error (MAPE) measures. Auto correlation analysis applied to study the existing pattern and linearity of EOG signal with eye movements. EOG signal measurement for this research classified in to five kinds: EOG horizontal (left and right) Vertical (up and down), and blinking. The EOG signal models of this research saved and used as a reference model file to classify the eye movements. a measurement and robot arm control system constructed by using arduino olimix 328, olimix sensor shield, and robot arm driving circuit, arduino C used as a programming environment, Minitab software used to build the model and correlation analysis ,Brain Bay software used to control and signal processing.***

**Key word:** Correlation, Double exponential smoothing, Electrooculography, Eye movement, Robot arm controller.

## 1.0 INTRODUCTION and BACKGROUND

Electrooculography will be a strategy for measuring those resting potential of the retina, coming about indicator will be called the electro oculogram EOG [1]. EOG indicator will be In light of electrical possibility contrasts between the corneal Also retina At eye development will be realized, the plentifulness of this sign ranges the middle of (15-200) µV Also its recurrence part try from 0 on 100 hz [2]. Numerous analysts attempted different systems on identify what's more dissect eye movement, Uzma Siddiqui and a. N Shaik [1].

Present a new technology of placing electrodes to record the polarization potential or corneal-retina potential. Manuel merino, et. al., [2] developed a signal processing algorithm to detect eye movements.

Abdulla xan et. al., [3] worked on amplification, noise removal and digitalizing of EOG signals .Damian pakulski and Artur Gmerek [4] developed a method to record and analyze EOG signals using classifier based on artificial neural network (ANN).C.Kvitha and G. Nagappan [5]built a "navigation perspective algorithm" to explore An wheelchair utilizing EOG signs. Arthi. Encountered with urban decay because of deindustrialization, engineering concocted, government lodgi. V What's more SureshR. Norman [6] recommend an alternate EOG estimation frameworks for the interfacing what's more control appliances. Veena g. Ukken et. al. , [7] planned a EOG built arm-hand control framework utilizing zigbee remote innovation organization. Krishna Mehta [8] reviewed distinctive routines about EOG sign Investigation.

Ngyen Kim-Tien What's more Nguyen Truong-Thinh [9] introduced An Different approaches to control the electrically powered wheelchair Toward utilizing EOG indicator recognition, the client controls the velocity Also controlling utilizing EOG and emg signs.

Zhao l. V, et. Al. [10] assembled An HCI framework dependent upon EOG, those framework comprise of EOG, securing unit, EOG design distinguishment What's more control unit. Hassein Shahabi. et. al. [11] exhibited another system for evacuating squinting impact starting with eeg signal, two models about EOG, eeg Also kalman channel been utilized. Siriwadee Anugsakun, et. al. , [12] suggested An strong order algorithm of the eye developments (eight movements). The algorithm was based on the onset analysis and classification and first derivative technique.

Chun Sing Louis Tsui ,et, al.[13] present a novel hand-free control system for an electric –powered wheelchair based on EMG signal and EOG for attention shift detection Andreas Bulling ,etl ., [14] investigation of eye movements presented. Eye movement used to recognize mental activities in this work a novel procedure for EOG modeling presented.

In this research, we applied double exponential smoothing (DES) method to analyze and modeling the EOG signal. The predicted EOG signal will be evaluated according to eye movement's angle and amplitude of EOG signal, the digitized output used to manipulate a robot arm. Moreover, we used accurate data acquisition system with five sensor system for vertical, horizontal, and blinking eye movements.

## 2.0 METHODS AND MATERIALS

## 2.1Exponential Smoothing and Correlation

In smoothing procedure recent observation are given larger weight than older observations in such a way that weight given to post data decrease exponential with time is exponential smoothing [15].The general form of DES[16],[17] is:

Let x (t) be the actual data at time t, t= 1, n
Then

$$F'(t) = \alpha x(t) + (1-\alpha) F(t-1) \qquad (1)$$

$$F'(t) = \alpha F'(t) + (1-\alpha) F'(t-1 \qquad (2)$$

$$F'(t+h) = F'(t) \qquad (3)$$

Where
F' (t), F' (t): the smoothing or derived value of time (t)
α: smoothing constant $0 \leq \alpha \leq 1$
F' (t+h): the prediction of time (t+h) made at time t, i.e., h period in to the future.
Forecasting provides many performance measures for forecasting algorithms. The following notations used to describe the measures [18]:

F' (t) the prediction of time t
e (t) prediction error at time t, e(t) =x(t)= f(t)
Then:
The cumulative prediction error

$$CFE = \sum e(t),\ t=1, .n \qquad (4)$$

The mean square error

$$MSE = [e(t)]\hat{}2 / n \quad , \quad t=1, n \qquad (5)$$

The mean absolute percent error

$$MAPE = 100[|e(t)| / x(t)] / n \quad , \quad t=1....n \qquad (6)$$

While the correlation is Apure scale –free measure of strength of linear association between two random variables [19].The correlation between x and y can be estimated as:

$$R = c(x,y) / [\sigma(x)\ \sigma(y)] \qquad (7)$$

C(x,y): covariance
σ (x): standard deviation of x
σ (y): standard deviation of y

## 2.2 EOG signal Measurements

The resultant EOG signal measurement are in low frequencies, thus this research uses band pass filter with range of ( 1-30 ) Hz [20]. The olimex 328 arduino used to control sensor shields. Five sensors method used to measure the EOG signals, the picture of the complete system arrangement show in fig. 1.0, the block diagram of EOG measuring and control was built using Brain Bay software, as shown in Fig. 2.0.

**Figure 1** EOG beased robot arm control system.

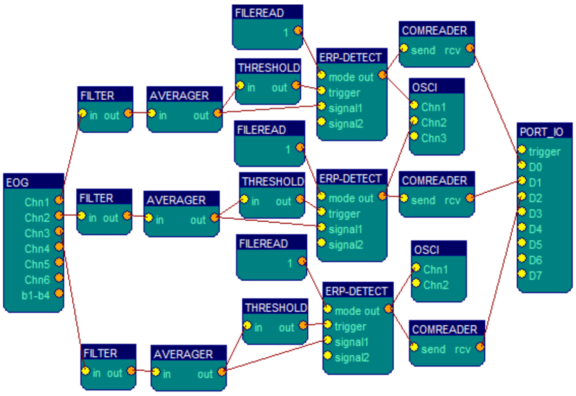

**Figure 2** Measuring Block Diagram of EOG Signals

The electrodes output signal will be supplied to the EOG bio amplifier. A three channel output of the bio amplifier will divided as channel 1 for vertical eye movement, channel 2 for horizontal eye movement, and channel 3 will be used for blinking signal. A three smeller processing steps applied to the three channels. The output of channel 1 pass to a low pass filter with an upper limit of 40 Hz. The average of each 10 sample calculated for the filter signal. A threshold output used as trigger of ERP-detect process. The ERP–detect compare the pattern similarity between the outputs of the average and saved one in FILEREAD depending on pattern similarity exciting in a channel, an instruction will be send to the parallel port through the COMRADER.

The range of eye movement is $100^{o}$ for vertical and $120^{o}$for horizontal eye movements as shown in Fig. 3.0 [21].

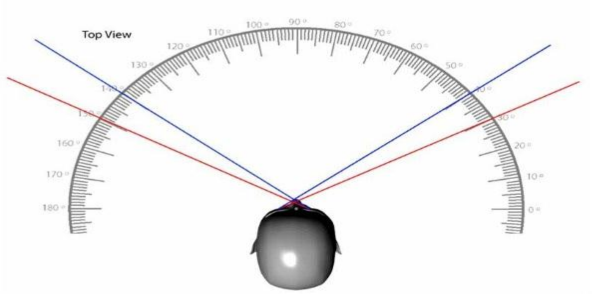

**Figure 3** Range of Eye Movements Angle.

The vertical eye movement measured as up (EOG VU) and down (EOG VD), while the horizontal eye movement measured as left (EOG HL) and right (EOG HR).The measured EOGVU in Fig.4.0.

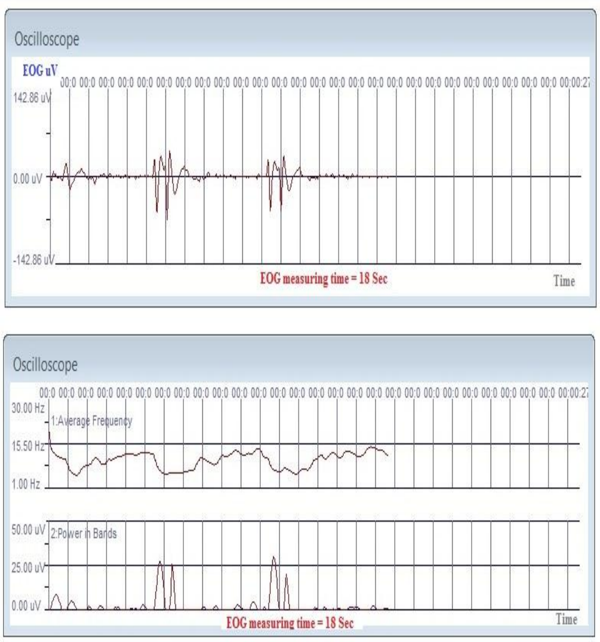

**Figure 4** Measured EOG VU.

showing good pattern repetition, the average frequency plot varies between (3-15)Hz and during EOG rising, the frequency of the EOG signal is decreased and approached to less than three Hz, while the power in band shows two peak values. The measured EOG VD in Fig5 shows higher peak values in power band, which can be used in pattern recognition to discriminate between EOG VU and EOG VD.

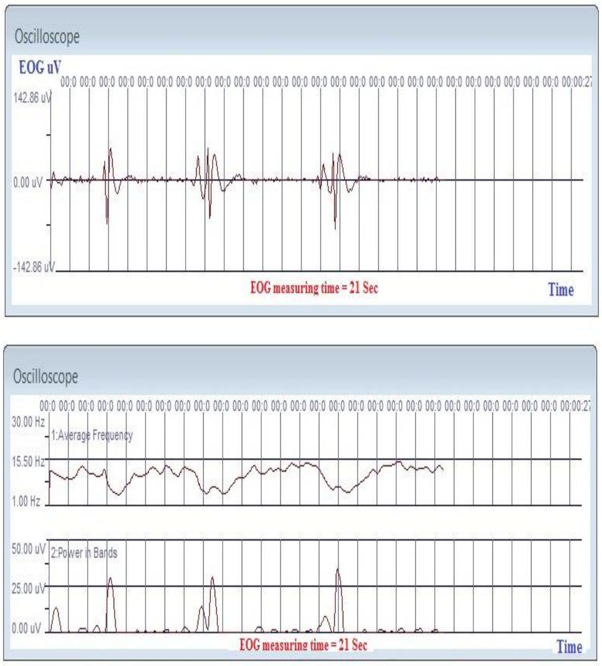

**Figure 5** Measured EOG VD

The measured EOG HL and EOF HR shown in Figs.6-7 respectively.Using the diffirence in power band peaks, agood discrimination between the two signals can be stasfied. The EOG signals of horizontal left and right are shown in Figs.5.0-6.0 respectively.

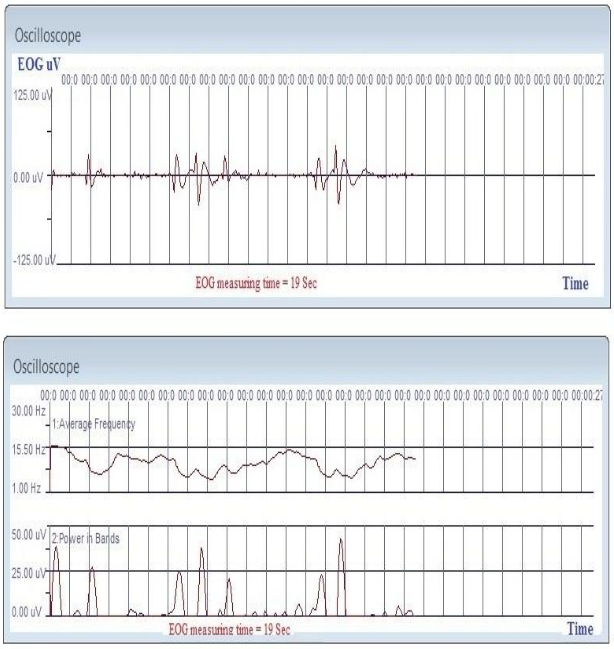

**Figure 6** Measured EOGHL

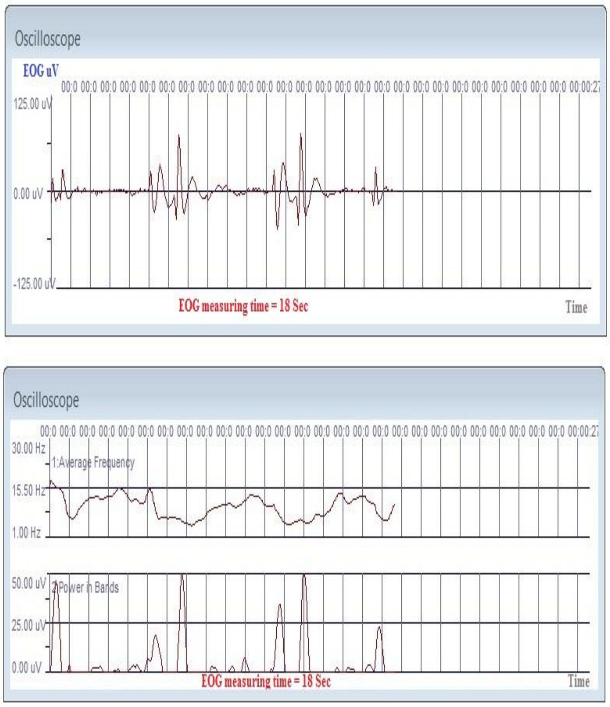

**Figure 7** Measured EOG HR

While the EOG of blinking is shown in Fig.8, the fast response of eye blinking shown in Fig.7.0.the lonely high peaks in power band used to deduct the eye blinking.

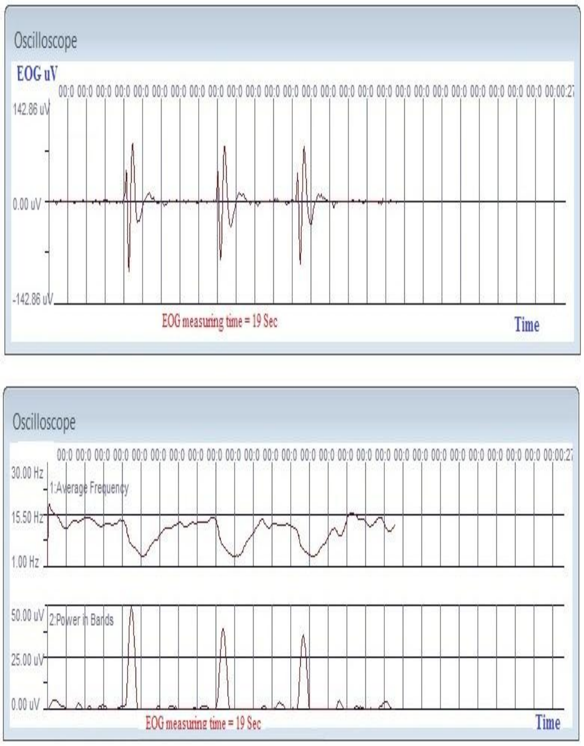

**Figure 8** Measured EOG of eye blinking

## 2.3. EOG reference model:

The predicted models has been calculated by using the numerical data from the measured EOG signals, Fig.9.0 shows the actual and the predicted model of (EOG HL), the following is an example of calculating the 5th value of the predicted EOG HL signal, the different behave of increasing and decreasing among the prediction EOD HL and EOG HR signal gave a big help for pattern recognition of eye movements.

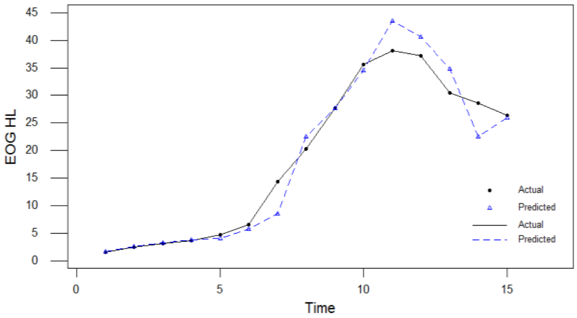

**Figure 9** Actual and predicted EOG HL.

Let $\alpha = 0.56$

And default $F(0) = F'(0) = X$ (1)

$X(t) = x(5) = 4.7$

$F(t-1) = 4.1$

Then: $F(t) = [0.56(4.7)] + [(1-0.56)(4.1)]$

$F(t) = 4.436$

$F'(t) = (0.56 * 4.436) + [(1-0.56)(4.1)]$

$F'(t) = 4.288$

Then:

$F(t+h) = 4.288$

Percentage error = (100%) – [(4.288/4.7)*100]

= (100%) – (91.2%) = 8.8%

The same procedure repeated for the other EOG signals. To calculate the predicated signals for the different EOG measurements.

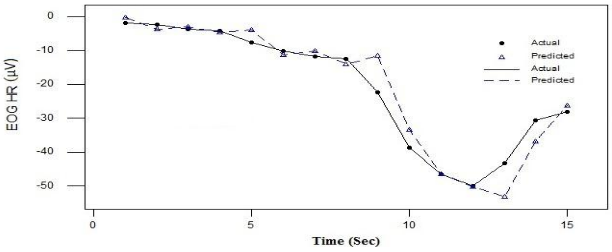

**Figure 10** Actual and predicted EOG HR

The predication and actual EOG HR is shown in Fig10.0 and the predication of EOG VU and EOG VD are shown in Figs.11 and 12.The resultant models show a high predication performance.

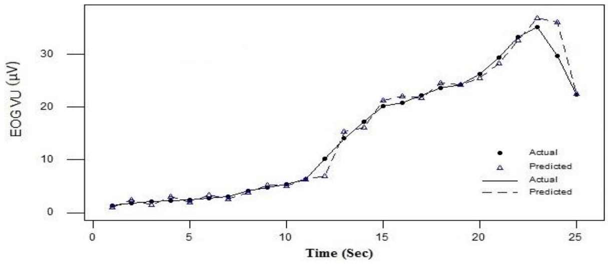

**Figure 11** Actual and Predicted EOG VU

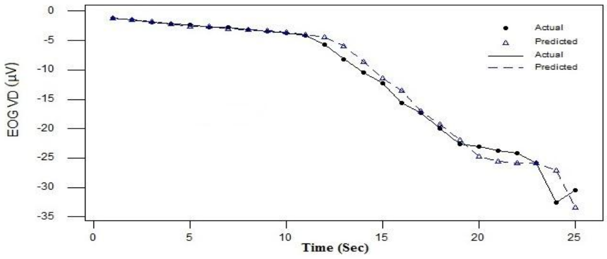

**Figure 12** Actual and predicted EOG VD.

For the eye blinking the actual and predicted EOG signal shown in Fig. 13.This model appeared less performance than the other models, the reason of this behave is caused by the sudden change of EOG potential as a result of high speed movement during the blinking.

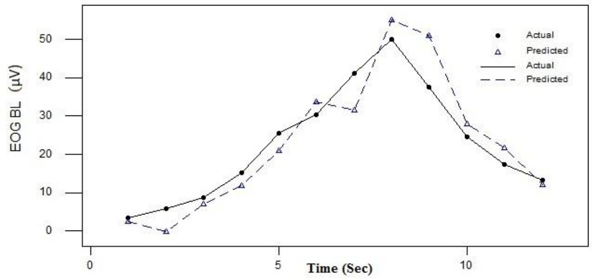

**Figure 13** Actual and predicted EOG BLINKING

An autocorrelation analysis is applied to evaluate the suitability of the EOG prediction models. Figs.14-18 show the eight leg autocorrelation graphs of EOG models. The resultant graphs show a good confidence of the prediction models.

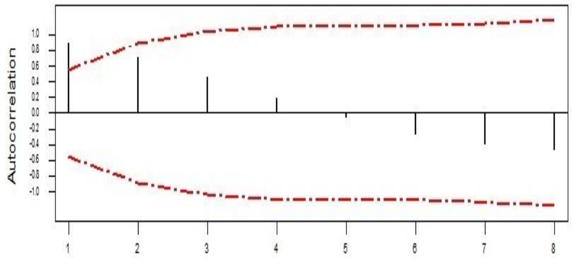

**Figure 14** Autocorrelation of EOG HL

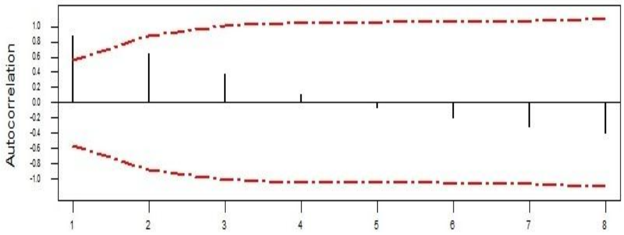

**Figure 15** Autocorrelation of EOG HR

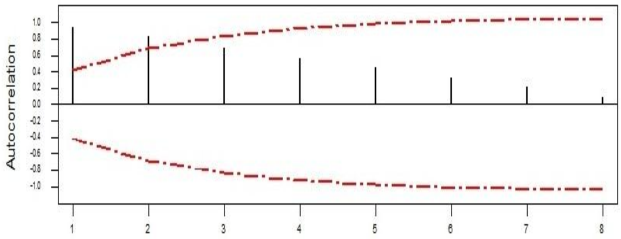

**Figure 16** Autocorrelation of EOG VU

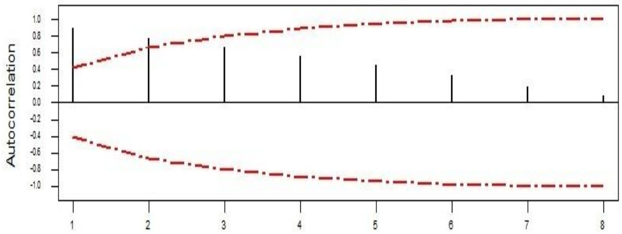

**Figure 17** Autocorrelation of EOG VD

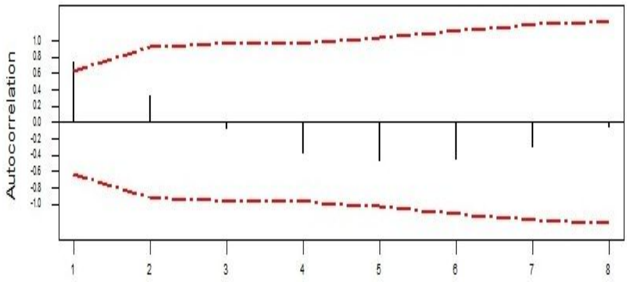

**Figure 18** Autocorrelation of EOG BLINKING

## 4.0 RESULTS

**Robot Arm Controller** constructed EOG models used to control a robot arm with five degree of freedom types TR5. The digital output of the measurement system used as an input to arduino 328 control board. An interface and drive circuit constricted to manipulate the robot arm (TR5) the flow chart of measurement and control process shown in Fig.19.The basic idea of the system based on comparing the measured signal with models saved previously in separate files to decide the type of eye movement and the amount of this movement, the result will be transferred in binary form to the parallel port then to the control and drive circuit to manipulate the robot arm.

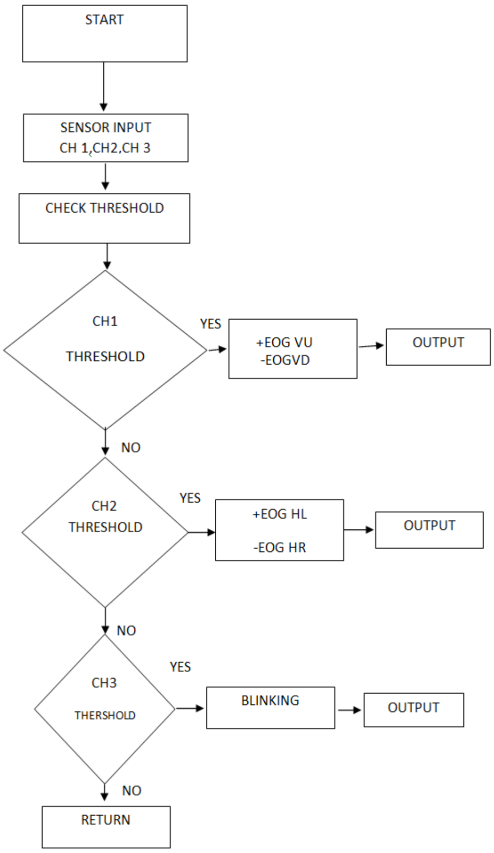

**Figure 19** Flow chart of Measuring and control system

The block diagram shown in Fig .20 illustrates the measurement and control system in a simple way.

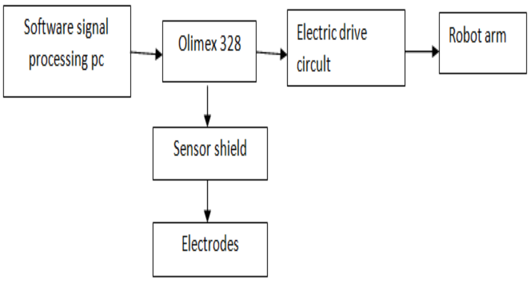

**Figure 20** Block diagram of robot arm controller

## 4.0 Conclusion

In this paper, we proposed EOG based robot arm controller. A double exponential smoothing module applied with high accuracy and sensitivity, a high correlation factor between EOG outputs with eye movement has been proved. The software filtering and pattern recognition caused the low cost of measuring and control system. The offline and online EOG measurements helped to build efficient EOG prediction models. The comparison technique used in this research gives a good benefits of reducing the needed time for pattern recognition of measured EOG signal.

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