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Eye-Dialect System for Aphasia Person Computing K-Means and EM Clustering Algorithms

Vipin S. Bhure[1], Shrutika P. Chaware[2]

[1]Assistant Professor, G. H. Raisoni Academy of Engineering and Technology, Nagpur, India
[2]P.G. Scholar, Department of Electronics & Telecommunication, G. H. Raisoni College of Engineering Nagpur, India

Abstract: ***Locked in syndrome (LIS) person is deprived to communicate in conventional way. Though suffering from diseases like spinal cord injury, amyotrophic lateral sclerosis (ALS), cerebral palsy, etc., person retains the ability to control their eye movements. This ability of voluntary eye movements for human computer interface (HCI) can be used as alternative orientation. In this paper, for different eye gestures acquired using Ag-AgCl electrodes and signal conditioning board AD8232 and interfacing with arduino AT mega 2560 output messages obtained by K-means clustering algorithm. Output for different gestures like voluntary blink, involuntary blink, gaze, vertical upward movement, vertical downward movement, horizontal left to right, horizontal right to left, diagonal left to right, diagonal right to left, etc. are used to communicate different messages like 'need water', 'need food', 'feeling uneasy', etc. using K-means clustering algorithm, the LIS person thus can communicate with outer world, enriching the quality of life. Efficiency of 98% is obtained for voluntary and involuntary blink respectively and 100% for gaze gesture.***

Keywords: Eye-Dialect ystem, Aphasia Person Computing, K-Means, EM Clustering

1. Introduction

Many people in the world are deprived of peripheral mobility because of some physical or mental disability. Some of the reasons for this disability can be accidents, stroke, paralysis, cerebral palsy, ALS, etc. Because of this people are unable to carry out conventional communication with others. Voluntary movement of legs, hands, head, fingers, trunk is restricted in most of the cases. In this context, eye's voluntary movement can be unfolded for attaining communication between the person and the rest of the world.

One such disability is amyotrophic lateral sclerosis (ALS), in which person suffering from this disease is restrained to move limbs and even head with advancement in disease. Similar manifestations can be observed in other motor neuron diseases like cerebral palsy, spinal cord injury, etc. In ALS as well as cerebral palsy, person suffers from locked in syndrome (LIS) but eye movements of the person are exceptionally conserved .Analysis on people with grave ailment proved many of them embrace the ability to control their eye movement which could be used to orate with external ambience.

The electro-oculogram (EOG) is the electrical signal that is analogous to the potential divergence of the retina and the cornea of the eye. The EOG is the electrical perception corresponding to the position of the eye. EOG abased techniques are suitable with ease for patients with severe cerebral palsy or those inherited with a congenital brain disorder or suffering with severe brain trauma.

EOG approaches have subsequent advantages:

1) The paramount application of the EOG is in the detection and measurement of eye movement.
2) EOG based recording techniques are modest and cheap.
3) EOG is often used to track eye movement patterns.
4) EOG readings can be measured even when the eyes are closed.
5) EOG can be exploited as a supreme visualizing parameter to help the ophthalmologists for examination of ophthalmic disorders in a better way.
6) EOG can be adopted in designing ophthalmic equipments which are capable of supplementing in disease diagnosis as well as for curative purposes.
7) In general completely or partially differentially able person have dominant vision which can be used as a supreme tool for carrying out their elementary works through human machine interface.

2. Related Work

EOG signal was first perceived Emil du Bois-Reymond, German physician in year 1848[9].Several methods have been adapted to solve the communication problem for ALS or other tetraplegic clinical conditions [10][11].Image processing technique for this problem is high-priced and sensitive to habitat circumstances. Reconstruction of eye-written traces from EOG signals in real time [2] and significant EOG signal's potential to be used as communication input for HCI. Average time required for selecting a button is large and conforming to only horizontal movements of eyes using single channel EOG based HCI system for communication with LIS patients [3]. Different voltage range for different gestures acquired using complete analog based EOG system [4].Author [5] carried the evaluation of the EOG in collaboration with a speller application. This is done by explicatory analysis of EOG glasses currently in exposition known as JINS MEME glasses. Devised virtual keyboard for communication without speaking and hand movements [6]. The virtual keyboard interface provided the users to write alphabets, words, numbers, etc. Research work [7] for physically disabled person using EOG signals proposed a password based security system where password is written by eye movements that is EOG signals.

3. Proposed Methodology

Proposed system comprises of designing a low cost and comfortable system which will solve the speech impairment problem of locked in syndrome (LIS) patients using different eye gestures. Non Intrusive design to solve speech impairment problem of the patients suffering from Amyotrophic Lateral Sclerosis (ALS), weakness of cerebrum, and injury to spinal cord. The proposed system can be used by disable or paralyzed person to communicate with the external world with the help of EOG technique.

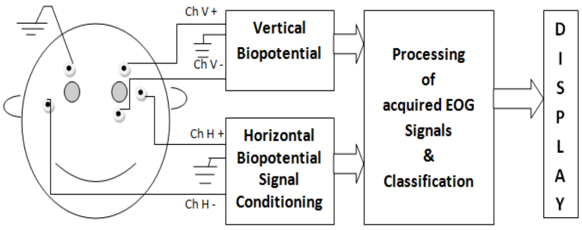

Figure 1: Proposed block diagram [6]

The goal of research work is to design and develop an EOG based Eye- Dialect System which is simple and cost effective system to aid patients suffering from locked in syndrome (LIS). Eye- Dialect here refers to conversational language, informal lingo. Electrooculography is the science of acquiring the resting conductivity of the eye and its variations. The cornea has a positive potential relative to the back part of the sclera which can be considered to be the frontal and rearward function the eye balls termed the corneal retinal potential (CRP).Our eyes can be visualized as a dipole as proposed by Louis Emile Javal as shown in fig.2.

In pre-processing EOG signal obtained using Ag - AgCl electrodes by placing the electrodes as shown in fig.4. Ag-AgCl electrodes convert the ion current at surface of skin to electron current acquired at mapping instrument via lead wires. Electrolyte gel between skin and electrodes possess free chloride ions and electrodes with silver atoms. Silver atoms oxidize and give cations simultaneously anions of chloride ions bond and results in flow of current from electrolyte to instrument to read proceeding electrodes.

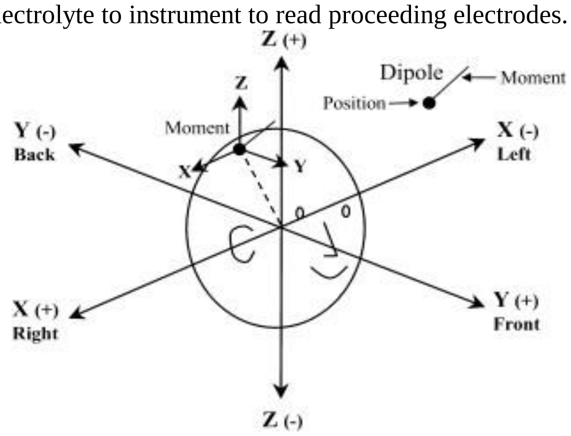

Figure 2: Louis Emile Javal's dipole structure of eye

Figures and System architecture comprises of three basic blocks –Pre-processing, Gaze reconstruction and Classification

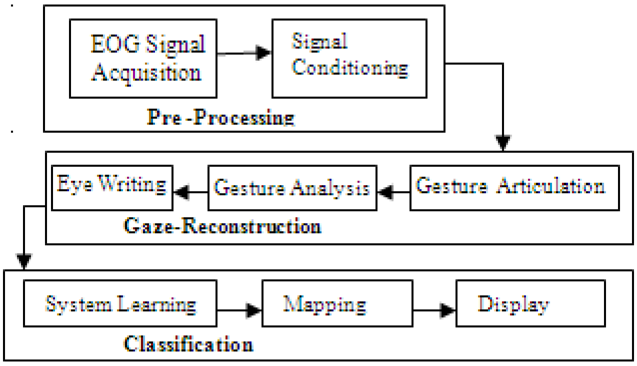

Figure 3: System Architecture

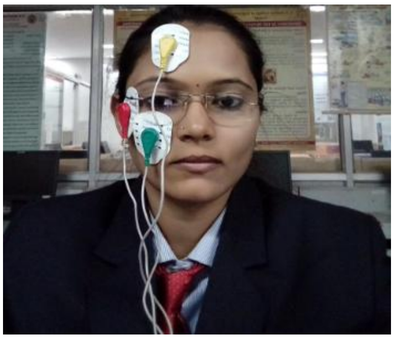

Figure 4: (a) Placement of electrodes

Signal conditioning is done by AD8232 which is a bio potential measurement integrated signal conditioning board drafted to acquire, amplify and filter bio-suspended signals. Signals acquired via Ag-AgCl electrodes used by AD8232 for signal reinforcement. With CMRR of 80 dB with DC blocking potential and gain of 100, AD8232 have high-pass filter for artifacts rejection allowing frequency over 0.5 Hz and low-pass filter allowing frequency below 40 Hz.

For communication of extracted EOG signals with the system here used Arduino AT mega 2560 which is fabricated to reset by software per connected system. With clock speed of 16 MHz, the 54 digital I/O pins and 16 analog input pins can be used for acquisition of EOG signals. The arduino converts the obtained decimal valued per electrodes to proportionate voltage by considering 5V as 1023 and any value below 5V will be proportionate between 5V and 1023.Using following equation (1), decimal output obtained from analog to digital converter (ADC) can be converted to proportionate analog voltage value.

$$Resulting\ Analog\ Voltage = \frac{Max\ System\ Voltage}{division\ of\ ADC} * ADC\ output \quad \ldots\ldots.(1)$$

For ADC output 360, the corresponding analog voltage will be:

Resulting analog voltage= (5/1023)*360

This analog voltage value obtained is communicated to system via arduino. For different gestures like voluntary blink, involuntary blink and gaze, different values are obtained using arduino as indicated in fig.4(b), fig4(c)and fig4(d) respectively. Some of the decimal values acquired from different gestures are as shown in table 1.

Table 1: Decimal values obtained for different gestures

Gesture	Voluntary Blink	Involuntary Blink	Gaze
Range Obtained	370-410	345-360	330-340

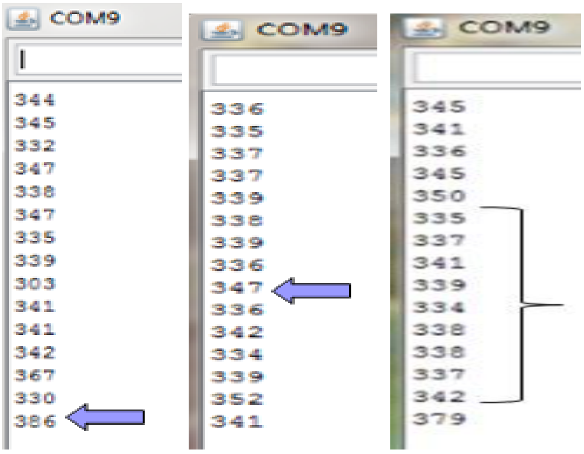

Figure 4 (b): Voluntary blink. **Figure 4 (c):** Involuntary blink. **Figure 4 (d):** Gaze

Table 2: Results for Different Gestures for Each Participant

Sr. No.	Name of Subject	Age (yrs.)	Gesture		
			Involuntary Blink	Voluntary Blink	Gaze
1	S1	18	356	370	339
2	S2	19	357	371	337
3	S3	21	359	378	335
4	S4	18	349	387	337
5	S5	20	350	373	339
6	S6	20	348	396	336
7	S7	21	350	378	334
8	S8	20	348	370	332
9	S9	19	352	376	333
10	S10	18	359	400	338
11	S11	19	357	390	337
12	S12	18	352	374	336
13	S13	19	359	375	338
14	S14	21	351	350	331
15	S15	18	358	382	334
16	S16	20	349	378	339
17	S17	20	353	401	338
18	S18	21	352	390	333
19	S19	20	346	402	339
20	S20	19	348	409	332
21	S21	18	349	380	338
22	S22	19	347	391	335
23	S23	14	349	396	336
24	S24	11	347	393	335
25	S25	30	349	398	338
26	S26	26	353	394	336
27	S27	25	357	389	332
28	S28	64	400	406	337
29	S29	53	356	403	331
30	S30	9	348	392	337
31	S31	56	348	407	333
32	S32	28	354	390	335
33	S33	26	356	393	336
34	S34	56	360	389	338
35	S35	50	347	386	336
36	S36	35	356	402	332
37	S37	40	362	400	332
38	S38	70	350	398	335
39	S39	30	348	393	339
40	S40	28	359	401	337
41	S41	16	354	402	338
42	S42	18	352	394	335
43	S43	44	365	402	336
44	S44	33	358	391	338
45	S45	32	355	395	336
46	S46	36	357	405	334
47	S47	39	363	401	331
48	S48	35	349	398	338
49	S49	41	361	407	332
50	S50	48	362	406	334
EFFICIENCY (%)			98	98	100

The analog voltage is plotted using the sampling rate of 100Hz using Nyquist sampling criterion as the maximum bandwidth of EOG signal is 40Hz [8]. Gaze articulated and analysed for different gestures like voluntary blink, involuntary blink, gaze, vertical upward movement, vertical downward movement, horizontal left to right, horizontal right to left by placing electrodes on 50 healthy subjects and disabled person are acquired as shown in fig.5(a), 5(b), 6(a), 6(b), 6(c), 7(a), 7(b), 7(c), 8(a), 8(b), 8(c), 9(a), 9(b), 9(c), 10(a), 10(b)and 10(c).

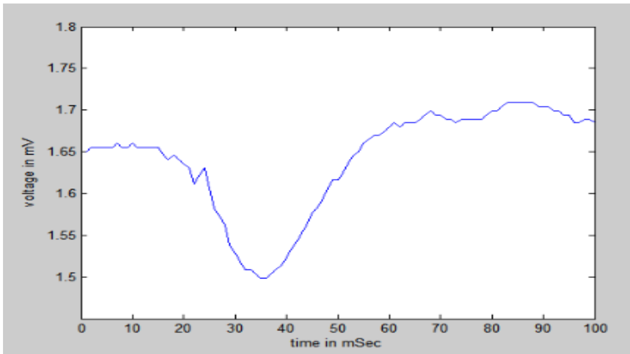

Figure 5 (a): Involuntary Blink of normal person

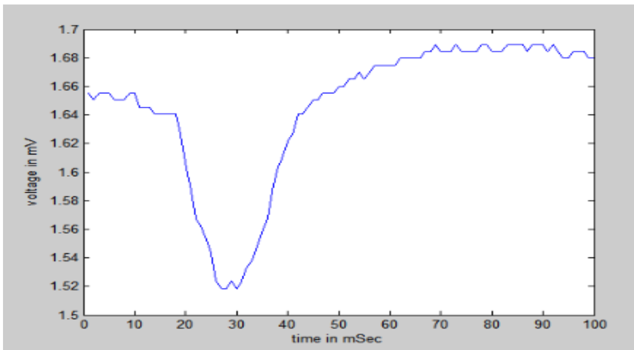

Figure 5 (b): Involuntary Blink of paralysed person

Table 3: Voltage Values Obtained for Different Gestures

Sr No.	Different Gestures	Voltage range obtained in (mV) according to different patterns
1	Gaze at a point	1.6 - 1.7
2	In-voluntary blink	1.65 - 1.5 - 1.7
3	Voluntary blink	1.7 - 2.2 - 1.7
4	Downward gaze	1.8 - 1.65
5	Upward gaze	1.7 - 1.9 - 1.74
6	Horizontal left to right gaze	1.62 - 1.74
7	Horizontal right to left gaze	1.65 - 1.
8	Diagonal down left to up right gaze	1.7 - 2.1
9	Diagonal down right to up left gaze.	1.6 – 2

For system learning used the K-means clustering algorithm. It is an efficient method of gathering perceptions into a distinct number of disjoint flocks referred to as K-clusters [10].

The flow chart for applied algorithm is as follows:

1. Partitioning sample space into K-clusters
2. Assignment of observations to clusters randomly
3. Measure distance of observation from the centroid of cluster for each sample
4. "IF" particular sample is nearest to its own cluster "THEN" denominate it "Else" choose distinct cluster
5. Repeat above steps until no observation is emigrated to another cluster

Figure 11(a) and 11(b) shows output for different gestures corresponding to mapped equivalent message. For voluntary blink displaying the message "need water", for down gaze displaying "need food", for leftward eye movement displaying "feeling uneasy", for upward eye movement displaying "feeling better", etc

Table 4: Message Displayed Using K-Means Algorithm for Different Gestures

S.no.	Eye gesture	Message displayed using K-means algorithm
1	Voluntary blink	Need water
2	Downward gesture	Need food
3	Upward gesture	Feeling better
4	Horizontal right to left	Feeling uneasy

Figure 6 (a): Voluntary blink gesture

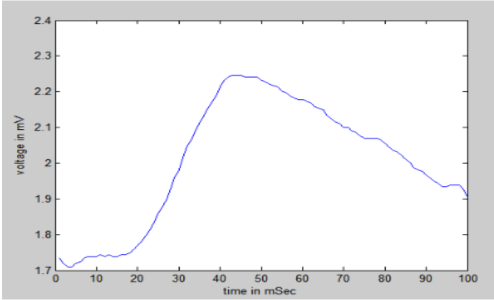

Figure 6 (b): Voluntary blink of normal person

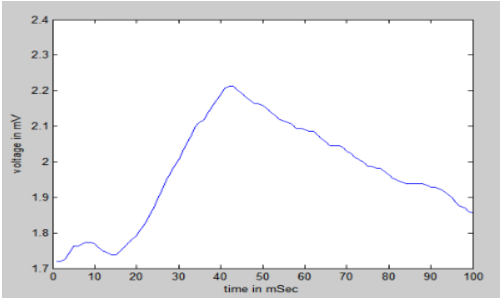

Figure 6 (c): Voluntary blink of paralysed person

Figure 7 (a): Downward eye gesture

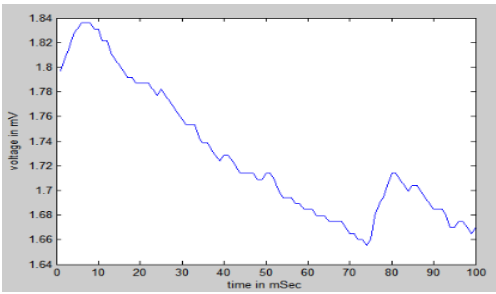

Figure 7 (b): Downward eye gesture of normal person

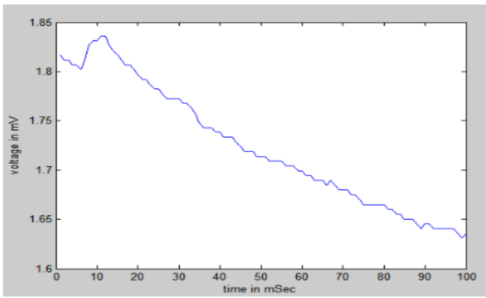

Figure 7 (c): Downward eye paralysed person

Figure 8 (a): Upward eye gesture

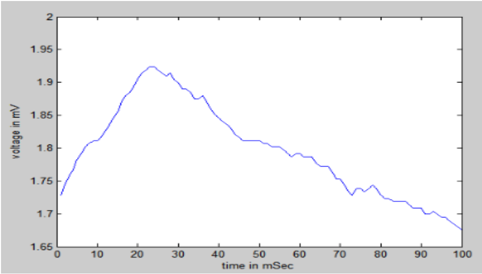

Figure 8 (b): Upward gesture of normal person

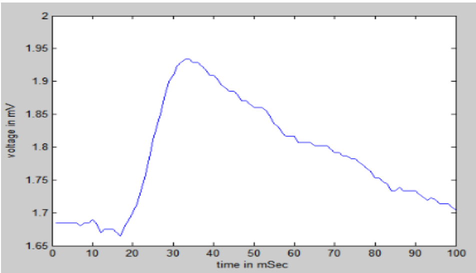

Figure 8 (c): Upward gesture of   paralysed person

Figure 9 (a): Horizontal left to right

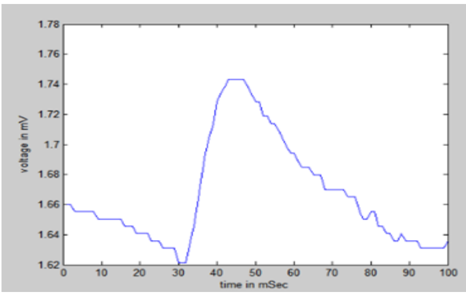

Figure 9 (b): Horizontal left to right gesture of normal person

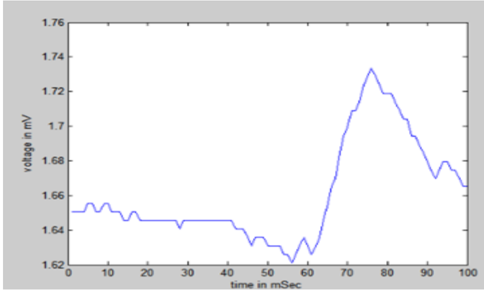

Figure 9 (c): Horizontal left to right gesture of paralysed gesture person

Figure 10 (a): Horizontal left to right

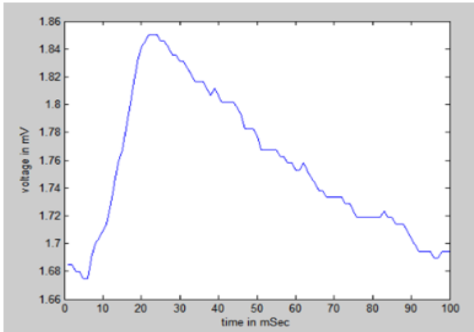

Figure 10 (b): Horizontal right to left gesture of normal person

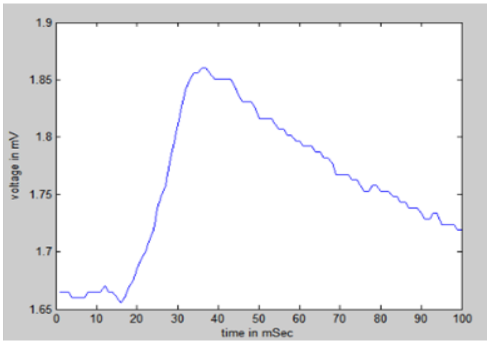

Figure 10 (c): Horizontal right to left gesture paralyzed person gesture

Output using K-means clustering algorithm:

0.0244

0.0146

-0.0049

-0.0049

-0.0098

-0.0586

0.1025

feeling better
0.0098

-0.1270

need food
0.0391

0.0879

-0.0928

Figure 11(a)

need water
-0.2734

-0.0391

0.0244

-0.0879

0.1709

feeling uneasy
0.0244

-0.0244

0.1367

-0.1563

need food
-0.0049

0.0488

Figure 11(b)

Table 5: Time taken to build model using different algorithms

Sr. No.	Name of clustering algorithm	Time taken to build model
1.	Expectation maximization (EM) Clustering	0.44 sec
2.	k-means clustering	0.03 sec

In table 5, time taken by Expectation Maximization clustering algorithm and K-means clustering algorithm is compared. Time taken by EM cluster for modeling of dataset is obtained to be 0.44 sec compared to 0.03 sec by applying K-means.

4. Conclusion

EOG can work better as an assistive device for disable person as reviewed through papers. EOG is having very wide scope in future. Thus we are able to obtained real time voltage for different eye movements, which can be significantly used as a communication medium to convey any message from LIS or ALS patient. In actual time ambience with contemplated gaze rejuvenation, eye-writing with EOG-based has future ability to aid evidence for HCI with diverse input patterns and trustworthy identification degree.

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Author Profile

Vipin S. Bhure, Assistant Professor at G. H. Raisoni Academy of Engineering and Technology, Nagpur. He have completed his M.Tech in VLSI from G. H. Raisoni College of Engineering Nagpur. And pursuning his Phd. from Sathyabama Institute of Science and Techology, Chennai. Reseach intrest focus on Embedded VLSI vlsi and MEMS.

Shrutika Chaware, M.Tech Electronics & Communication from G. H. Raisoni College of Engineering Nagpur. Her area of interest is Communication and Embedded System.