An Image Based Eye-Blink Assistive System For Paralyzed Patients

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Abstract - *The main aim of this paper is to remove difficulties faced by completely paralyzed patients suffering from Motor Neuron Disease (MND) and Locked-in Syndrome (LIS). Paralyzed patients cannot communicate as they suffer from speech disorder, the only part that remains unaffected is eyes and communication is possible only through their eye movements. The proposed system is based on a Video-Oculography (VOG) technique which is efficient when compared to other existing techniques. In this system methods like face detection, eye blink detection and image processing are employed to communicate the needs of patients to the concerned person through a text and an audio message using twilio application.*

***Key Words*: Motor Neuron Disease, Locked-in Syndrome, Speech Disorder, Video-Oculography, Face Detection, Eye Blink Detection, Image Processing, Twilio.**

1. INTRODUCTION

Motor Neuron Disease (MND) and Locked-in Syndrome (LIS) are incurable medical conditions where the patient is completely paralyzed. It also leads to inability in communication through speech. Because of this, performing voluntary actions is not possible and it becomes very difficult for the patients to express their needs. A caretaker has to assist the patient 24/7. In most of the cases the caretaker might not understand what the patient is trying to convey. Many systems have been developed to address this issue. Currently the technology used is Brain wave controlling and Electro-oculography. Both the methods are expensive and also uncomfortable.

1.1 Outline of the Proposed System

The proposed method uses Video-Oculography technique which is less expensive, comfortable and not painful. In the proposed system, firstly the patient's face is detected and extraction of eye region is done using Face Detection algorithm. Then, eye-blink detection is done using Eye-Blink algorithm.

Paralyzed patients should choose an image from the set of images being displayed on the screen, by blinking their eyes voluntarily as per their requirement. The chosen image is communicated to the concerned person as the patient's requirement through an audio and a text message on their phone.

We use OpenCV-Python for face and eye detection, Tkinter module for displaying of images and Twilio application for text and voice message. Using such image processing and machine learning techniques, the patient's intent or needs can be conveyed more effectively and efficiently.

2. EXISTING METHODS

Research on problems faced by paralytic patients was started in 19th century. Initially, it was done manually by tracking the neural movements in the brain which indicates the person's need. Further on evolution in technology, various techniques were used to resolve issues faced by paralytic patients. Various techniques such as ElectroEncephaloGram (EEG), Electro-OculoGraphy (EOG), Eye-Blink Count etc. This section briefs the above mentioned techniques.

2.1 ElectroEncephaloGram (EEG)

An electroencephalogram (EEG), is a non-invasive test used to record the electrical activity in the human brain [1]. In this method, electrodes are placed at various positions on the head around the scalp of the patient for measuring the electronic activity of the brain as shown in the fig 1. The recorded electronic impulses are considered as ElectroEncephaloGram (EEG).

Fig -1: EEG

Various limitations involved in this method are spatial resolution, signal to noise ratio during measuring electrical impulses, analysing the recorded electrical activity to understand the concerned patient needs. The main disadvantage in this method is that the device should be worn by the patients 24/7 in-order to convey their needs.

2.2 Electro OculoGraphy (EOG)

Electrooculography (EOG), is a technique used for measuring the corneo-retinal standing potential which exists between the front and the back of the human eye [1], [10]. The resulting signal is recorded as electrooculogram. Measuring of eye movement is done by placing pairs of electrodes either above or below of the eye or to the left and right of the eye as shown in the fig 2. If there is an eye movement from the center position towards one of the two electrodes, that particular electrode records a signal as the positive side of the retina and the other electrode records a signal as the negative side of the retina. As a result, a potential difference is measured between the pairs of electrodes. Initially, the resting potential is assumed to be constant and the recorded potential difference which is a measure of eye position is used to select a particular intent by the patient.

Fig -2: EOG

Various limitations involved in this method are signals being seldom deterministic, even for the same person in different environment. EOG signal gets increased with increase in luminance intensity. It's a painful process as electrodes are placed around the eyes which leads to inability in eye movement.

2.3 Eye-Blink Count

Eye-Blink count is based on video-oculography approach where in the user's eye movements are recorded through a live camera [5], [9]. In this proposed method each and every basic need or intent is associated with a fixed number of blink counts. The patients have to provide an appropriate count in order to communicate their need as shown in fig 3. The main disadvantage concerned with this approach is that, the patient needs to be trained in prior and they will have to remember the count associated with each basic need.

Fig -3: Eye-Blink Count

3. PROPOSED METHOD

The proposed method is a system developed for paralytic patients to record their timely requirements, especially for those who are suffering from Locked-in Syndrome (LIS) and Motor Neuron Disease (MND). This system employs Human Eye-Computer Interaction in such a way that, the patients can convey their needs to concerned person effectively by just blinking their eyes. Paralytic patient suffering from speech disorder would be able to find this system useful as they can communicate without much efforts.

As mentioned earlier, the existing methods make use of painful methods such as EEG, EOG and Eye-blink counts. All these methods include invasive devices which are considered to be cumbersome in usage and are not affordable due to their expensive cost.

Considering these challenges, we have proposed a system which makes use of efficient algorithms of machine learning and a non-invasive video-oculography technique. The main reason for choosing video-oculography technique is that, it is a simple non-invasive method which consumes less time and comparatively accurate and cost effective.

The main objective of the proposed method is to develop a system which is an electrode less, cost effective and hands-free operational system through which patients can communicate their basic intent to the concerned person accurately and effectively.

3.1 Workflow of the System

The work flow of the proposed system "An Image Based Eye-Blink Assistive System for Paralyzed Patients" is as shown in the fig 4. It consists of four main modules being Image slideshow, Face and Eye detection, Eye blink detection, and Text and voice message using twilio. Each and every module is explained in the further section.

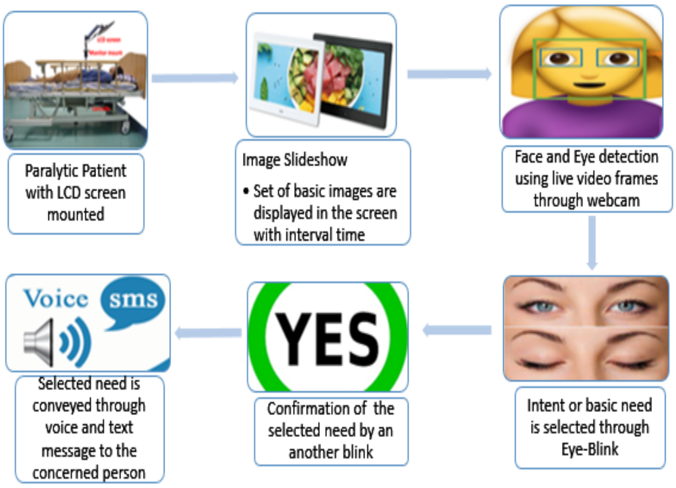

Fig -4: Workflow of the system

4. IMPLEMENTATION

4.1 Image Slideshow

Set of resized images are displayed in an infinite loop with a specific interval. There is no restriction for the image type, the code supports all types including GIF, PNG, JPG, and JPEG etc. We have included basic intent images like, food, water, eatables (fruits, juices), rest room, TV (entertainment), make a call (either friends or family), emergency (doctor) etc. Each image is displayed in a cyclic loop with a specified interval. This module is implemented by including python packages such as tkinter, glob, itertools, pil and so on to get the desired image slideshow.

4.2 Face and Eye Detection

A. Haar Cascade Classifier algorithm

OpenCV contains many pre-trained classifiers for detecting face, eyes, nose and other facial features. Firstly, we need to load the required XML classifier. Then load the input image or video in gray-scale mode. Here, captured images or video frames should be converted to gray scale because haar cascade classifier works with only gray-scale mode.

B. Facial Landmarks Indexes

The facial landmark detector is implemented inside dlib python library, which produces 68 (x, y) coordinates which are mapped to a specific facial feature. After successfully detecting face images from the captured video frames, these coordinate points are used to extract region of interest (ROI).

C. Feature Extraction (Eyes)

In the proposed method the region of interest after successfully detecting face, is eye region. The 68 facial coordinate points indicate face region, among these coordinates the coordinate points numbered from 37-42 indicate left eye and 43-48 indicate right eye. For detection of eyes we need to load XML pre-trained classifier. These classifiers are used to extract eye region from the extracted facial features.

4.3 Eye-Blink Detection

The next module that is implemented in the proposed system after successfully detecting face and eye region, is the Eye-Blink detection. Eye-Blink detection is implemented using Facial landmark algorithm.

A. Facial Landmark Algorithm

Facial landmark is a real time algorithm which is used to detect eye blinks from a video sequence through standard camera. On estimating the facial landmark positions (face and region of interest), the algorithm extracts a single scalar quantity called as eye aspect ratio (EAR). There exists a relation between the height and width of these coordinates [11]. An equation is derived which reflects this relation as depicted below,

$$\mathrm{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

where p1 upto p6 are 2D facial landmark locations.

The numerator of this equation computes the distance between the vertical eye landmarks while the denominator computes the distance between horizontal eye landmarks. The EAR remains constant when an eye is opened and falls to zero when closed, the dip in the eye aspect ratio indicates a blink as shown in the fig 5.

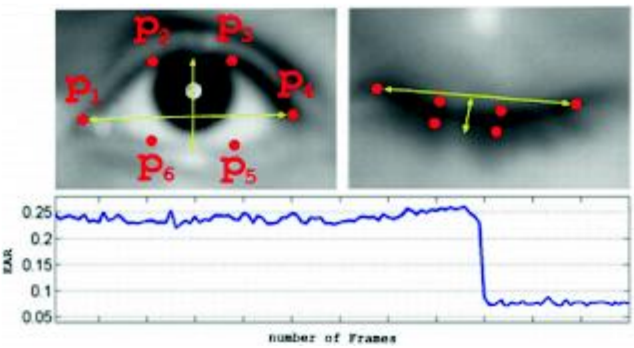

Fig- 5: EAR ratio

Eye-Blink detection is implemented to get the responses from the patients through the selected image from the slideshow, and also is used to confirm the selected input image by providing another blink for yes.jpg image in the slideshow. After confirming the selected input, the image is converted to text and voice message using twilio.

4.4 Text and Voice Messages

This module is implemented using twilio application. Twilio allows users to programmatically make and receive phone calls, send and receive text messages, and perform other communication functions using its web service APIs. Each and every basic need is associated with an appropriate text and voice message so that the concerned person can understand the patient's needs and respond immediately. The proposed system includes voice message as an extra feature so that if the concerned person has not seen the text message, would respond to the voice call immediately.

5. Experiment and Results

5.1 System Deployment

The proposed system should be used with a webcam of 1MP as minimum resolution so as to obtain good quality video frames through the webcam (live video camera). The LCD screen should be mounted on a stand such that, the patient can see the screen and provide the input without much effort. The distance from the screen and the patient should be minimal, so that the system can detect face and eyes properly as it is the major part of the system. The graphical user interface (GUI) of the system is as shown in the fig 6. The required images are displayed on the screen with a delay period of 3 seconds, as per the analysis that we have done, the system consists of all basic fundamental needs of a paralytic patients, few of them are as shown in the fig 7. However depending on the specific needs of the patient, the images can be further on added. Along with the image slideshow there's a screen that indicates eye blink detection, this is included for the experimental purpose for us to analyze whether a blink has happened or not. In the system deployment, this part will be hidden from the user/ patient.

Fig -6: GUI of Proposed System

```
water.jpg
############
0
call.jpg
############
0
food.jpg
############
0
fruits.jpg
############
0
juice.jpg
############
0
physician.png
############
0
restroom.jpg
############
0
snacks.jpg
############
0
tv.jpg
############
0
```

Fig-7: Few of the basic needs included in the system

5.2 Results

The patient's/user's live video is captured through the webcam from which the frames containing face and eyes are detected. The detected images/frames are converted to gray scale. From these converted frames an eye blink is detected. Simultaneously, images (basic needs) will be displayed on the screen for the user/patient to convey his/her needs by an eye blink.

Whenever a blink happens or is detected, the value zero in the above fig. 7 is changed to 1 and that particular image gets selected. The updated value is reflected in the text document named connectection.txt which is used for the connection of eye-blink detection and the image slideshow code.

Upon selecting an image as an input by the patient, it should be confirmed by providing another blink. For the confirmation, an image called yes.jpg as shown in the below Fig-8 which is included at the end of the image slideshow. Further, the confirmed input will be conveyed to the concerned person. This is done using an application called twilio. For each and every image, a text and voice code is linked. The concerned person's contact number is stored, to which the text and voice responses are sent by a twilio number as shown in the fig 9.

Fig -8: Confirmation Image

Fig-9: Output of Proposed System

6. CONCLUSION

The proposed system 'An Image Based Eye-Blink Assistive System for Paralyzed Patients' addresses the challenges faced by patients suffering from MND and LIS neuron diseases. This system is intended to assist the paralyzed and physically challenged to lead a normal life by controlling things and communicating their needs with less effort in an effective and efficient way. The proposed system makes use of simple and efficient methods like Image processing and algorithm of machine learning and twilio application through which the patient can convey his/her needs accurately and efficiently. The system has many advantages when compared to the existing methods such as cost effective, precise results, user friendly, non-invasive device, and also faster in conveying the responses. The above-mentioned features contribute a greater accuracy rate in conveying the selected need to the concerned person precisely. The system is flexible such that it can deployed at any location like hospitals, or even at personal places helping the patient/user to lead a normal life without any external human assistance.

7. FUTURE WORK

The objective of the proposed system has been achieved pertaining to the scope constraint, quality constraint and monetary constraint applied in accordance with the defined functionality of the system. The positive features of the proposed system such as flexibility, cost effective, user friendly etc. help the patients to convey their needs to the caretaker either at hospital or at personal places like home.

Features that are not included in the system can be considered as future enhancements. Currently, the system helps the paralyzed patients to satisfy their basic needs indirectly through the caretaker.

As a future enhancement to this system, home automation control system and virtual keypad can be included where in the patients can directly control home appliances without depending on the caretaker and using virtual keypad they also can involve in textual communication.

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