**International Journal of Innovative Research in Engineering**
*Volume 4, Issue 1 (January-February 2023), PP: 151-154.*
*www.theijire.com* **ISSN No: 2582-8746**

# Facial Movement Based Robotic Arm Control Using Arduino and Python

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**How to cite this paper:**
Dr.S.Ramesh[1], Mohammed Al Fahad[2], Prem Prakash S[3], Kavinraj V[4], Deepa V[5], "Facial Movement Based Robotic Arm Control Using Arduino and Python", IJIRE-V4I01-151-154.



***Abstract:*** *Physically disabled people such as People with severe speech and motor impairment (SSMI)are an important part of our society who has not yet received the same opportunities of inclusion as others in the Society Therefore, it is necessary to develop easily accessible systems to achieve their inclusion within the new technologies. So, we aimed to automate the eye tracking process electronically by using commercially available tablet, computer, or laptop without requiring any dedicated hardware for eye gaze tracking and thereby using the data obtained to control a robotic arm which allows a user with SSMI to manipulate physical objects.*

***Key Word:*** *Severe Speech and Motor Impairment (SSMI); Eye Gaze Tracking; Robotic Arm.*

## I.INTRODUCTION

This paper presents a non-invasive eye gaze controlled robotic manipulator for people with severe motor impairment (SSMI). We have developed a video see through eye gaze-controlled interface and a web cam-based gaze estimation software and then combined them into a single system where users with SSMI can control a robotic arm using only a webcam. We followed a user centered design process and all three modules (eye gaze-controlled robot interface, webcam-based gaze estimator and webcam-based robot control system) were separately evaluated with end users. Eye tracking is the process of measuring either the point of gaze where one is looking or the motion of an eye relative to the head. Eye tracking is traditionally used for analyzing visual perception, eye gaze movement [Ducholowski, et al., 2018] and making visual perception models [Biswas, et al., 2009]. In recent times, eye gaze has also been used to directly control a graphical user interface. Eye gaze-controlled interfaces have been used for people with SSMI, who cannot use existing computer peripherals like mice, touchpads, or keyboards as they are not capable of using their muscles voluntarily. This causes their muscles to continuously contract leading to stiffness and tightening which interferes in normal movement and speech. The main reason for spasticity is damage to the portion of brain or spinal cord that controls voluntary movements. Such disabilities can be caused by birth (a defect in the neural or information processing system), or by an accidental injury. People with SSMI often uses a technique called eye pointing to communicate with outside world. One of their parents, caretakers or teachers hold a printed board in front of them and by analyzing their eye gaze manually, their intentions are interpreted as shown in figure 1. This technique is often error prone and time consuming and depends on a single caretaker. We have tried to automate this process electronically by using commercially available tablet, computer or laptop and without requiring any dedicated hardware for eye gaze tracking.

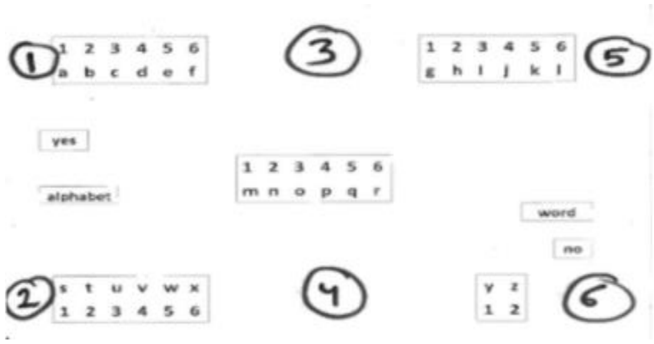


*Figure 1: Non-electronic eye pointing chart*

## II.LITERATURE REVIEW

There is a wide variety of published research for cost-effective, low-resolution webcam-based eye tracking solutions. Many webcam-based systems initially detect face using standard Open CV library [Viola, et.al., 2001] and then based on the relative position of pupil within the standard geometry of eyes estimate gaze position. However, none of these web cam-based trackers are evaluated as extensively as commercial infra-red based gaze trackers. [Khonglah, et.al., 2015] reported an eye gaze tracker that used Viola-Jones [2001] detector to detect face and a blob detection algorithm to detect glint from the pupil. However, the system was tested using a heat map on interfaces having only two targets. [Cristanti, et.al., 2017] proposed an eye gaze-controlled Android system for people with SSMI using Haar Cascade for eye detection. However, the paper did not report any evaluation on pointing and selection times for users with SSMI and accuracy was only measured in terms of eye detection. [Cuong's, et.al., 2014] system did not detect face, rather directly detected eyes and tested for only five positions (Right, Left, Straight, Up and Down) on screen. [Sewell, et.al., 2010] used a feed-forward two-layers neural network to estimate gaze vectors from the images of eyes but already reported problem in extrapolation about training the network while detecting eye gaze for one of 50 random points on screen. [Papoutsaki, er.al., 2017] proposed the Search Gazer system that extends web gazer system with a regression model that maps eye features to gaze locations and search page elements during user interactions and circular hough transform was used to track the iris movement at real time under varying lighting conditions.

## III. EXSISTING SYSTEM

There are also a few commercial webcam-based gaze trackers, but they are mainly advertised for recoding browsing behaviour of web users. [Papoutsaki, er.al., 2017] proposed the Search Gazer system that extends web gazer system with a regression model that maps eye features to gaze locations and search page elements during user interactions and circular Hough transform was used to track the iris movement at real time under varying lighting conditions. [Cristina, et.al., 2014] suggested to detect iris from low resolution images of eye by its intensity values instead of shape followed by Kalman filters to get a smooth trajectory of cursor. [Lin, et.al., 2013] designed an approach to negate the influence of variance in lightning conditions for correctly detecting eyes. Geometrical features were used to locate the eyes correctly. The system used SVM to classify the eye images to get the gaze points at one of the 9 gaze locations. [Kim, et.al., 2015] designed a wearable system which used Emotiv Epoc EEG recording headset along with custom-built eye tracker. The pupil center was assumed to be an ellipse and was estimated from the binarized image. RANSAC algorithm was used to remove outliers from extracted points. Furthermore, the system interpolated gaze point using second order polynomial. Eye movement was mapped to cursor movement and Brain Computer Interface (BCI) was used for selection task. The system was evaluated with four different interface protocols using Fitts' Law task with 9 able-bodied users. [Agrawal, et.al., 2019] reported an eye gaze-controlled application using viola-jones type landmark detector and a user study with able bodied users can select one of nine targets in a screen within 2.6 secs on average. There is not much reported work on using webcam-based eye gaze-controlled interface for users with SSMI.

## IV.PROPOSED SYSTEM

The proposed setup consists of a robotic arm, an eye tracker and a processing unit with a video see through display, which was implemented using a computer. The robotic arm is made from a standard, off the shelf robotics kit. It consists of multiple linkages forming a simple chain. It has 6 degrees of freedom, controlled by servo motors placed at the base, elbow, wrist and arm joints of the robot. Another servo motor is used to actuate the clamper mechanism at the front of the robotic arm. These servo motors are controlled by an Arduino. Information from the algorithm processed by the python program is sent to the microcontroller via serial communication through USB port of the computer. The user interface for robotic control was transparent and overlaid on top of the live camera feed. An eye tracker was placed at the bottom of the screen. The distance between the computer and the robotic arm and camera viewing angle can be changed to accommodate both sources and destinations in the field of view of the camera. In our setup, the computer was 1 foot away from the arm. We used low-cost web camera mounted as the eye tracker and took the gaze coordinates from the tracker and feed them into our own algorithms, to smoothen and process gaze data. Our algorithm records gaze coordinates at 60 Hz and uses a median filter and Bezier curve to smoothly move a cursor based on eye gaze movement. During interaction, a red dot on the screen indicates the location of the user's eye at any given instant. The overall step by step working of the system is given as a block diagram as shown in the figure 2. As our program uses only open-source libraries such as OpenCV, Dlib and other basic generic software and hardware it can be implemented is system that supports python and has at least 512 MB RAM.

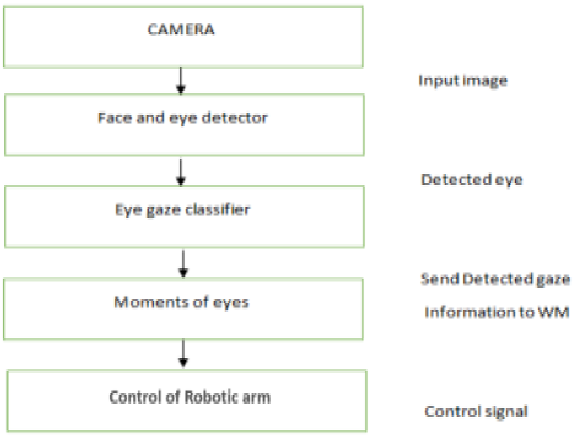


*Figure 2: Block diagram of proposed system*

## V.RESULTS AND DISCUSSION

Our work aims to help in the rehabilitation process of users with SSMI through use of cyber physical systems. We selected a particular task of fabric printing, which is currently undertaken by such users in a spastic society with the help of a caretaker. We developed and evaluated a proof of concept (PoC) eye gaze controlled robotic arm using low cost commercially off the shelf components. Any user with motor impairment could use the system without assistance for two pick and drop tasks and the time duration, although higher than their able-bodied counterpart, but was not significantly different than able-bodied users. We investigated the reach ability of the robotic arm at a random position within the field of reach of the robot and we could reach the designated target within one minute in second session. We noted that users can change the direction a greater number of times to reach target faster, which indicates selecting the same key multiple times by dwelling on the key was slower compared to selecting a different key. Future work will consider adapting the amplitude of movement based on users' previous interaction history, for example when a same key is chosen multiple times, we can progressively increase amplitude to reduce number of selections. Users with SSMI may also require instructions in their native language and dialect while undertaking the task and which may also contributed to slower interaction speed. We also investigating different velocity and acceleration profiles in the kinematics equations. Finally, it may be noted that our users used this system for first time, and we can add more screen elements for point-to-point movement, for example, we can use eight-way control instead of four-way control to increase interaction speed further.

## VI.CONCLUSION AND FUTURE SCOPE

This paper presents an eye gaze controlled robotic arm to help in the rehabilitation process of users with severe speech and motor impairment. Initially, we compared different algorithms to estimate eye gaze from webcam and compared their performance through user studies. Using the Open CV based intelligent eye gaze tracking system, users with SSMI can select one of nine regions of screen in 3 secs on average. We developed new algorithm to control a video see through graphical user interface (GUI) with eye gaze, use the GUI to control a robotic arm and kinematics equations to smoothen the arm movement for pick and drop task. Any user can undertake the designated task twice in first attempt in an average time less than 15 secs and can also bring the robotic arm to any random position within its field of reach in less than 60 secs. Finally, we evaluated the whole system involving the webcam-based eye gaze tracker and video see through human robot interface and we were able to bring the robotic arm at a pre-designated point within its working envelop in 2 mins on average. The also performance improved while we undertook the task second or third time than the first time. Our Future work is improving the robotic control algorithm to further reduce task completion times for representative object manipulation tasks and to design a gripper for the robotic arm for undertaking the fabric painting task and deploy the system with the same user interface. We have integrated the gaze-controlled video see through display with a robotic arm with higher payload and a short clip can be found at the supplementary material. It may also be noted that the gaze controlled see through interface can be used for other cyber physical systems like robotic wheelchair, UAV or UGV besides the robotic arm. In parallel we are working on increasing the accuracy of the webcam-based gaze tracker and creating a dataset involving users with SSMI.

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