

Innovative Solutions for Independence: A Synthesis of Recent Advances in Smart Assistive Technologies for Quadriplegics

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Abstract—Quadriplegia, also known as tetraplegia, is a paralysis that affects both limbs and the whole body from the neck down. Sometimes it is curable, although in most cases, injury causes permanent paralysis. It's a severe neurodegenerative disease where a person's muscles cannot be deliberately controlled or moved with the progression of the disease. Hence, these patients need personal assistance and attention to carry out their day-to-day activities. Living with quadriplegia is pricey as it needs the deployment of a permanent attendant or assistive devices. This has also been evident that the ocular muscles remain intact for a quadriplegia patient, and it is hardly affected with the progression of the disease. The current study discusses the design and development of an eye movement controlled interactive user-interface for patients suffering from quadriplegia where a person has zero physical movements. The developed system allows the detection of face followed by detection of eyeball using a camera. The user-interface screen has customized menus available as "Hungry", "Thirsty", "Light Off/On", "Fan Off/On", and "Emergency Assistance" to be chosen using eye movement and voluntary blink. The commands were generated in accordance with the intended eye movements and voluntary blinks. 20 volunteers participated in the study to validate the efficiency of the system. The overall efficiency of the system was found to be 91.25 %. The proposed low-cost system is safe, portable, user friendly and can be effectively used by quadriplegics to enhance their quality of life.

Index Terms— Quadriplegia, Smart assistive systems, User-interface, personal care assistance, python.

I. INTRODUCTION

All four limbs become paralyzed in Quadriplegia, a medical condition that severely reduces a person's independence and quality of life. It is still difficult to meet quadriplegic demands despite innovations in rehabilitation and treatment. Potential options for increasing functionality, independence, and general well-being are provided by smart assistive devices [1].

Smart assistive systems use modern innovations such as eye tracking and human-computer interaction to help quadriplegics with movement, communication, personal hygiene, and control over their surroundings. Vital signs are tracked by wearable sensors, and powered help for daily duties is provided by robotic exoskeletons. Real interaction and connection are made possible via voice-controlled interfaces and neuroprosthetic implants, which

help to close the gap between user motivation and action. Patients can move their eyes to pick different parameters on screens [2].

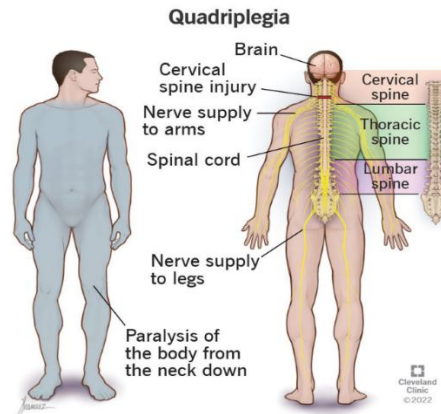


Fig 1:Quadriplegia

For people with quadriplegia, this Smart Assistive System is an innovative way that can enhance their independence and quality of life. Nurses and patient care staff members, who are unable to give care around-the-clock, have less work to do due to this creative approach. By supporting independence, confidentiality, and dignity, the system empowers people with paraplegia to take charge of their life and engage actively in society.

II. LITERATURE REVIEW

This study, which is based on electrooculography (EOG), was suggested for use with electric wheelchairs meant for those with quadriplegia or quadriparesis. The device records electrooculogram signals—a reflection of eye movements—using electrodes. These signals are processed by an Arduino microcontroller, which makes the distinction between up and down motion, left and right eye movements, and blinking. The wheelchair's control commands enable users to propel the wheelchair forward, backward, left, or right and stop it depending on detected movement and blinks. The researchers stress how wireless, portable, and user-friendly their concept is. Moreover, they state that they can operate the wheelchair with EOG signals with an average accuracy of 90%, suggesting that this control method would be a good alternative for people who have severe mobility limitations [3].

III. METHODOLOGY

A. Eye Tracking Methodology

Face Mesh and Important libraries

Patients who are quadriplegic have the aim of feel less reliant on others as a result of the system. It tracks eye movements and sends out real-time alerts using laptop vision. Face Mesh, a machine learning model created by the media pipe team, is used by the system to extract face landmarks. It is capable of detecting 486 landmarks in real-time live video streams.

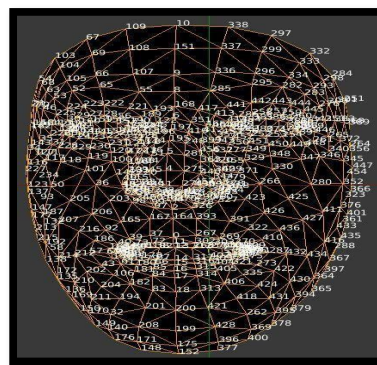


Figure 2 : All facial landmarks

The code makes use of a number of Python libraries, such as Media Pipe for media processing [4], OpenCV for computer vision [5], pyautogui for popup message generation, Time for time functions, and the assembly library for execution. Together, these libraries can process pictures and videos, identify the parts of the face, produce pop-up messages, and operate with time functions. The assembly library gives the necessary features to carry out these requirements.

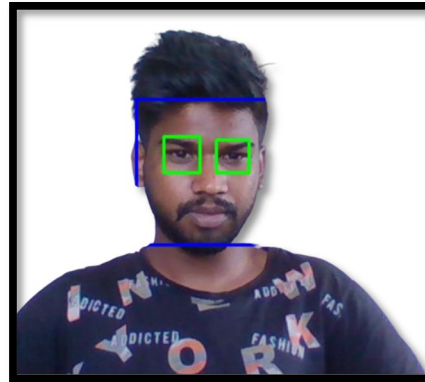


Figure 3 : Eye detection And Face Detection

B. Landmark Detection

Landmarks are used by OpenCV, primarily for facial recognition, to detect and track features of objects or images. These landmarks are locations on an individual's face that identify and monitor facial characteristics such as the mouth, nose, eyes, and jawline. The code uses 16 landmarks for the left eye and 15 for the right eye, including eye corners, eyelids, and iris landmarks, out of the 486 facial landmarks provided by MediaPipe. Because the eyebrow landmarks were eliminated, the landmarks for the left eye were selected. For applications like gaze tracking or eye movement analysis, this enables more accurate data on eye motion and position, which helps the separation of eye movements from general facial movements.

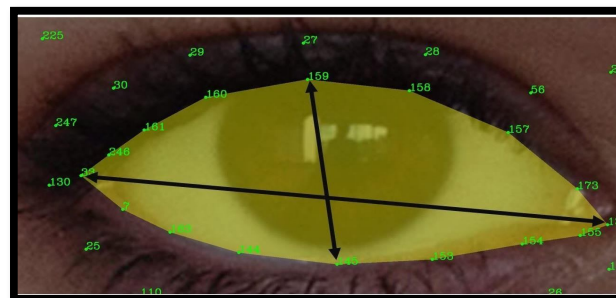


Figure 4 : All eye landmarks of eye region

C. Eye Tracking

Media Pipe's face landmark detection algorithm differentiate between left and right eye landmarks. The "L_Eye" and "R_Eye" arrays have separate postings for each eye, where each element contains the x-y location of a variety of nearby landmarks. It is essential to track eye movement using these markers. In addition, separate arrays marked "left eye" and "right eye" provide a more focused collection of landmarks designed specifically for gaze direction detection. To calculate the horizontal eye location in this case, the landmark coordinates on the left and right are used. It's important to remember that landmarks [33 & 133] are mainly used for iris tracking and gaze recognition, and they relate to the edges of the left eye. After identification, the algorithm determines each eye's minimal enclosing circle, which shows its size and location based on the captured landmarks.

D. Patient Interactive Digital Screen

To provide a visually pleasing display, the online interface of a "Smart Assistive System for Quadriplegia" makes utilizes CSS styles and HTML. Interactive parameters are shown in a grid-based arrangement, with each parameter having a defined size and location. Interactions like clicking a parameter, starting a timer, and alerting the user are managed via JavaScript functions. Quadriplegics are able to interact with each other and operate

their gadgets due to the system's speed and timing feature, which ensures an engaging and dynamic user experience.

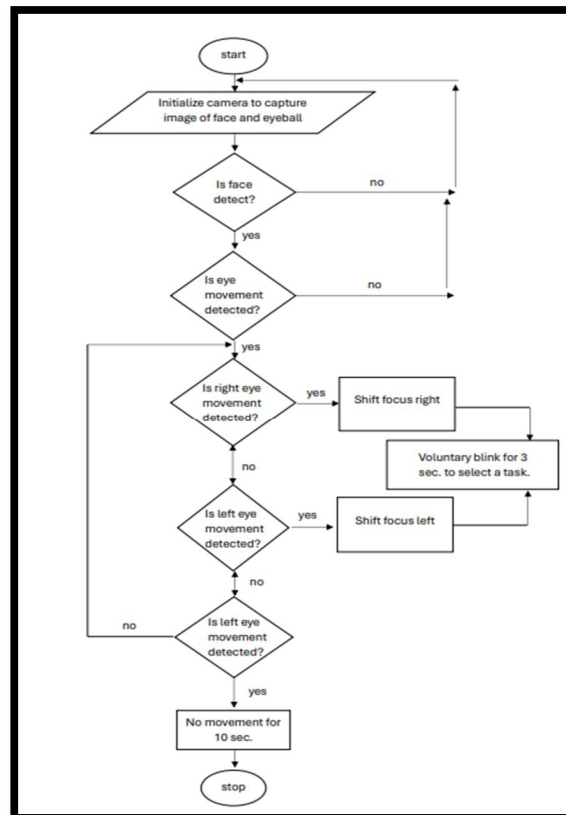


Figure 5 : Real time eye tracking using landmark



Fig. 6 Patient Interactive User Interface

Flowchart



Result

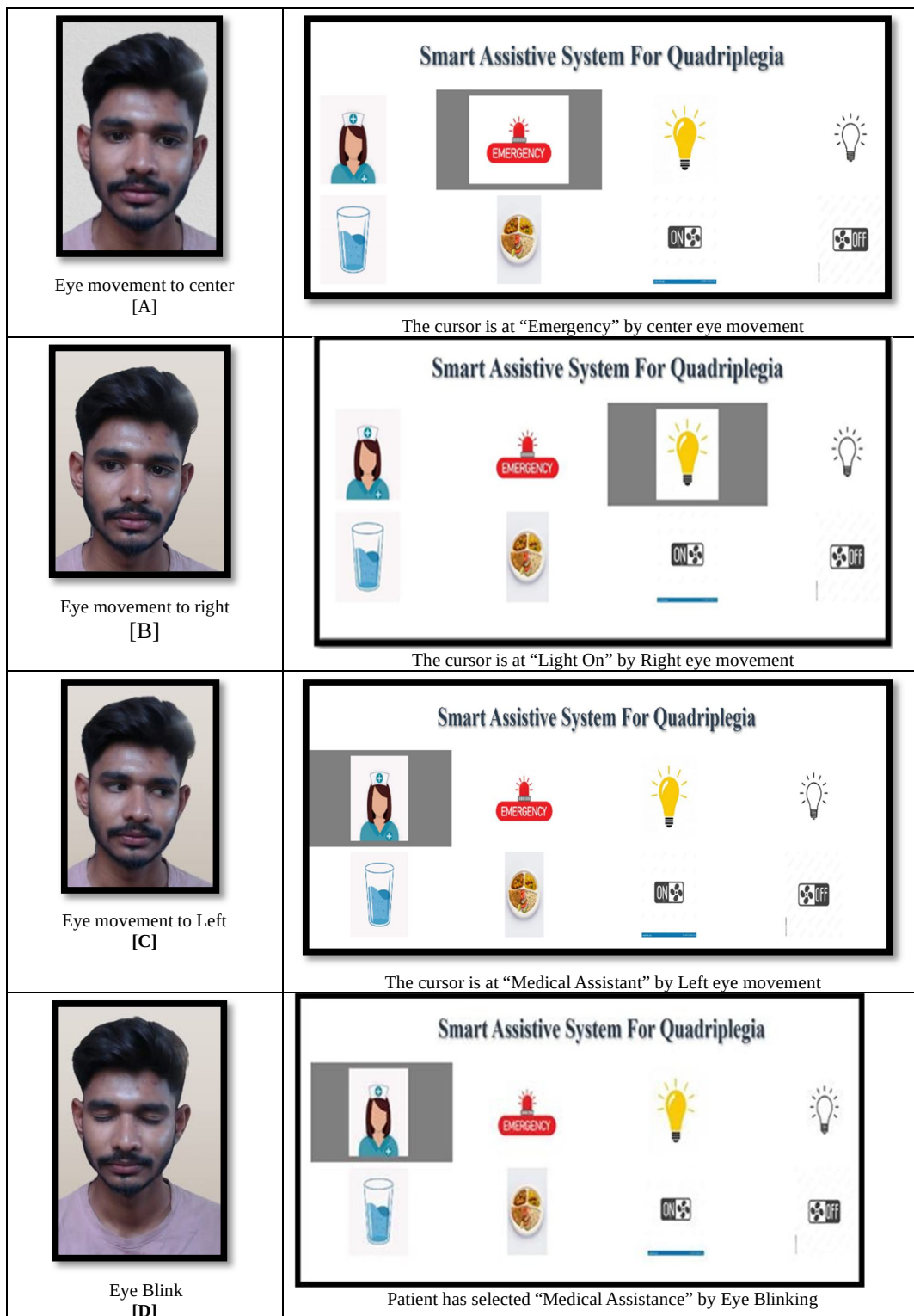


Fig. 9 Real time Eye ball movement detection and navigation

At the onset of the procedure the face was detected followed by the detection of the eye by default the eye was at the centre position, the emergency menu in the user interface was selected in Fig 9(A). The volunteer was advised

to select “Light on” by right eye movement, the same has been shown in Fig 9(B). Fig 9(C) denotes the selection of medical assistance menu through left eye movements (2 times). The voluntary blink of minimum 3sec enable the user interface to select and activate the medical assistance menu in the user interface in Fig 9(D).

Performance Evaluation of the Proposed Assistive System

No. of Volunteer	Select “Medical Assistance”	Select “Water”	Select “Light on”	Select “Light off”
V-1	✓	x	✓	✓
V-2	✓	✓	✓	✓
V-3	x	✓	✓	✓
V-4	✓	✓	✓	x
V-5	✓	x	✓	✓
V-6	✓	✓	✓	✓
V-7	✓	✓	✓	✓
V-8	✓	✓	✓	✓
V-9	✓	x	✓	✓
V-10	✓	✓	✓	✓
V-11	✓	✓	✓	✓
V-12	✓	✓	✓	✓
V-13	✓	✓	x	✓
V-14	x	✓	✓	✓
V-15	✓	✓	✓	✓
V-16	✓	✓	✓	✓
V-17	✓	✓	✓	✓
V-18	✓	✓	✓	✓
V-19	✓	✓	✓	✓
V-20	✓	✓	✓	✓
Correctness of the system (in percentage)	18/20 = 90%	17/20 = 85%	19/20 = 95%	19/20 = 95%
Overall Efficiency of the system	= 91.25%			

The system was evaluated by a group of 20 individuals. All participants were trained and educated about system and were also provided with proper demonstration and handling by core project members. The system obtained an overall accuracy of 91.25%, representing a high degree of efficiency in assisting the requirements of the patients. 2 of the volunteers fail to activate the “medical assistance” menu because of lack of judgement during

eye movement. 3 of the volunteers fail to active “need water” menu as they tried down eye movement to select this menu instead of left/right eye movement (Volunteer-5). Volunteer-1 and Volunteer-9 made insignificant eye movements. Hence they failed to select the “need water” menu. Volunteer-13 and Volunteer-4 failed to activate it “Light on”, “Light off” menu accordingly because of inappropriate eye movements. These results show a stable and effective system that performs well in all tested areas and can properly perform the majority of patient’s needs.

IV. DISCUSSION

Quadriplegia affects independence and quality of life in addition to affecting all four limbs. Wearable sensors, robotics, artificial intelligence, and human-computer interaction are examples of smart assistive devices that can enhance well-being, functionality, and independence. But issues like affordability, usability, and consumer acceptance need to be resolved. In order to enhance the quality of life for quadriplegics, this project aims to identify current solutions, barriers, and potential areas for future study and development.

V. CONCLUSION

We have successfully designed and created a low-cost, eye-movement for quadriplegics. The system uses a camera that recognizes the patient's face and eyeballs, allowing them to communicate with an unique screen through voluntary blinks and particular eye movements. This patient interactive digital board includes basic settings for vital demands like hunger, thirst, and normal adjustments, as well as an emergency assistance option. Validation with 20 volunteers showed a promising overall efficiency of 91.25%. This project displays the possibility and usefulness of an eye-tracking interface as a safe, movable, and simple to use solution to improve the quality of life for quadriplegics by giving them more control over their environment and providing their requirements.

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