Grenze International Journal of Engineering and Technology, June Issue

Mobility Assistance for Amyotrophic Lateral Sclerosis Patients using Eye Gaze Tracking

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***Abstract*—This paper introduces the design and development of an advanced eye-gaze tracking system that enables Amyotrophic lateral sclerosis (ALS) patients to control a smart wheelchair using their eye movements. Amyotrophic Lateral Sclerosis (ALS), also known as Lou Gehrig's disease, is a progressive neurodegenerative condition that affects motor neurons, leading to muscle weakness, loss of mobility, and difficulties with speech, swallowing, and breathing. Predominantly affecting individuals aged 40 to 70, ALS progresses rapidly, causing significant deterioration in quality of life. While most ALS cases are sporadic with unknown causes, 5-10% are familial. The proposed system utilizes a grid-based interface to precisely interpret the user's gaze, enabling seamless wheelchair navigation. Integrated safety features, including emergency stop mechanisms and proximity sensors, enhance obstacle detection and ensure user safety. By segmenting the visible space into actionable regions, the system delivers intuitive and reliable control. Designed with a focus on affordability and ease of use, this solution aims to improve independence and mobility for ALS patients. Early testing reveals that the system is highly responsive, reliable, and practical, representing a meaningful advancement in assistive technologies for neurodegenerative disorders.**

***Index Terms*— Amyotrophic Lateral Sclerosis (ALS), eye-gazetracking system, Affordability, Neurodegenerative condition, Grid-based interface and motor neurons.**

I. INTRODUCTION

Amyotrophic Lateral Sclerosis (ALS) is a neurodegenerative disease that severely affects muscle control, making everyday tasks like walking, eating, and speaking difficult or impossible. As the disease progresses, patients become fully dependent on others, and their quality of life declines. However, there is a growing need for solutions that help ALS patients maintain their independence, dignity, and control. One promising solution is eye-gaze tracking technology, which allows people with limited physical movement to control devices and communicate using only their eye movements. This technology can help ALS patients interact with their environment, perform daily tasks, and regain some independence, greatly improving their quality of life.[1]
The centre aspect of the system will allow users to control the operation of a smart wheelchair through precise eye movements, thereby presenting an effective solution towards mobility challenges caused by ALS.

Grenze ID: 01.GIJET.11.2.14_21
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Such technology can be one of the key breakthrough innovations of assistive solutions which may aid the patients in more accessibly moving and interacting with their surroundings. ALS patients will have the power to move from place to another using only their eyes, an attempt to provide some kind of freedom amongst the loss. We are working for the designing of an effective assistive system with the integration of the latest advanced technologies like machine learning so that such person might be empowered to live more independently, besides interacting more intimately with their environment in accordance with their choices. It contributes to the machine learning technology field while attempting to particularly bridge the significant gap that has always occurred in the care and support services of people suffering from ALS. In this respect, we are attempting to give a new lease on life for the ALS patient by conferring upon him or her some kind of independence, dignity, and control in life through the development and deployment of this eye gaze tracking system.This technology will equip ALS patients to overcome many of the challenges they currently face, offering them greater mobility and access to the world around them. It represents a step toward breaking the limitations of current assistive technologies. The goal is to empower patients to live independently, with autonomy, and to restore hope for a better quality of life[2].

II. PROPOSED SYSTEM

A. Description

ALS is a disease that progressively reduces the human ability to control voluntary movement of muscles, thereby pushing the affected person to complete paralysis. Loss of mobility through a progression of paralysis is one among the most devastating consequences of ALS. Such loss severely constrains patient independence and participation in all acts of life. When the disease advances, even those wheelchairs used in the traditional sense-manual and powered with ability, since ALS patients cannot ultimately harness either the manual or powered devices with either their hands or their feet. Thus, there is a sense of urgency for innovations that can give way to ALS patients the chance to recapture a sense, where they could freely move through their world with minimal bodily exertion.

Then, eye gaze tracking technology would further provide an innovative solution to this problem.The accuracy and responsiveness of the eye-tracking system must be finely tuned to ensure reliable performance, particularly given the potential for fatigue and involuntary eye movements in ALS patients. Additionally, the system must be intuitive and customizable to accommodate the varying degrees of motor impairment and personal preferences of users. As an ability an ALS patient retains well, their ability to control their eye movements -a function which remains intact, unlike other motor functions -can now be translated into devices being able to be controlled, such as a smart wheelchair[3]. The design principle here is straightforward yet elegant: rather than using his or her body, an ALS patient can use eye movements to control wheelchair functions like forward motion, left and right turns, stopping, as well as speed alone lift a finger; this translates the eyes into a control device, giving effortless vehicle navigation. But bringing it to life comes with some big technical and practical hurdles. For the system to be efficient in its eye tracking, it has to be sensitive and fast.Involuntary movements around the eyes in ALS patients make the system sensitive to activation unless the system is properly tuned to provide a response when it is deliberately moved. Such algorithms are bound to filter out noises or unwanted activation from involuntary eye shift while responding rapidly to commands. In addition, the system should adapt to a user's specific needs since the level of motor may vary significantly from one ALS patient to another.

The other important feature when developing this smart wheelchair is creating a user-friendly interface. ALS patients are already burdened with the immense physical and emotional pressure of this disease, so at least that which should not be given to them is a complicated system that increases their anxiety level. The user interface has to be straight forward, simple, clear, and flexible to the need or capability of each patient. A successful design would only make sure that the technology which the patients can comfortably adapt to their environment. Development of this eye gaze tracking-based smart wheelchair requires very thorough examination of several key factors: the technical requirements needed to specify and obtain accurate eye tracking, architecture to allow for smooth operation of the wheelchair, and designing an easy-to-learn-and-use interface. Most practical challenges to being overcome in allowing ALS patients to access the technology successfully would be addressed by these elements.

The purpose of this project is, therefore, to provide an opportunity for the change of mobility offered to ALS patients. It will not reverse the physical degradation that results from ALS but will give back to the patient what the disease slowly takes away: a feeling of control and freedom. Giving patients the opportunity to move around their environment with little or no effort could be of significant improvement to their quality of life. This appeal would permit people to retain enough independence to make their lives a little easier, more satisfying, and full of

more possibilities. This approach will delve into the potential benefitsand limitations of this technology, along with strategies for overcoming practical challenges. The ultimate goal is to provide ALS patients with a viable mobility assistance solution that enhances their independence and improves their quality of life[4].

The objectives of this project are to develop a robust eye gaze tracking system that provides a highly accurate and reliable interface tailored to ALS patients for seamless and precise control of a smart wheelchair. Ensuring safety and reliability is another critical goal, involving the incorporation of advanced safety features such as an emergency stop mechanism, real-time system status monitoring, and fault detection to safeguard users and maintain consistent performance during operation. The system also aims to optimize responsiveness by minimizing delays, which is essential for smooth interaction and for addressing issues like eye fatigue and involuntary movements through efficient real-time processing algorithms. Enhancing user independence is a key focus, enabling ALS patients to navigate their environment with minimal physical effort, thereby improving their autonomy and quality of life. Usability and comfort are also prioritized, ensuring the interface is intuitive, requires minimal training, and is ergonomically designed for extended use, especially considering users with limited mobility[5]. The system includes customizable control features, allowing adjustments in sensitivity, speed, and precision based on individual user needs. Continuous monitoring capabilities are incorporated to enable caregivers or family members to oversee the system remotely, ensuring sustained safety and effectiveness over time. Lastly, the system is designed for compatibility with smart home devices, empowering users to operate household appliances, lighting, and doors through eye gaze, thereby extending the system's utility in everyday life[6].

B. Methodology

The proposed system follows a structured methodology combining both hardware and software elements to achieve accurate eye-gaze-based wheelchair control for ALS patients. The system architecture integrates key components such as a Near-Infrared (IR) camera, a Lidar sensor, a mini-computer (such as a Raspberry Pi), and image processing software like OpenCV. The Near-IR camera is responsible for capturing live video streams of the user's eyes, offering high-resolution and consistent performance across varied lighting conditions. These video feeds are then processed in real time by the mini-computer, which runs specialized computer vision algorithms using OpenCV to detect and track the direction of the user's gaze. The gaze detection algorithm determines where the user is looking and translates that into navigation commands such as moving forward, turning left or right, or stopping the wheelchair.To ensure safe operation, the system integrates a Lidar sensor that continuously scans the environment for obstacles. This data is fused with the gaze detection output to avoid collisions. If an obstacle is detected in the intended direction of movement, the system overrides the user command and stops or redirects the wheelchair to prevent accidents. This combination of gaze control and real-time obstacle detection allows the wheelchair to operate safely while responding intuitively to the user's intentions. The decision-making module passes validated commands to a control unit that interprets the instructions and generates motor control signals. These signals regulate movement parameters such as direction and speed. A motor driver unit then actuates the wheelchair's motors accordingly. A power management unit ensures consistent and efficient energy distribution to all components, including the camera, sensors, mini-computer, and motors, while monitoring battery levels for uninterrupted performance.

To ensure usability, the system features a simple and intuitive user interface that requires minimal training and is customizable to the user's needs. This interface considers the unique motor limitations of each ALS patient, offering adjustable sensitivity settings to minimize the impact of involuntary eye movements and fatigue. Additionally, the system includes support for smart home integration, enabling users to control devices such as lights and doors using their gaze. The entire methodology focuses on empowering ALS patients by offering a highly responsive, safe, and user-friendly mobility solution that enhances their independence and quality of life.The system uses several key components as depicted in Fig 1.It includes a Near-IR camera, Lidar, a mini-computer like a Raspberry Pi, and OpenCV for processing images and tracking where the user's pupil. The process starts with the Near-IR camera, which captures a live video stream of the user's eyes. This type of camera is ideal for tracking eye movements because it works well in different lighting conditions and can take detailed images of the eyes. The camera's main job is to figure out where the user is looking, and that information is used to control the wheelchair. Essentially, wherever the user looks, the wheelchair will go. The video captured by the Near-IR camera is then processed by the mini-computer using OpenCV, which is software specialized in image processing. The mini-computer acts as the control center for the system, running algorithms that analyze the user's gaze direction. Based on where the user is looking, it determines whether the wheelchair should move forward, turn, or stop. OpenCV is used for processing the images of the user's eyes and detecting the direction of their gaze as shown in Fig 2. The algorithms translate this eye movement into commands that

control the wheelchair. So, by simply looking in a certain direction, the user can instruct the wheelchair to move that way, all without needing to use their hands [7].

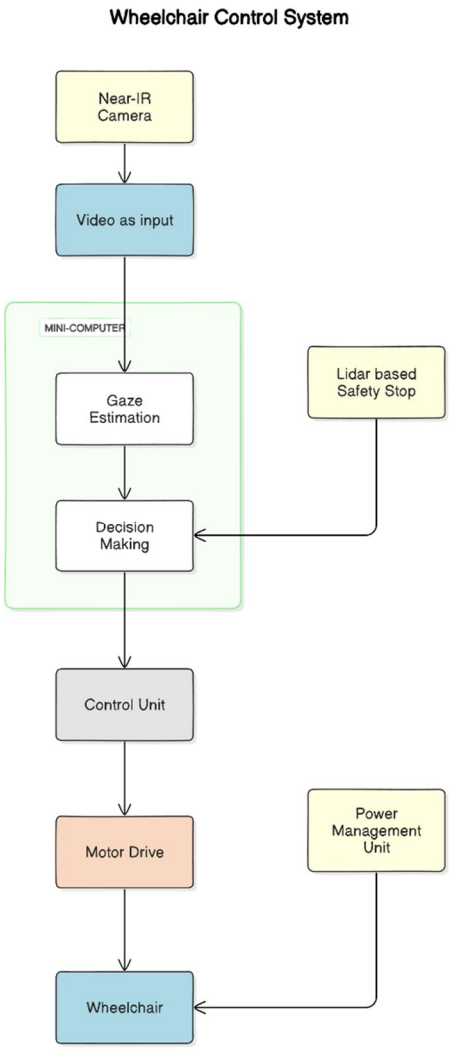

Figure 1. Flow of the eye gaze tracking system

Once the system has determined the user's desired direction, it doesn't stop there. The decision-making takes this gaze information and combines it with data from the Lidar sensor to ensure the wheelchair can move safely. Lidar works like the eyes of the wheelchair, scanning the area around it to detect obstacles. It continuously measures distances to make sure there's nothing in the way. If the Lidar detects an obstacle, it overrides the user's gaze command to prevent a collision. For example, if the user tries to move forward but there's something blocking the path, the system will stop the wheelchair or change direction to avoid the obstacle. In essence, this smart wheelchair system blends the user's eye movements with real-time safety checks from the Lidar sensor. This ensures that the wheelchair moves exactly where the user wants while also keeping them safe from obstacles in their path, offering both freedom of movement and peace of mind.

The control unit interprets the instructions given from the decision-making module into signals that fire up the motors of the wheelchair. Control includes the signals such as; speed or directional adjustments and safety overrides, all based on user eye gaze input. The motor drive receives the signals emitted by the control unit and energizes the motors, which help move the wheelchair. It modifies the parameters of movement, such as speed and direction, to ensure smooth operation. Wheelchair - final product of what the control system produces; it carries out the commands processed through all the previous parts, including real movements compatible with the user's will and environmental safety parameters. Power Management Unit controls the distribution of

electrical power to various components in the wheelchair, such as the minicomputer, sensors, and motors. Oversees economical usage of power, regulated voltage, and battery life monitoring to keep the performance reliable. The Wheelchair Control System integrates multiple advanced technologies to create a mobility aid device that is both user-centered and safe. By incorporating gaze estimation along with Lidar-based obstacle recognition, it allows intuitive and responsive control. This would be particularly useful for people with limited physical abilities but who could control their gaze, thus giving them greater independence in locomotion[4].

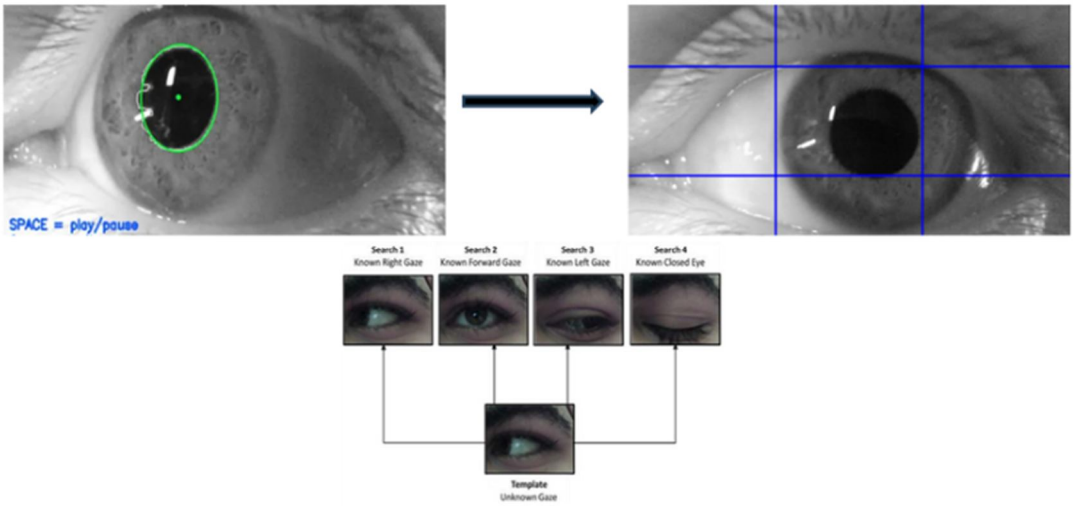

Figure 2. Application of algorithm on user's eye

III. CONCLUSIONS

Eye-gaze-controlled wheelchairs are transforming the lives of ALS patients, giving them the independence to manage daily tasks and connect with others without constantly relying on caregivers. Built-in features like proximity sensors ensure safe navigation, while affordability makes them accessible to more people. These technologies not only restore a sense of freedom but also bring comfort and confidence to patients and their families. As assistive technology advances, it offers hope for an even better future for those facing mobility challenges[10].

The system offers increased independence for ALS patients by enabling them to control their mobility through precise eye gaze tracking, thereby reducing their reliance on caregivers for movement. This enhanced mobility significantly improves their quality of life, allowing for more active participation in daily activities and social interactions. The integration of advanced technologies, such as proximity sensors, ensures safe navigation by automatically detecting and avoiding obstacles, minimizing the risk of accidents. Furthermore, by leveraging affordable and accessible technologies, the system provides a cost-effective alternative to traditional assistive devices, making it more widely available and accessible to patients.

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