

Eyes in Motion: Utilizing Eye Tracking for Assistive Technology

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Abstract—Millions of people worldwide suffer from mobility impairments due to conditions such as Cerebral Palsy (CP), Spinal Cord Injuries (SCI), and quadriplegia, significantly impacting their independence and ability to perform daily tasks. Despite advancements in assistive technology, access remains limited due to its cost. My research explores cost-efficient eye-tracking solutions to provide intuitive robotic control for individuals with severe disabilities. Specifically, I developed a prototype system that enables gaze-based interaction with a robot, establishing a foundation for further advancements in accessibility-focused robotics. My process involved iteratively refining eye-tracking algorithms, improving communication between devices, and addressing real-world challenges in hardware and software integration.

I. INTRODUCTION

Approximately 12.2% of Americans experience mobility disabilities, often requiring lifelong assistance [1]. Many assistive technologies, like joystick-controlled wheelchairs or voice-command systems, pose limitations for individuals with limited dexterity. Eye-tracking offers a non-invasive and efficient alternative for control mechanisms, enabling interaction without reliance on external limb movement. My research aims to investigate how gaze detection can be utilized to control robotic devices, ultimately enhancing mobility solutions for these individuals.

II. METHODOLOGY

To ensure a low-cost approach to eye tracking, I used a laptop webcam instead of costly commercial eye-tracking hardware. My initial focus was on understanding existing assistive technologies and reviewing literature on eye-tracking implementations in robotics. After this foundational research, I began by developing a facial landmark detection system using the dlib library, concentrating specifically on identifying a user's eyes. Over several weeks, I refined my approach by implementing image-masking and segmentation techniques to improve eye detection accuracy.

To identify a user's gaze direction, I utilized a crosshair overlay method, which allowed me to calculate gaze direction based on pixel density in various quadrants. I then developed a pixel-based system to determine gaze direction and detect blinks, which I used as an interaction trigger. This was iteratively improved by adjusting threshold values and optimizing the system to reduce the need for exaggerated eye movements.



Fig. 1. First attempt at image segmentation and preprocessing

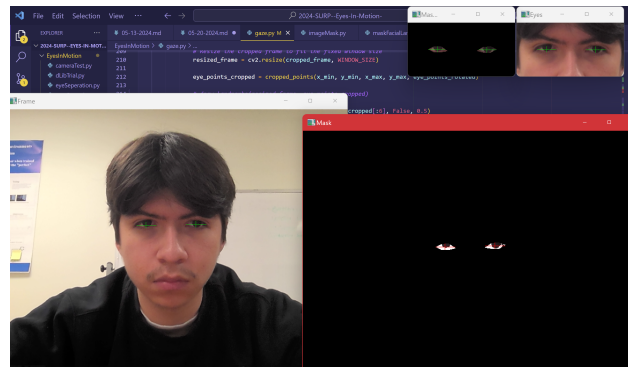


Fig. 2. Finalized Image segmentation and masking

Next, to enable real-time robotic control, I implemented a Remote Procedure Call (RPC) system for communication between my eye-tracking software and the NVIDIA JetBot, which is powered by the Jetson Nano platform. This involved setting up an SSH connection, configuring the Jetson Nano to run Python scripts remotely, and troubleshooting connectivity issues. I also worked on setting up Wi-Fi on the Jetson Nano, resolving repository errors due to incorrect system time, and installing necessary firmware updates to ensure compatibility.

III. RESULTS

I successfully developed an eye-tracking script capable of detecting gaze direction with a high degree of accuracy. This software enabled real-time communication with the JetBot, laying the groundwork for gaze-based robotic control. However, I encountered hardware challenges, particularly with motor connections, due to incorrect cabling. These issues prevented full robot mobility, but the system's software components were fully integrated and functional.

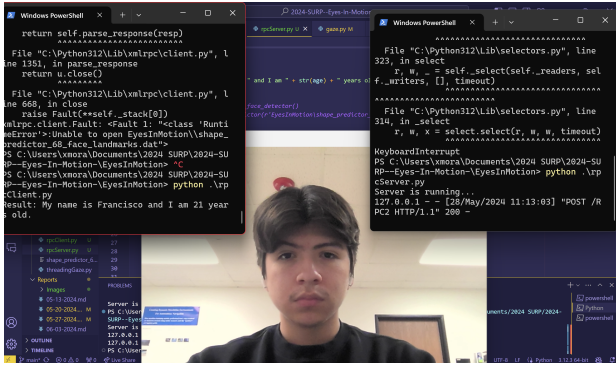


Fig. 3. SSH Connection and Communication between Jetson Nano and laptop

IV. FUTURE WORK

Moving forward, I plan to continue this research throughout the semester and summer, focusing on integrating a Neural Network-based gaze estimator. Leveraging deep learning techniques, I aim to improve the accuracy and robustness of gaze estimation, reducing reliance on traditional computer vision methods. This involves training a convolutional neural network (CNN) on diverse datasets to enhance generalization across users and lighting conditions.

To ensure accessibility, I will develop a user-friendly interface that allows users to customize control settings without programming knowledge. This will include intuitive calibration tools and adaptive settings to accommodate different user needs. Additionally, usability testing with individuals who have mobility impairments will provide valuable feedback, guiding iterative improvements.

My long-term objective is to transition this research into a deployable product by collaborating with rehabilitation centers and assistive technology providers. This will ensure that the technology effectively improves independence and quality of life for those with severe disabilities.

V. CONCLUSION

This research demonstrates the feasibility of using low-cost eye-tracking systems for assistive technology applications. By leveraging computer vision techniques and real-time communication protocols, I developed an accessible and scalable prototype that holds promise for future advancements in mobility assistance. Continued refinement of this technology will contribute to developing an intuitive and inclusive assistive technology ecosystem, with potential applications extending beyond robotics into broader accessibility solutions.

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