# Mobile Robot Motion and Direction Control Through AI Driven Prediction of Face Orientation

*Abstract*—**Mobility limitations significantly impact the independence of individuals with physical disabilities, necessitating the development of advanced assistive technologies. Mobility assistance is essential for physically challenged people such as accident survivors and patients with spinal cord injury (SCI) or heart disease. This paper introduces an AI-driven mobile robot motion control system that integrates multiple control methods, including face orientation, voice commands, and wireless inputs, to enhance accessibility and ease of use. The system enables users to navigate the robot intuitively, reducing reliance on conventional input devices. Additionally, a remote control web interface feature allows other users to monitor and operate the system when necessary. By incorporating intelligent motion control techniques, this research aims to improve mobility, autonomy, and overall quality of life for individuals with physical impairments.**

*Index Terms*—**Direction Control, Mobile Robot, Face Orientation, Head-Motion, Image Processing, Remote Monitoring.**

## I. Introduction

People with disabilities experience many difficulties while interacting with systems, applications, or devices [1]. People aging with mobility disability face transportation difficulties, which can hinder their participation in society [2]. One of the difficulties that stroke or spinal cord injury (SCI) survivors encounter is mobility [3]. Additionally, physical and functional losses due to aging and diseases decrease human mobility, independence, and quality of life [4]. Individuals with mobility impairments may require assistive solutions to independently perform specific daily tasks [5]. However, not all assistive technologies can help mobility-challenged people to move freely. A manually operated device, however, lacks both comfort and maneuverability for individuals with physical disabilities [6]. Electric-powered mobility solutions were designed to reduce physical exertion and enhance user maneuverability [7]. Assistive technologies, especially mobile robots, can help impaired users to navigate safely and quickly among obstacles and other hazards [8].

Mobile robots have contributed substantially to the welfare of modern society over the years [9]. These robots are becoming increasingly influential in advanced applications, given their potential for autonomous intervention [10]. Providing mobile robots with autonomous capabilities is advantageous as it allows one to dispense with the intervention of human operators, which may prove beneficial in economic and safety terms [11]. Mobile robots have been implemented in many applications like medical treatment, security, pattern recognition, games, and many more because they are more intelligent nowadays with artificial intelligence technology [12], [13]. This article aims to develop a mobile robot prototype that can be driven independently by users who face mobility challenges due to physical impairments, including monitored by other users through a web interface.

The primary audience for a face-oriented controlled mobile robot system is individuals with impairments who have limited or no use of their hands or arms, including those with spinal cord injuries, muscular dystrophy, cerebral palsy, or multiple sclerosis. These individuals face mobility challenges that make independent movement difficult. This article aims to provide a solution that enables mobility-challenged individuals to maneuver freely, which is essential for their independence [14]. The proposed system focuses on developing a mobile robot that can be controlled via the user's facial movements, along with voice and joystick modules as alternative control methods. Additionally, a web interface has been designed for continuous monitoring and control of the system. Caregivers can also operate the system remotely, reducing the physical strain they experience while assisting patients.

## II. Literature Review

An AI-based humanoid head-bot for imitating a range of expressions, recognizing individuals, and interacting with visitors through general conversation has been introduced by Baki *et al.* [15]. The head-bot skeleton was developed using several hexagonal blocks of PVC sheet to mimic a human-head-like structure. Hassani *et al.* [16] developed an interface that allows individuals with disabilities to control a mobility system using head gestures based on the acceleration and rotation rate of the user's head. However, the system was limited to the X and Y axes of the user's head angles, which limited the movement of the wheelchair in some defined directions. Patil *et al.* [17] designed a system that was operated with the help of a tilt of the head movements. In this work, a low-budget system with a better accuracy rate was achieved. A semi-autonomous head-motion controlled mobility system was proposed for quadriplegic patients by Kader *et al.* [18]. A 3-axis accelerometer sensor was used to detect head movement, while two DC motors enabled navigation. Additionally, two sonar sensors were implemented to detect obstacles in the front and back directions. However, the authors suggested working on IoT based health monitoring system to monitor the physical condition of the patient continuously.

Bakouri *et al.* [19] developed and implemented a voice control algorithm to operate a smart robotic system using neural network techniques. Network In Network (NIN) and Long Short-Term Memory (LSTM) structures were integrated into the system, along with a built-in voice recognition algorithm. The system was implemented in both indoor and outdoor environments, which resulted in an accuracy rate of 98.2% for the proposed five voice commands - left, right, yes, no, and stop. Though, enhancing the system with GPS technology can allow the users to design their routes for future work. Artificial neural networks were trained through the user's voice commands based on neural networks and a backpropagation algorithm by Karande *et al.* [20]. The proposed prototype was trained using five voice commands - Forward, Backward, Left, Right, and Stop. The commands were written on target hardware wirelessly by using a Bluetooth module for the motion of the DC motors. Akhtaruzzaman *et al.* [21] delineated the various gaits like walking, turning, obstacle overcoming, and stepping downstairs and upstairs for a humanoid system. To develop the system, an efficient algorithm was developed based on the various analyses of gaits and the predefined map of the test environment.

Karim *et al.* [22] constructed a mobility system using a microcontroller and other electronic devices to control the motors and process the voice commands. The system was designed in such a way that it remains cost-effective and can be commercialized for needy users. Rulik *et al.* [23] designed a multimodal control method for robotic self-assistance that can assist patients with disabilities in performing self-tasks daily. Two interchangeable operating modes - chin and finger joystick control frameworks were developed to control the movements of the assistive robot. However, to pick up heavy objects, the system needed high torque, and the performance of the system also became low. Kulkarni et al. [24] developed a signal-controlled mobility system that can be operated with minimal hand movement. The proposed system was implemented with Arduino-grounded predispositions, which is similar to the Arduino NANO and UNO microprocessors. The system was developed to address the challenges of using joysticks. As future work for the system, a mixed optical indicator was proposed for integration to detect the retina and operate the system.

Although various solutions have been developed to address motion control challenges, few have integrated multiple control techniques simultaneously. This paper presents the development of a mobile robot controlled through face orientation, voice commands, and wireless inputs, aiming to enhance mobility and independence for individuals with physical disabilities. Additionally, a web interface is developed for continuous monitoring and control of the system through that interface.

## III. Methodology

The proposed system introduces an AI-driven mobile robot motion control prototype equipped with multiple control modules for individuals with physical disabilities. Additionally, the robot can be remotely operated by other users for both monitoring and control purposes.

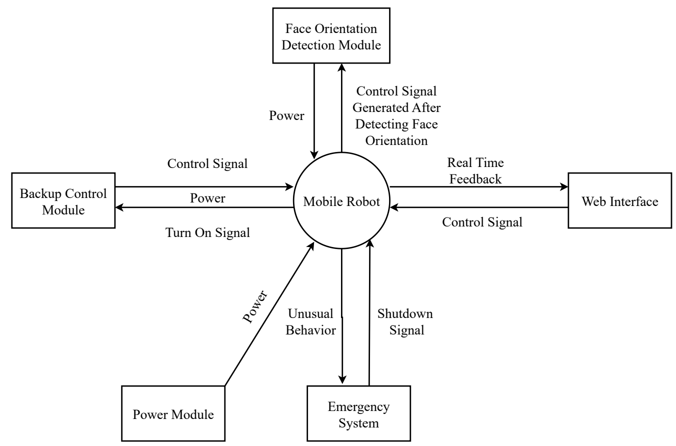



Fig. 1. Overview of the System

As shown in Fig. 1, the system is divided into multiple modules and subsystems like the face orientation detection module, backup control module, web interface, power module, and emergency system. The web interface, power module, and emergency systems all operate parallel with either face orientation detection or a backup control module. Here, the backup control module contains the voice and joystick control.

The overview of the proposed system's architecture is presented in Fig. 2, which represents the flow of information between different physical and logical components in the system. The system can be controlled manually, vocally, or by facial movements. The patient can use any of these three control techniques to operate the system. Additionally, another user can operate the system vocally and manually using a web interface. If the patient chooses manual control, the joystick data will be delivered straight to the ESP-32. If voice or facial motion is selected, the processor (in this system, a Raspberry Pi) will first receive voice input from a microphone or video feed from a webcam, process the data, and then extract the user's intended commands before sending them to the ESP-32. The ESP-32 will receive the user's webpage command directly. Then, the robot will be ordered to proceed in the direction chosen by the patient from this ESP-32. A buzzing alarm will sound if an emergency arises at any time, alerting the user. For the safety of the patient, some control commands might also be blocked at the same time. The robot would automatically detect any obstacle in its path and sound the buzzer to let the patient and user know there was an obstacle in the path of the wheelchair. A power supply module has been

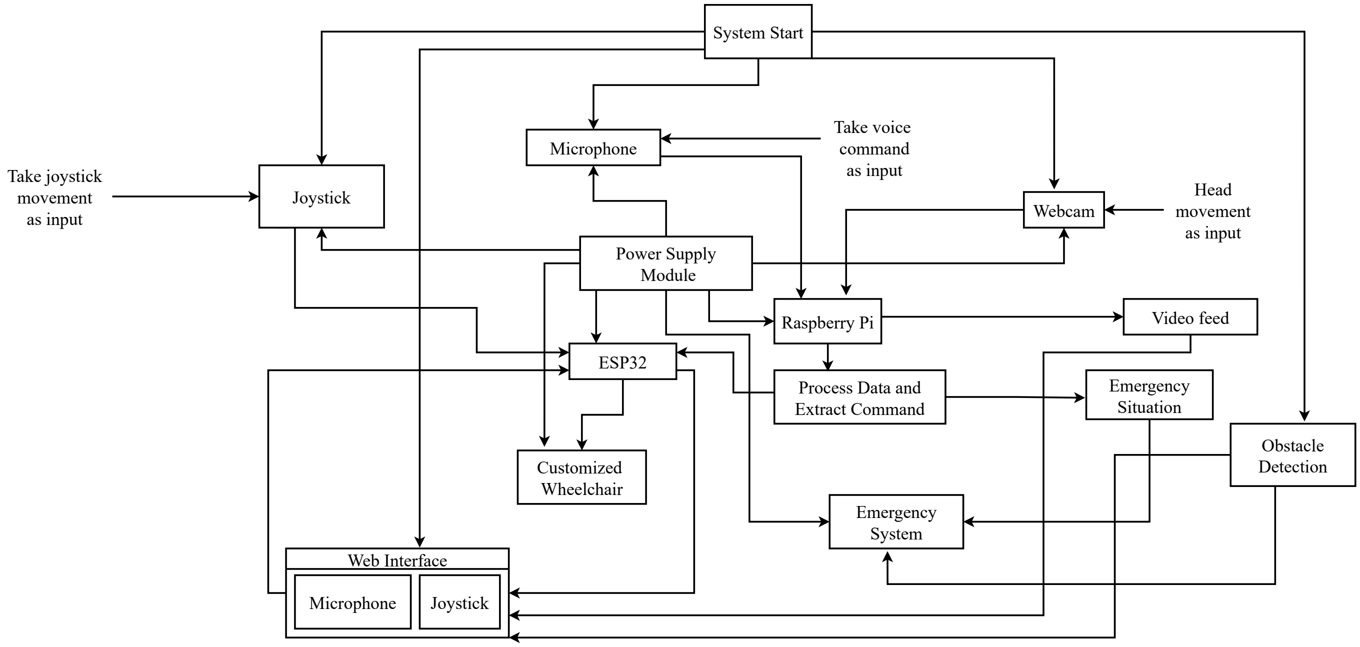



Fig. 2. System Architecture

incorporated to provide proper voltage and current delivery to all the components.

## IV. Design and Development

The proposed system consists of a robot prototype, and its movements are primarily determined by the patient's facial movements, which are observed through a camera. Two backup control modules, voice command, and joystick control, are also added to the system to achieve greater control versatility. The circuit diagram is shown in Figure 3.

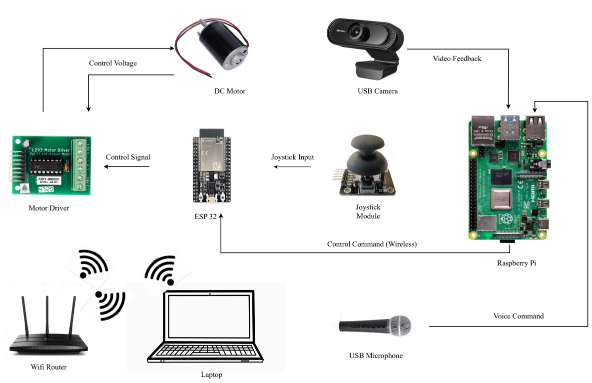



Fig. 3. Circuit diagram of the system

### A. Design

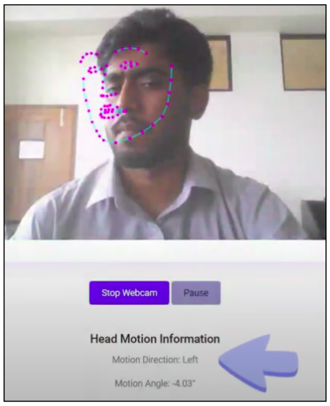
The proposed system incorporates various control methods and features, primarily based on the user's facial orientation. In addition, voice command and joystick control are added as backup control systems. Furthermore, the system intelligently handles situations when obstacles are placed around it. To produce a seamless and coordinated system, the various elements of the prototype, including facial motion detection, voice command control, manual joystick control, and obstacle detection, are combined. Communication protocols and software interfaces permit seamless interaction between various components to ensure that control commands are correctly processed and carried out and that obstacle information is reliably identified and responded to.

### B. Facial Orientation Detection

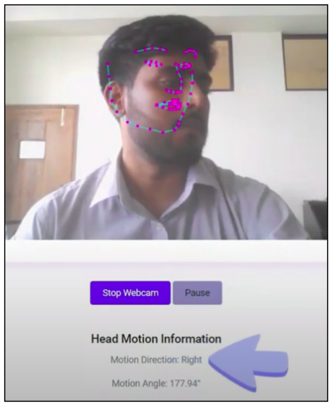
Controlling the prototype through the facial orientation of the user is the primary feature of this study. Video feedback of the facial movements of the user is detected by the camera feeds obtained from a USB webcam that is placed in front of the prototype. A javascript library named face-api.js is used to analyze the camera feed and detect the orientation of the user's face. For facial motion detection, this javascript library uses models like SSD Mobilenet, Tiny Face Detector, MTCNN, 68 Point Face Landmark Model, Face Expression Recognition Model, etc. Four face movement directions - left, right, up, and down were detected for this study. The directions were shown in a custom-made website, which is shown in Fig. 4.

### C. Backup Control System

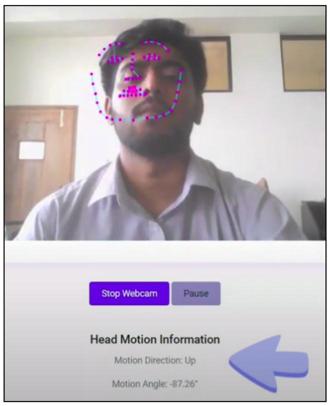
The backup control system is made up of two components - voice command and joystick control. In the voice command mode, the system took basic voice commands like "move left", "move back," and "stop" and acted accordingly, as shown in Fig. 5 (a). In the joystick control, the user can move the system through a manual joystick device as well as remote joystick control through the custom-made website, as shown in Fig.



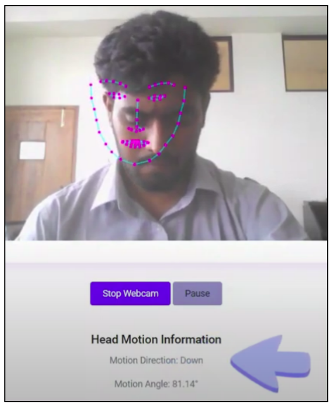

(a) Left Orientation of Face




(b) Right Orientation of Face




(c) Up Orientation of Face

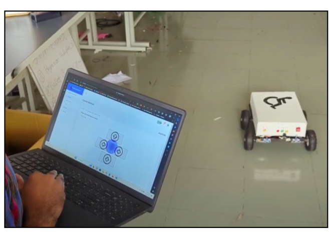



(d) Down Orientation of Face

Fig. 4. Facial Orientation Detection

5 (b) and 5 (c). All of these backup control systems were integrated so that users could control the system according to their preferences.

(a) Voice Command



(b) Remote Joystick Control

(c) Manual Joystick Control

Fig. 5. Backup Control System

### D. Obstacle Detection

In this feature, the primary objective was to measure the distance between the system and the obstacle. This process was done by an ultrasonic sonar sensor module, which sent an ultrasound and received the reflection of that sound. By measuring the duration between the time of firing and the time of receiving, the system calculated the distance between the prototype and the obstacle. If the distance was less than 20 cm, the prototype stopped moving in that direction by generating an alarm, as shown in Fig. 6.

### E. Emergency Stop Switch

An emergency stop switch has been integrated into the system, allowing the operator to turn it off quickly if an uncomfortable situation occurs, such as a low battery. Users can halt the system by clicking the switch, as shown in Fig. 7.

Fig. 6. Obstacle Detection

Fig. 7. Emergency Stop Switch

## V. Evaluation and Result Analysis

An evaluation study was conducted in a software laboratory using the agile process to assess the system's accuracy and reliability. Test cases were designed for each primary functionality, and 10 student participants were asked to execute these test cases five times. All of the participants were aged between 24-25 years old.

Before the evaluation, participants were briefed on the system's objectives and functionalities. During the study, they interacted with the system for 4–5 minutes, exploring its features and providing feedback on usability and effectiveness. Subsequently, they were assigned specific tasks to evaluate the system's performance in meeting user requirements.

Throughout the process, participants could ask questions and share opinions while researchers recorded key data, such as the number of attempts and the time taken to complete tasks. At the end of the evaluation, participants shared feedback on usability and effectiveness and provided suggestions for improvement. The evaluation focused on measuring how quickly the system responded to directions and made intelligent decisions. A recorded summary of the

TABLE I
ANALYSIS OF SYSTEM PERFORMANCE

| Task | Module | Result | Number of Attempts (Mean ± SD) | Task Completion Time (Mean ± SD) (sec) | Number of Times Asking For Help (Mean ± SD) (sec) |
|---|---|---|---|---|---|
| Log in | Software | 100% | 1 ± 0 | 12.64 ± 8.02 | 0 ± 0 |
| System Control with Head Motion | Software | 83% | 1.25 ± 0.43 | 20.56 ± 2.75 | 0.2 ± 0 |
| System Control with Voice Command | Software | 77% | 2.6 ± 0.44 | 17.71 ± 4.28 | 0 ± 0 |
| System Control with Joystick | Software and Hardware | 100% | 1 ± 0 | 10.01 ± 1.94 | 0 ± 0 |
| Obstacle Detection | Hardware | 100% | 1 ± 0 | 0.17 ± 0.02 | 0 ± 0 |
| Emergency Stop | Hardware | 100% | 1 ± 0 | 0.33 ± 0.07 | 0 ± 0 |
| Speed Control | Hardware | 71% | 1.4 ± 0.55 | 2.25 ± 0.55 | 0 ± 0 |

findings is presented in Table I.

From Table I, it is evident that participants struggled to perform the designated tasks through face orientation, which had the highest mean completion time. Additionally, participants required assistance to operate the system's primary feature, as observed by the researchers. The voice modules and speed control also took longer than expected to implement. Apart from the login system and emergency stop, participants faced challenges completing the required tasks. Many participants were unfamiliar with the system and found it difficult to use efficiently, as it was entirely new to them. They were given a brief opportunity to use the system before being asked to perform a set of tasks. The outcomes and findings from the system provided valuable feedback for future development, motivating us to improve the system's accuracy, reliability, and user-friendliness while working towards making it more error-free. The visual representation of the results is shown in Figure 8, 9 and 10 respectively.

## VI. CONCLUSION AND FUTURE WORK

The system in this study was controlled using facial movements, voice commands, and joystick control. A web interface was also developed to assist users in remotely controlling the robot prototype. The system was evaluated using the agile process with seven test cases, though additional relevant test cases could be explored in the future. Currently, the system can be controlled and monitored within the local area network, with plans to extend the range beyond the local area network. A limitation of the system is that it supports only four voice commands in English. Integrating Bengali language support could provide an innovative solution for Bengali users. Additionally, incorporating brain wave signals and upgrading

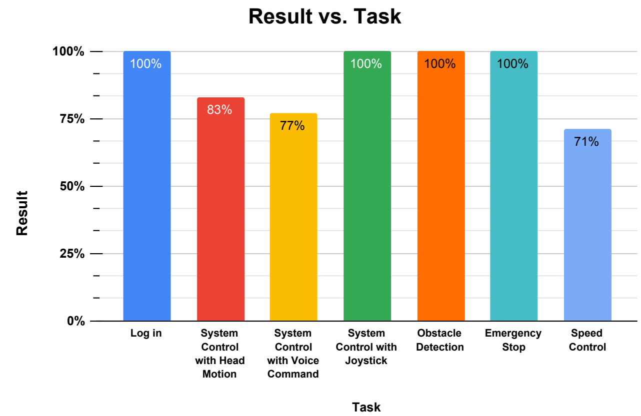



Fig. 8. Result vs. Task

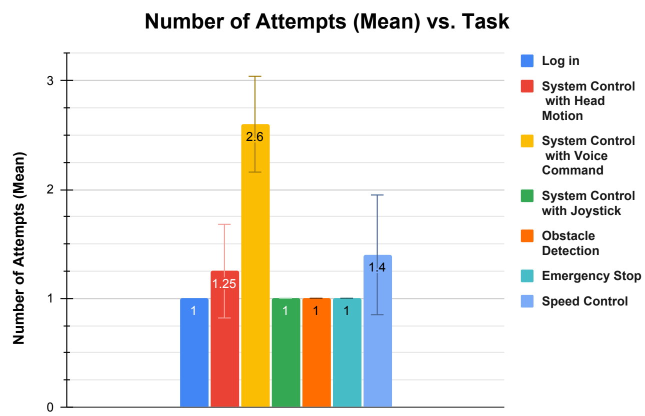



Fig. 9. Number of Attempts (Mean) vs. Task

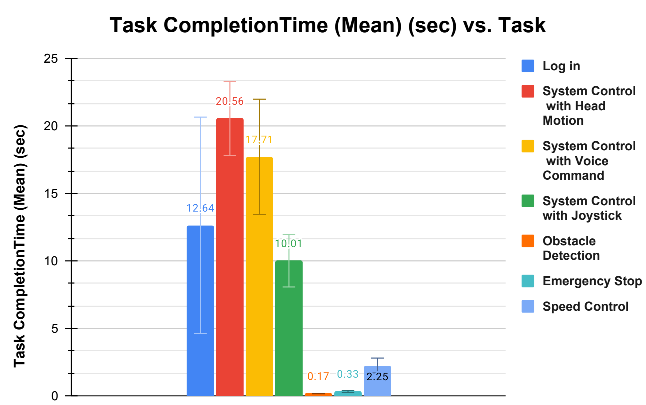



Fig. 10. Task Completion Time (Mean) (sec) vs. Task

the system from semi-autonomous to autonomous could significantly enhance the overall functionality and quality of the proposed system.

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