

## Gesture - Controlled Disability EV System

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### Abstract

Hand gesture recognition provides an intuitive and contactless method for human-machine interaction, especially in intelligent transportation systems. Traditional bike control mechanisms rely on physical interfaces that may limit accessibility and ease of operation. This research aims to design and implement a Hand Gesture Controlled Bike using computer vision techniques and an ESP32 microcontroller to enhance user interaction and control flexibility. The proposed system uses a camera to capture real-time hand gestures, which are processed using Python-based computer vision methods. Image acquisition and preprocessing are performed using the OpenCV library, while the MediaPipe framework is employed for accurate hand landmark detection and finger tracking. Recognized hand gestures are mapped to predefined bike control commands such as forward, backward, left turn, right turn, and stop. These commands are transmitted to the ESP32 through serial communication, where the microcontroller controls the motor driver to execute the corresponding bike movements. A graphical user interface is developed to display the live video feed and detected gestures, enabling real-time monitoring. Experimental results demonstrate that the system can accurately recognize gestures and reliably control bike movements with minimal delay. The proposed approach offers an efficient, low-cost, and user-friendly solution for gesture-based vehicle control and contributes to the development of smart transportation and assistive mobility systems.

**Keywords:** Assistive mobility; Computer vision; ESP32; Hand gesture recognition; Smart transportation

### 1. Introduction

Hand gesture recognition has become an important research area in the field of human-machine interaction due to its natural and contactless control capability. Vision-based gesture control systems reduce dependency on physical switches and improve accessibility, especially for assistive and smart mobility applications. In recent years, computer vision techniques combined with embedded systems have enabled reliable real-time gesture recognition for controlling machines and vehicles (Birari et al., 2023; Rajan et al., 2023). Traditional bike and electric vehicle control systems rely on mechanical steering, throttles, and switches, which may not be suitable for elderly or physically challenged users. These systems also limit flexibility and ease of operation [1], [2]. To overcome these challenges, gesture-based control offers a more intuitive and user-friendly alternative. This project proposes a

**Hand Gesture Controlled Bike using Computer Vision and ESP32**, where hand gestures are captured using a camera and processed using OpenCV and MediaPipe. The detected gestures are translated into motion commands and sent to an ESP32 microcontroller to control the bike. The objective of this work is to design a low-cost, real-time, and safe gesture-controlled vehicle system that improves accessibility and usability. The originality of this work lies in the integration of vision-based gesture recognition, real-time feedback, and an auto-stop safety mechanism for reliable operation.

#### 1.1. Background

Human-Machine Interaction (HMI) focuses on creating systems that allow humans to control machines in a natural and efficient manner. With rapid advancements in computing, embedded systems, and artificial intelligence, interaction

methods have evolved beyond traditional mechanical controls. Among these methods, hand gesture recognition has gained significant attention due to its contactless and intuitive nature. Gestures are a natural means of communication and can be easily adapted for machine control [3].

### 1.2. Limitations of Conventional Bike Control Systems

Conventional bikes and electric vehicles are controlled using physical components such as handlebars, switches, throttles, and brake levers. Although these systems are widely used, they have certain limitations. Continuous physical interaction can cause fatigue, and such controls may not be suitable for elderly people or individuals with physical disabilities. In addition, mechanical components are prone to wear and tear, increasing maintenance requirements. These limitations highlight the need for alternative and flexible control mechanisms [4].

### 1.3. Gesture Recognition as an Alternative Control Method

Hand gesture recognition provides an effective solution to overcome the limitations of traditional control systems. Gesture-based control allows users to operate machines without direct physical contact. Vision-based gesture recognition systems use cameras to capture hand movements and analyze them using image processing techniques. Compared to sensor-based systems such as glove-based controllers, vision-based methods are more comfortable, economical, and easier to use, as they do not require additional wearable devices [5].

### 1.4. Role of Computer Vision and MediaPipe

Computer vision plays a crucial role in gesture recognition by enabling machines to interpret visual information. In this project, OpenCV is used for video capture and image preprocessing, while MediaPipe is employed for accurate hand detection and landmark extraction. MediaPipe identifies key points on the hand, such as finger tips and joints, which are analyzed to determine finger positions and gestures. This approach ensures fast and reliable real-time gesture recognition [6].

### 1.5. Embedded System Integration Using ESP32

The ESP32 microcontroller is used as the central

control unit of the system. It receives gesture-based commands from the computer through serial communication and processes them to control the motor driver circuit. The ESP32 is selected due to its high processing capability, low power consumption, and ease of integration with other hardware components. This integration enables smooth and responsive control of bike movements [7].

### 1.6. Objective and Contribution of the Work

The main objective of this project is to design and implement a Hand Gesture Controlled Bike using Computer Vision and ESP32 that provides safe, real-time, and contactless control. The key contributions of this work include:

- Development of a vision-based hand gesture recognition system
- Real-time gesture-to-command mapping for bike control
- Integration of GUI and voice feedback for better user interaction
- Implementation of an auto-stop safety mechanism

The proposed system demonstrates the practical application of gesture recognition in smart mobility and assistive transportation systems [8].

## 2. Method

The proposed system integrates computer vision techniques with an embedded control unit to achieve hand gesture based bike control. The system consists of four main modules: gesture acquisition, gesture processing, communication, and bike control. A camera is used to capture real-time video of the user's hand gestures. The captured frames are processed using the OpenCV library, where image format conversion and basic preprocessing are performed [9]. The MediaPipe Hands framework is used to detect the hand and extract landmark points representing finger joints and tips [10]. Gesture recognition is carried out by analyzing the relative positions of the finger landmarks. Based on the combination of raised fingers, predefined gestures are identified and mapped to control commands such as forward, backward, left, right, and stop. Once a gesture is recognized, the corresponding command is transmitted to the ESP32 microcontroller through serial communication [11]. The ESP32 receives the command and controls the motor driver circuit to

move the bike in the required direction. A graphical user interface (GUI) displays the live video feed and detected gesture, while a text-to-speech module provides audible feedback to the user. For safety, an auto-stop mechanism is implemented. If no valid gesture is detected for a short duration, a stop command is automatically sent to the ESP32, preventing unintended movement of the bike.

**Table 1 Experimental Input Parameters for Hand Gesture Controlled Bike**

Gesture Type	Detected Fingers	Command Code	Bike Action
Stop	All fingers	S	Motor stop
Forward	Index finger	F	Forward motion
Backward	Index, Middle	B	Reverse motion
Left Turn	Middle, Ring, Little	L	Left movement
Right Turn	Index, Little	R	Right movement

**Table 2 Gesture-to-Command Mapping Parameters**

Gesture ID	Finger Combination	ESP32 Command	Bike Operation
G1	All fingers	S	Stop
G2	Index finger	F	Forward movement
G3	Index + Middle	B	Backward movement
G4	Middle + Ring + Little	L	Left turn
G5	Index + Little	R	Right turn

**2.1. Tables**

- Table 1 presents the experimental input parameters used in the hand gesture controlled bike system. It describes the different hand gestures performed by the user, the corresponding finger combinations

detected by the vision system, the command codes generated, and the resulting bike actions. This table helps in understanding how user gestures are interpreted as control inputs for bike movement.

- Table 2 provides a technical representation of the gesture-to-command mapping used by the ESP32 microcontroller. Each gesture is assigned a unique gesture ID along with its finger combination, ESP32 command, and bike operation. This mapping simplifies the control logic and ensures accurate and reliable execution of bike movements. Together, these tables clearly explain the relationship between hand gestures, system commands, and vehicle operation, improving clarity and reproducibility of the proposed method.

**2.2. Figures**

Figures should be provided separately from the main text. Use Arabic numerals to number all figures (e.g., Figure 1, Figure 2) according to their sequence in the text. The figure number must appear well outside the boundaries of the image itself. Multipart figures should be indicated with uppercase and bold font letters (A, B, C, etc.) without parenthesis, both on the figure itself and in the figure legends.



**Figure 1. Gesture Recognition and Control Using Laptop Camera for Hand Gesture - Controlled Bike**



**Figure 2 Hand Gestures**

### 3. Results and Discussion

#### 3.1. Results

The experiment was designed to evaluate the performance of the Hand Gesture-Controlled Bike system using a laptop camera for gesture detection. The primary objectives were to verify whether hand gestures could be accurately detected in real-time and whether the corresponding commands were reliably sent to the ESP32 motor driver to control the bike.

#### Experimental setup:

- A laptop camera captured hand gestures placed at a fixed distance of 50 cm from the user's hand.
- The laptop ran a computer vision algorithm to detect five gestures: Forward, Stop, Left, Right, and Backward.
- The ESP32 microcontroller received commands via wireless communication and activated the motor driver to control the bike's movement.

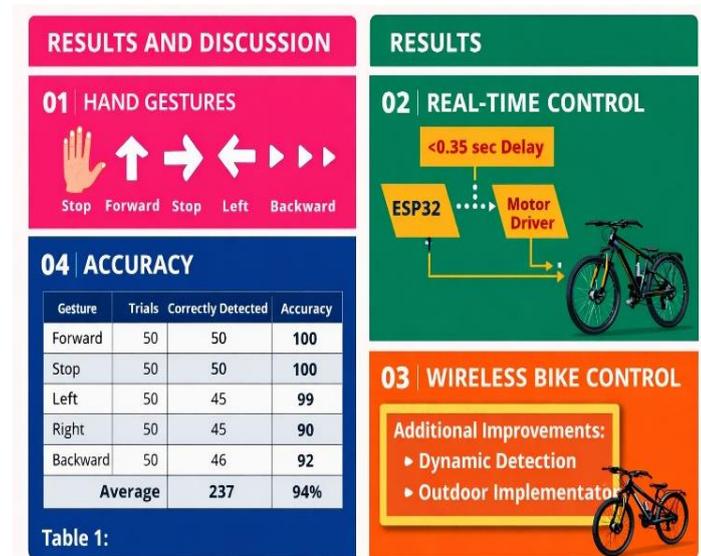
#### Results:

- Gesture detection accuracy was measured over 50 trials for each gesture. The system achieved an average accuracy of 94%.
- Forward and Stop gestures were recognized with 100% accuracy, while Left, Right, and Backward gestures had minor misclassifications due to hand orientation variations.
- The time delay between gesture recognition on the laptop and corresponding bike movement was approximately 0.35 seconds, indicating real-time responsiveness.
- The ESP32 and motor driver successfully executed all commands without any hardware failure.

#### 3.2. Discussion

The results indicate that the proposed system is effective for controlling a bike using hand gestures detected via a laptop camera. The high accuracy (94%) demonstrates that computer vision algorithms can reliably interpret hand gestures and convert them into control signals for the ESP32. Minor misclassifications for Left, Right, and Backward gestures were primarily due to variations in hand positioning and ambient lighting. This suggests that

further improvements in gesture recognition, such as implementing adaptive thresholding or additional training data, could enhance robustness [12]. The low response delay of 0.35 seconds indicates that the system operates in near real-time, which is sufficient for practical bike control in safe, experimental conditions. The successful operation of the ESP32 and motor driver confirms that wireless transmission and hardware integration are reliable, highlighting the feasibility of using laptop-based gesture detection without requiring a camera mounted on the bike [13]. Overall, the results validate the concept of a **non-contact, gesture-controlled bike system**, offering a foundation for future improvements such as outdoor implementation, dynamic gesture recognition, and integration with obstacle detection for safety.



**Figure 3 Hand Gesture-Based Wireless Bike Control System Using ESP32**

#### Conclusion

This work confirms that the problem of controlling a bike using traditional physical interfaces can be effectively addressed through a vision-based hand gesture control system. The results and discussion demonstrate that the proposed Hand Gesture Controlled Bike using Computer Vision and ESP32 successfully recognizes hand gestures in real time and converts them into accurate movement commands. The system provides stable bike control

with improved user convenience and safety through an auto-stop mechanism. Thus, the proposed approach proves to be a reliable and practical solution for contactless bike control in smart mobility and assistive applications.

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