Design and Development of a Safety-Based Hand Gesture Controlled Wheelchair using Atmega8 and Dual Ultrasonic Sensors

Siddhi Badrinath jangale
Sayli Ganpat Hase
Avantika Ganesh Bidave
Asmita Prashant Ugale
Department of electronics and telecommunication, Amrut Vahini polytechnic, Sangamner, Maharashtra, India
1.jangalesiddhi53@gmail.com
, 2.sayalihase12@gmail.com

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ABSTRACT**:** This paper presents the design and development of a safety-based hand gesture-controlled wheelchair prototype using an ATmega8 microcontroller. The system uses an MPU6050 sensor to detect hand tilt gestures for movement control. A touch sensor is used for safe activation, while two ultrasonic sensors are used for front obstacle detection and staircase edged etection. The ATmega8 processes all sensor inputs and controls the motor driver circuit for safe prototype emovement. The system is powered by a 12V supply, with a voltage regulator providing 5V to the controller and sensors. The proposed system is low-cost, simple, and suitable as an assistive mobility prototype with improved operational safety

1. Introduction:

Mobility support is very important for physically disabled and elderly people who face difficulty in moving independently.Traditional manual wheelchairs require physical effort, and joystick-based electric wheelchairs may not be easy to use for users with weak hand movement or limited finger control. Therefore, there is a need for a simple and safe wheelchair control system.

This paper presents a safety-based hand gesture-controlled wheelchair prototype using an ATmega8 microcontroller. The system uses an MPU6050 sensor to detect hand tilt and control the wheelchair movement in forward, backward, left, and right directions. A touch sensor is used to ensure that the wheelchair moves only when the user's hand is properly placed. Two ultrasonic sensors are used to improve safety: one sensor detects obstacles in front of the wheelchair, while the other downward-facing sensor detects staircase edges or sudden drops. The system uses a motor driver circuit to drive low-speed DC geared motors for prototype movement. A 12V power supply is used, and a voltage regulator converts 12V into 5V for the microcontroller and other low-voltage components. This system provides easy control, improves safety, and can be used as a low-cost assistive mobility prototype.

2. LITREATURE REVIEW

Hand gesture-controlled wheelchairs and smart assistive mobility systems have become important for improving the independence and safety of physically disabled and elderly people. Many researchers have developed different wheelchair control methods such as joystick control, voice control, and gesture-based control.

In [1], the authors presented a smart wheelchair system for disabled users and discussed different control methods used in assistive mobility devices. The study highlighted the importance of user-friendly control systems for improving independent movement.

In [2], a hand gesture-controlled wheelchair system was proposed using motion sensing technology. The system used hand tilt or motion-based input to control wheelchair movement in different directions. The results showed that gesture-based systems can provide easier control compared to conventional wheelchairs.

Another study in [3] discussed the use of ultrasonic sensors in assistive navigation systems. The authors explained that ultrasonic sensors can help in detecting obstacles and improving user safety by preventing collisions during wheelchair movement.

The work presented in [4] focused on microcontroller-based wheelchair control systems. The researchers showed that embedded controllers can be effectively used to process sensor inputs and control wheelchair motion in real time.

In [5], the authors discussed the use of MEMS sensors such as MPU6050 for motion detection and gesture recognition applications. The study showed that such sensors are suitable for detecting hand tilt and can be used in real-time control systems.

From the above studies, it can be concluded that gesture control, obstacle detection, and embedded systems play an important role in the development of smart wheelchair systems. However, many existing systems provide limited safety features. Therefore, the proposed work focuses on a safety-based wheelchair prototype using hand gesture control, touch-based activation, front obstacle detection, and staircase edge detection.

3. METHODOLOGY

The proposed system is designed to control a wheelchair prototype using hand gestures and improve user safety through sensor-based protection. The methodology consists of touch-based activation, gesture detection, processing, safety monitoring, and motor control.

1. Touch-Based Activation

A touch sensor is used to ensure that the wheelchair prototype starts only when the user's hand is properly placed on the control section.
If the touch is not detected, the system remains in stop condition.
This helps in preventing accidental movement and improves user safety.

2. Hand Gesture Detection

An MPU6050 sensor is used to detect the tilt of the user's hand.
The sensor senses motion and tilt in different directions.
Based on the hand movement, the system identifies commands such as forward movement, backward movement, left turn, and right turn.

3. Microcontroller Processing

The ATmega8 microcontroller receives input signals from the touch sensor and MPU6050 sensor.
It continuously checks whether the touch sensor is active.
If valid hand contact is detected, the controller processes the gesture data and determines the required direction of movement.

4. Front Obstacle Detection

An ultrasonic sensor is placed at the front of the wheelchair prototype.
It continuously measures the distance between the wheelchair and obstacles in front. If an obstacle is detected within a predefined range, the microcontroller stops the motors immediately.
This helps in preventing collision.

5. Staircase / Edge Detection

A second ultrasonic sensor is mounted at the front in a downward-facing position using a PVC strip support.
This sensor continuously measures the distance between the wheelchair and the ground.
When the wheelchair approaches a staircase edge or sudden drop, the distance increases suddenly.
The ATmega8 detects this change and stops the wheelchair automatically to prevent falling.

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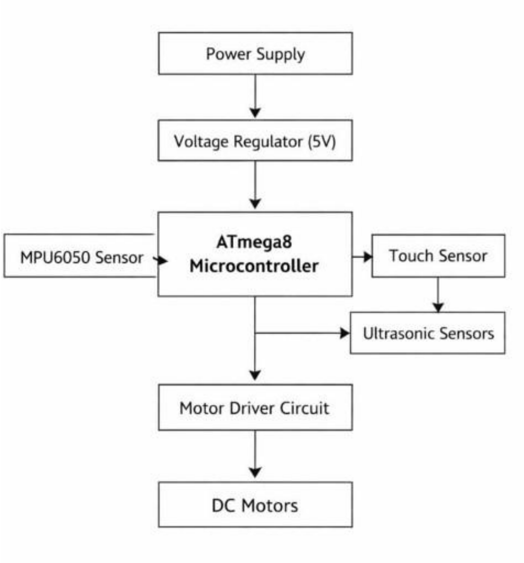
6. Motor Control and System Operation After checking all safety conditions, the
ATmega8 sends control signals to the motor driver circuit.
The motor driver controls the low-speed DC geared motors used in the prototype.
The overall system operation includes touch- based activation, gesture detection, obstacle checking, staircase detection, and motor control.
This integrated approach provides safe and reliable movement of the wheelchair
prototype



4. PROBLEM STATEMENT:

Many physically disabled and elderly people face difficulty in moving independently using conventional wheelchairs. Manual wheelchairs require physical effort, and some users may not have enough hand strength or control to operate them comfortably. In many existing systems, accidental movement, obstacle collision, and staircase or edge-related accidents can create serious safety risks.
Traditional wheelchair systems may not provide proper gesture-based control and real-time safety monitoring. Due to the absence of obstacle detection, staircase detection, and user verification, the chances of unsafe movement increase. Therefore, there is a need for a smart and safety-based wheelchair system that can be controlled easily through hand gestures while also providing protection against obstacles and staircase edges.
The proposed hand gesture-controlled wheelchair prototype uses an MPU6050 sensor for gesture detection, a touch sensor for user safety verification, and ultrasonic sensors for obstacle and staircase detection to provide safer and more reliable movement assistance.

OBJECTIVES OF THE STUDY

1. To design and develop a safety-based hand gesture-controlled wheelchair prototype using ATmega8 microcontroller.
2. To detect hand tilt gestures using MPU6050 sensor for controlling wheelchair movement in different directions.
3. To implement a touch sensor for ensuring that the wheelchair moves only when the user's hand is properly placed.
4. To detect front obstacles using an ultrasonic sensor and stop the wheelchair automatically for safety.
5. To detect staircase edges or sudden drops using a downward-facing ultrasonic sensor.
6. To improve safety, reliability, and ease of movement for physically disabled and elderly users through a low-cost prototype system.

5. LIMITATIONS OF STUDY

Prototype Model Only: The proposed system is developed as a prototype model and is not tested for full-scale real wheelchair operation with actual human load.

Limited Gesture Control: The system is designed to detect basic hand tilt gestures such as forward, backward, left, and right. Complex gesture commands are not included in the current design.

Sensor Accuracy Dependence: The performance of the system depends on the accuracy of the MPU6050 sensor, touch sensor, and ultrasonic sensors. Any sensor error may affect movement and safety response.

Limited Detection Range: The ultrasonic sensors have a limited sensing range and may be affected by environmental conditions or surface properties.

No Wireless Communication: The current system is wired and does not include wireless communication or remote monitoring features.

Basic Safety Implementation: The system provides obstacle detection and staircase detection, but advanced features such as speed control, voice control, GPS tracking, or emergency alert systems are not included.

6. RESULTS AND DISCUSSION

The developed safety-based hand gesture- controlled wheelchair prototype was tested to evaluate its gesture-based movement and safety response. The system successfully detected hand tilt using the MPU6050 sensor and generated movement commands such as forward, backward, left, and right. The ATmega8 microcontroller processed these signals and controlled the motor driver circuit for prototype movement.

The touch sensor worked effectively as a safety feature by allowing movement only when the user's hand was properly placed on the control section. When touch was not detected, the prototype remained in stop condition, preventing accidental movement.

The front ultrasonic sensor successfully detected obstacles placed in front of the prototype and stopped the motors automatically when an object came within the sensing range. Similarly, the downward- facing ultrasonic sensor detected staircase edges or sudden drops by sensing a sudden change in ground distance and stopped the prototype to avoid unsafe movement. The testing results show that the proposed system provides simple gesture-based control, improved operational safety, and reliable prototype movement. The system can be considered a low-cost and safety-oriented assistive mobility prototype for further development

7. ADVANTAGES OF THE SYSTEM

1. Improves user safety through touch-based activation.

2. Detects front obstacles and helps prevent collision.

3. Detects staircase edges or sudden drops to avoid unsafe movement.

4. Reduces the need for continuous manual effort in controlling the wheelchair.

5. Uses low-cost and easily available electronic components.

6. Can be further developed into a more advanced smart wheelchair system.

8. FUTURE SCOPE:

The proposed hand gesture-controlled wheelchair prototype can be further improved by adding advanced features for real-world applications. Future development may include wireless communication for remote monitoring, speed control for smoother movement, voice control for alternative user input, GPS tracking for location support, and GSM-based emergency alert systems. The system can also be upgraded with higher-capacity motors and battery backup for use in a full-scale wheelchair.

Additional sensors and intelligent algorithms may improve obstacle detection accuracy and overall reliability.

9. APPLICATIONS

1. Assistive mobility support for physically disabled users
2. Mobility aid for elderly people with limited movement
3. Smart wheelchair prototype for rehabilitation centers
4. Low-cost educational project in embedded systems
5. Research model for assistive healthcare technology.

10. CONCLUSION

This paper presented a safety-based hand gesture-controlled wheelchair prototype using an ATmega8 microcontroller for assistive mobility applications. The system uses an MPU6050 sensor to detect hand tilt gestures for movement control, a touch sensor for safe activation, and two ultrasonic sensors for obstacle and staircase detection. The microcontroller processes these inputs and controls the motor driver circuit to move the wheelchair prototype safely.

The developed prototype demonstrated simple gesture-based control and improved safety through automatic stopping under unsafe conditions. The proposed system is low-cost, practical, and suitable as a prototype model for further development in smart wheelchair applications for physically disabled and elderly users.

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