Smart Wheel Chair

Sulakshna. S.Patil[1], Shubham Gahininath Mane[2], Rushikesh Balasaheb Bangar[3], Vaibhav Bandu Potphode[4]
[1, 2, 3, 4] Dept of Electronics and Telecommunication
[1, 2, 3, 4] Sinhgad Institute of Technology Lonavala, India

Abstract- *This paper presents the design and construction of a smart wheelchair prototype that enhances mobility and autonomy for individuals with disabilities. The system integrates obstacle detection using ultrasonic sensors and environmental interaction through hand gestures and voice commands. Designed on an Arduino platform with Bluetooth control and Android interfacing, the system also features patient monitoring capabilities, ensuring both mobility and safety. The smart wheelchair emphasizes affordability, user-friendliness, and adaptability in varied environments.*

Keywords- Assistive Technology, Bluetooth Control, Obstacle Detection, Ultrasonic Sensor, Accelerometer, Fall Detection, Emergency Alert System, IoT in Healthcare, Motor Driver, Buzzer Alert, Remote Monitoring, Embedded Systems, Patient Safety,

I. INTRODUCTION

The advancement of embedded systems and smart technologies has opened new horizons in the development of assistive devices for differently-abled individuals. Among these innovations, smart wheelchairs play a critical role in enhancing mobility, autonomy, and safety for patients with physical disabilities. This project focuses on the design and implementation of a *Smart Wheelchair* system that combines multiple sensors and modules to offer intelligent, responsive, and secure navigation.

At the core of this system lies a Raspberry Pi, which acts as the main processing unit. The wheelchair can be wirelessly controlled using a smartphone via a Bluetooth terminal application. Specific numeric commands allow intuitive operation ‘1’ for moving forward, ‘2’ for backward, ‘3’ for turning right, ‘4’ for left, and ‘5’ to stop. The system is designed to respond instantly to user input while ensuring safety through the integration of real-time sensors.

An ultrasonic sensor mounted on the front actively scans for nearby obstacles. If an object is detected within a critical range, the wheelchair halts immediately and triggers an audible buzzer to alert the user. Additionally, an accelerometer monitors the wheelchair’s orientation. In case of a tilt or a fall, the system activates an emergency protocol—an alert email is sent to the caregiver or family member, along with an image captured by an onboard camera, providing visual context of the situation.

To ensure a comprehensive safety net, a panic button is also included in the design. When pressed, it immediately activates the buzzer and sends a distress signal. This adds an extra layer of manual control in case of unforeseen emergencies. The integration of a camera further strengthens situational awareness by providing live evidence of incidents.

The proposed system emphasizes low-cost, user-friendly design while maintaining high efficiency and reliability. By combining motion control, environmental sensing, emergency response, and wireless communication, this Smart Wheelchair bridges the gap between technology and healthcare. It demonstrates how IoT and automation can play a transformative role in improving the quality of life for individuals with special needs.

II. BLOCK DIAGRAM

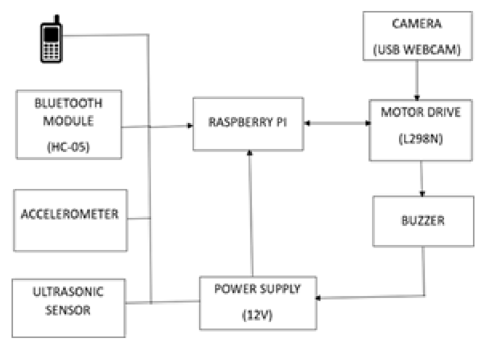

Fig 1 : Block diagram of Smart Wheelchair

The block diagram of the Smart Wheelchair project represents a comprehensive and intelligent system designed to provide mobility, safety, and remote monitoring for individuals who are physically challenged or elderly. The central processing unit of this setup is the Raspberry Pi, which plays a vital role in managing all the sensors, modules, and communication protocols used in the system.

The wheelchair is primarily controlled using a Bluetooth- based mobile application. A mobile phone with a Bluetooth terminal app connects to the system wirelessly through the HC-05 Bluetooth module. This module is interfaced with the Raspberry Pi and acts as a communication bridge between the user's mobile phone and the wheelchair's control system. The user can input specific commands into the app to move the wheelchair in different directions. For instance, sending the number ‘1’ will move the wheelchair forward, ‘2’ will move it backward, ‘3’ will make it turn right, ‘4’ for a left turn, and ‘5’ to stop the wheelchair. These commands are received by the Raspberry Pi, which then sends corresponding signals to the motor driver module (L298N).

The motor driver (L298N) is responsible for controlling the motors of the wheelchair based on the commands from the Raspberry Pi. It regulates the power and direction of the motors, enabling precise movement. A stable 12V power supply is used to ensure that the motor driver, Raspberry Pi, sensors, buzzer, and other components operate efficiently.

To ensure safety while the wheelchair is in motion, an Ultrasonic Sensor is installed at the front. This sensor continuously monitors the surroundings and detects any obstacle or object that comes within a predefined distance. If an obstacle is detected, the Raspberry Pi immediately halts the movement of the wheelchair and triggers a buzzer, alerting the user about the presence of an obstruction. This helps in avoiding collisions or accidents, especially when the user is unable to react quickly.

Another critical component of the system is the Accelerometer. It is used to detect sudden tilting or flipping of the wheelchair. In the event of an accident, where the wheelchair tilts too much or completely flips, the accelerometer senses this unusual movement and sends a signal to the Raspberry Pi. The system then takes immediate action by activating the buzzer and sending an emergency email alert to the registered caretaker or family member. This email contains a message that the patient might be in trouble due to the wheelchair being overturned or falling.

To make the system even more effective during emergencies, a USB camera (webcam) is also connected to the Raspberry Pi. When a fall or tilt is detected, the camera automatically captures an image of the current scene, including the condition of the patient. This image is then attached to the emergency email and sent to the concerned person. This visual feedback allows the caretaker to assess the situation quickly and take necessary action without delay.

All these components work in coordination to create a smart, responsive, and reliable wheelchair that not only provides mobility but also ensures the safety and monitoring of the user. The system is designed to be user-friendly, efficient, and highly beneficial for people who need assistance with movement and require constant supervision for safety reasons. This project showcases how modern embedded systems, sensors, and IoT concepts can come together to build assistive technology that can have a real impact on people's lives.

III. HARDWARE DESCRIPTION

1. Raspberry Pi

The Raspberry Pi is a small, powerful, and affordable single-board computer used as the brain of the system. It processes all inputs from sensors and modules and executes the Python code that controls the wheelchair. It also handles Bluetooth communication, decision-making, email alerts, and image capture using the camera.

2. *HC-05 Bluetooth Module*

The HC-05 is a serial communication Bluetooth module that allows the Raspberry Pi to connect wirelessly with a smartphone. It receives control commands sent from the Bluetooth Terminal app and transmits them to the Raspberry Pi for action. It plays a key role in the remote control functionality of the wheelchair.

3. *Motor Driver (L298N)*

The L298N is a dual H-bridge motor driver used to control the direction and speed of DC motors connected to the wheelchair. Based on the commands received from the Raspberry Pi, the motor driver manages forward, backward, left, and right movements, as well as stopping the wheelchair.

4. *DC Motors*

DC motors are used to drive the wheels of the wheelchair. They provide the actual movement according to the input from the motor driver. These motors are robust and capable of carrying the load of a person seated on the wheelchair.

5. *Ultrasonic Sensor*

The ultrasonic sensor is used for obstacle detection. It emits ultrasonic waves and measures the distance of objects in front of the wheelchair. If an obstacle is detected within a predefined safe range, it sends a signal to the Raspberry Pi to stop the wheelchair immediately and trigger a buzzer alert.

6. *Accelerometer Sensor*

The accelerometer measures changes in orientation and movement. In this project, it detects if the wheelchair tilts, flips, or falls. When such abnormal movement is detected, it triggers an emergency protocol that includes activating a buzzer and sending an email alert to the caregiver.

7. *Buzzer*

The buzzer acts as an audio alert system. It is activated in two cases: when an obstacle is detected by the ultrasonic sensor and when a fall is detected by the accelerometer. It alerts nearby people to assist the patient quickly.

8. *USB Camera (Webcam)*

A webcam is connected to the Raspberry Pi to capture images during emergency situations. When the wheelchair flips or falls, the camera captures an image of the patient's condition and sends it via email to the registered contact, helping them understand the situation visually.

IV. LITERATURE SURVEY

Table I: Comparative Literature on Smart Wheelchair Designs

Sr. No.	Title	Authors	Implemented Method	Merits
[1]	Design of Voice-Controlled Smart Wheelchair for Physically Challenged Persons	Khagendra Joshi, Rakesh Ranjan, Erukonda Sravya, Mirza Nemath Ali Baig	Voice recognition for direction control	Hands-free control, accessible interface
[2]	Wheel Chair with Health Monitoring System Using IoT	S. S. Nayak, P. Gupta, A. B. W. Upasana	IoT-based vitals tracking with mobility support	Remote health tracking
[3]	Smart Assistive Mobility: Designing An Autonomous Wheelchair	Sahil Sharma, Kushi Tibrewala, Harshit Dhiman, Prof. Dimpal Khambhati	IoT-based mobile control and Multi-Mode Control System	Multi-mode Control, Obstacle Detection, Voice Command Accessibility
[4]	Smart Wheelchair Controlled Through a Vision-Based Autonomous System	Usman Masud, Nawaf A. Almolhis, Ali Alhazmi, Jayabrabu R., Fezan U. Islam, A. R. Farooqi	Vision-based object detection and tracking	Visual perception adds autonomy
[5]	Voice and Gesture Controlled Smart Wheelchair	Mradul Mehrotra, Narendra S. Pal, Kavisha Saxena, Divyam Agarwal	Combined hand gesture + speech interface	Versatile user input options
[6]	Smart Wheelchair Using Arduino UNO	Deepak Kumar, Reetu Malhotra, S. R. Sharma	Basic voice + sensor control via Arduino	Low cost, customizable, accessible

The evolution of smart wheelchairs has led to the integration of intelligent systems that enhance mobility and independence for physically challenged individuals. Table I summarizes key research contributions in this domain by analyzing six selected papers in terms of their methodologies, advantages, and limitations.

Design of Voice-Controlled Smart Wheelchair for Physically Challenged Persons

This paper presents a voice-controlled wheelchair model using basic Arduino-based interfacing. The system relies on speech recognition modules to interpret user commands like "forward" or "stop" to control movement. The biggest merit of this system is its hands-free control, making it highly accessible for users with motor disabilities. Additionally, it uses relatively low-cost components. However, the major drawback is that its performance significantly deteriorates in noisy environments, making it unsuitable for outdoor or crowded areas where background noise can interfere with voice recognition [1].

Wheel Chair with Health Monitoring System Using IoT

This work integrates IoT capabilities with a wheelchair to enable real-time health monitoring, including parameters such as heart rate and body temperature. The design features remote connectivity for caregivers to receive alerts via the internet. Its primary strength lies in its dual function— mobility and healthcare—making it ideal for elderly users or patients with medical conditions. Nevertheless, this approach introduces network dependency, which can lead to latency or inaccessibility in areas with poor connectivity [2].

Smart Assistive Mobility: Designing An Autonomous Wheelchair

The paper presents an autonomous wheelchair integrating joystick, voice, and IoT control to enhance mobility for individuals with disabilities. Features include obstacle detection, LASER guidance, and a motorized sunroof. The system improves safety, comfort, and independence, offering a scalable, user-friendly solution adaptable to various environmental and personal needs [3].

Smart Wheelchair Controlled Through a Vision-Based Autonomous System

In this model, the wheelchair operates using computer vision techniques, including object tracking and obstacle detection via onboard cameras. The system makes use of image processing to interpret environmental data and autonomously navigate. This allows the wheelchair to detect and avoid obstacles intelligently, even without direct user control. While the visual intelligence provides high autonomy, the system is resource-intensive, requiring powerful processors and cameras, making it costly and power-hungry for widespread use [4].

Voice and Gesture Controlled Smart Wheelchair

This research offers a hybrid input model, combining voice commands and gesture-based control using accelerometers. Users can switch between modes depending on comfort and context, increasing usability for individuals with diverse disabilities. The approach is highly flexible and accessible, allowing users to control movement through voice or simple hand tilts. However, it does require calibration and proper training, and may not be suited for patients with both speech and motor impairments simultaneously [5].

Design of Voice-Controlled Smart Wheelchair for Physically Challenged Persons

This is a foundational design utilizing Arduino UNO, ultrasonic sensors, and Bluetooth-based voice control. The system includes both basic obstacle avoidance and health monitoring via a pulse sensor. Its main advantage is its low-cost and modularity, making it ideal for academic prototypes and small-budget deployments. However, the design is limited to basic functionality and lacks advanced capabilities like autonomous navigation or adaptive learning, restricting its use to controlled environments [6].

One of the most significant trends is the focus on multi- modal control interfaces. Projects like the one by Mehrotra et al. demonstrate the value of combining voice and gesture inputs. This ensures that users with different types of disabilities (e.g., vocal or motor impairments) are not excluded from using the system. Such redundancy not only improves usability but also increases system robustness in environments where one control method may fail (e.g., noisy surroundings affecting voice commands) [5].

Meanwhile, the design centered solely on voice control shows the appeal of simplified, intuitive systems. Voice- controlled wheelchairs offer a high degree of freedom for users with intact speech abilities. However, the lack of an alternative control path (like joystick or gesture input) means that the system can become completely non-functional if the voice input is misinterpreted or ambient noise interferes with command recognition [1].

The authors implemented their technique by integrating joystick, voice, and IoT-based controls into an autonomous wheelchair using ATMEGA 2560 and NodeMCU. Obstacle detection was achieved with ultrasonic sensors, and additional features like LASER guidance, sunroof, and remote controls were included. The system ensures flexible, safe, and user-friendly mobility for individuals with different disabilities [3].

Another standout feature is the integration of healthcare monitoring, as explored by Nayak et al. Their IoT-based model provides real-time updates of the user's vital signs, which can be accessed remotely by caregivers. This approach aligns with the growing need for remote patient monitoring—a trend accelerated by aging populations and global healthcare challenges. However, systems that rely on constant internet access may face connectivity limitations, especially in rural or underdeveloped regions [2].

In terms of hardware, designs like that by Kumar, Malhotra, and Sharma showcase the potential of Arduino-based systems. These platforms are cost-effective, open-source, and highly customizable. Such designs are ideal for educational projects, prototyping, and local adaptations. They allow students, researchers, and developers to experiment with features like Bluetooth control, ultrasonic sensing, and pulse detection without relying on expensive proprietary technologies. However, their basic architecture limits advanced functions like image processing, GPS integration, or AI-based learning [6].

Table II. Feature Extraction Techniques in Wheelchair Control Systems

Sr. No.	*Feature Type*	*Authors*	*Techniques Used*	*Advantages*	*Limitations*
[1]	Voice Recognition	Khagendra Joshi, Rakesh Ranjan, Erukonda Sravya, M. N. A. Baig	Speech-to-text via microphone input	Easy control, hands-free	Poor accuracy in noisy areas
[2]	Pulse Monitoring	S. S. Nayak, P. Gupta, A. B. W. Upasana	Pulse sensors + IoT module	Health alert system, continuous feedback	Sensor accuracy, cloud dependency
[3]	Navigation Vision	Usman Masud et al.	Camera + image processing algorithms	Precise obstacle and path detection	High processing requirements
[4]	Gesture Detection	Mradul Mehrotra, Narendra S. Pal et al.	Accelerometer tilt interpretation	Intuitive for hand users	Not reliable for tremor patients
[5]	Voice + Gesture Hybrid	Mradul Mehrotra, Narendra S. Pal et al.	Dual-signal parsing	Increases accessibility	Increases processing complexity
[6]	Simple Sensor Trigger	Deepak Kumar, Reetu Malhotra, S. R. Sharma	Trigger thresholds from basic sensors	Cost-effective, low latency	Not adaptive to variable contexts

Feature extraction is a core element of any intelligent wheelchair system. It refers to the process of identifying and isolating meaningful information from raw data—whether it originates from a voice input, physical gesture, biomedical sensor, or environmental scanning system. Effective feature extraction enables the system to understand the user's intent or physiological condition and translate it into appropriate motion commands, emergency alerts, or system adaptations.

Voice Recognition

One of the easiest ways to operate a wheelchair is by voice recognition, especially for those with poor motor control. This system uses a microphone to record voice inputs, which are then translated into text using built-in voice modules or speech-to-text APIs.

The frequency spectrum, pitch, energy levels, and phoneme patterns are the main characteristics that were taken out of the signal. After that, a predetermined command set is compared to these features. This method's primary benefit is that it may be used hands- free, increasing accessibility. However, contextual factors have a significant impact on its efficacy, as background noise may cause misinterpretations or hinder command recognition.

Pulse Monitoring

Pulse monitoring introduces a biomedical aspect to wheelchair control systems. A pulse sensor placed on the user's fingertip uses photoplethysmography (PPG) to detect blood volume changes. The extracted feature here is the heartbeat frequency or BPM (beats per minute).

The sensor captures analog waveforms that are processed using signal filtering techniques such as moving average or low- pass filters. These values are essential for real-time health assessment, especially for elderly or medically vulnerable users. If pulse levels cross a certain safety threshold, the system can trigger alerts or even halt movement. However, such systems require direct skin contact and may be affected by motion artifacts or improper sensor placement.

Navigation Vision

Vision-based systems use camera sensors combined with image processing algorithms to extract features from the surrounding environment. These may include object detection, lane following, color tracking, and facial recognition. The extracted features typically involve shape contours, object boundaries, movement vectors, and spatial orientation. The advantage of vision systems is their ability to offer autonomous navigation and obstacle avoidance with a high degree of intelligence. They are suitable for dynamic environments such as hospitals or public spaces. However, they require high processing power, proper lighting, and robust software libraries (like OpenCV), making them more resource-intensive and sensitive to environmental changes.

Gesture Detection

Gesture control is implemented through accelerometer sensors that track movement along three axes (X, Y, Z). Features extracted include angular displacement, tilt angle, and velocity of hand motion. The system maps specific hand tilts to commands such as “move forward,” “turn left,” or “stop.” The key advantage is that gesture control is intuitive and requires no spoken interaction, making it ideal for users with vocal disabilities. However, it may not be suitable for users with neurological disorders like Parkinson’s, as tremors and involuntary movement can result in command errors.

Voice + Gesture Hybrid Input

This system extracts features from both speech and gesture inputs, creating a multi-modal interface. The voice input is processed using keyword spotting, while gesture data from accelerometers is analyzed simultaneously. The system extracts signal confidence levels, command timing, and context prioritization as part of feature fusion. The major benefit is increased accessibility—users can switch between inputs depending on their ability or environment. However, synchronization is a challenge, as concurrent signals can conflict or overlap, requiring robust decision algorithms to ensure safe and accurate interpretation.

Table III. Classification Methods for Wheelchair Input Interpretation

Sr. No.	*Method*	*Authors*	*Description*	*Merits*	*Demerits*
[1]	Threshold-based	Deepak Kumar, Reetu Malhotra, S. R. Sharma	Static range-based trigger	Fast, lightweight	Not adaptive
[2]	ML (SVM Classifier)	Mradul Mehrotra, Narendra S. Pal et al.	Feature-based intent classification	Smart response accuracy	Needs training data
[3]	Manual Logic	Khagendra Joshi, Rakesh Ranjan et al.	Hardcoded command-response	Simple to implement	Inflexible, error-prone
[4]	Vision-based Recognition	Usman Masud et al.	Pattern recognition from camera input	Detailed recognition	High computational load
[5]	Sensor-Driven Switching	S. S. Nayak, P. Gupta et al.	Smart switching based on health/obstacle	Real-time safety-aware	Complex to balance all inputs
[6]	Gesture-Voice Fusion	Mradul Mehrotra, Kavisha Saxena et al.	Fusion classifier for dual signal types	Combines flexibility and robustness	Increases system latency

Smart wheelchair systems are designed to process user input in real-time and convert it into reliable control commands. These inputs—typically from voice, gestures, sensors, or vision systems—must be accurately classified to ensure smooth and safe operation. The classification method used plays a vital role in the efficiency and adaptability of the system. Several classification strategies are employed across different research models, each offering distinct advantages and facing unique limitations.

One of the simplest and most widely used methods is threshold-based classification, as demonstrated in the design by Deepak Kumar, Reetu Malhotra, and S. R. Sharma. In this approach, analog sensor inputs, such as those from accelerometers, are continuously monitored. When the input value exceeds a pre-defined threshold, a specific action is triggered—such as moving forward or turning. This method is highly efficient in terms of speed and computational demand, making it ideal for microcontroller- based systems. However, it lacks adaptability and can produce incorrect outputs if the sensor readings are not properly calibrated or if there is input noise [1].

A more advanced approach involves the use of machine learning algorithms, particularly Support Vector Machines (SVM), as used by Mradul Mehrotra, Narendra S. Pal, Kavisha Saxena, and Divyam Agarwal. SVMs can classify complex input patterns by training on large datasets of gesture and voice signals. Once trained, the model can generalize well, providing accurate classification even under varying conditions. This makes SVM suitable for systems requiring higher robustness and adaptability. However, implementing ML-based classification increases system complexity and demands more memory and processing power, which can be challenging for embedded platforms [6].

Some systems, such as the one presented by Khagendra Joshi and colleagues, rely on manual logic or hardcoded conditions. This method directly maps specific input keywords or sensor values to control signals using simple conditional statements. It is straightforward to implement and allows for quick system prototyping and debugging. However, such systems are rigid and difficult to scale, as each new command must be manually added to the codebase. Furthermore, manual logic fails to accommodate variations in input due to user inconsistency or environmental changes [3].

Another powerful classification method is based on vision-based recognition, as employed by Usman Masud, Nawaf Abdulaziz Almolhis, and co-authors. Their system uses camera input and image processing techniques to identify objects, obstacles, and paths. By classifying visual patterns, the system can navigate autonomously or assist the user in steering around obstacles. This type of classification enhances situational awareness and enables smart interaction with the surroundings. However, the approach is computationally intensive and may not perform well in low- light or high-motion scenarios unless supplemented with advanced processing hardware [4].

A more context-sensitive approach is sensor-driven switching, demonstrated in the work by S. S. Nayak, P. Gupta, and A. B. W. Upasana. Their system uses data from health and obstacle sensors to dynamically alter the system's behavior. For example, a sudden increase in heart rate might prompt the wheelchair to stop and notify a caregiver. Similarly, ultrasonic sensors can trigger automatic stops or rerouting upon detecting obstacles. The classification logic here involves condition-based switching across different modules. While this enhances safety, integrating multiple data streams without conflict requires careful logic handling and prioritization mechanisms [5].

Finally, the system proposed by Mradul Mehrotra and team utilizes gesture-voice fusion classification. This approach processes both gesture and voice input simultaneously and prioritizes one over the other based on signal quality or user preference. The system extracts features from both inputs and uses a decision fusion algorithm to determine the final action. This enhances user flexibility and reduces the chances of command failure. However, synchronization between the two input types must be managed properly, or it could lead to latency or misinterpretation [6].

Table IV. Sensor Integration Techniques in Wheelchair Systems

Sr. No.	Sensor Type	Authors	Usage	Benefits	Constraints
[1]	Ultrasonic Sensor	Deepak Kumar, Reetu Malhotra, S. R. Sharma	Obstacle detection	Avoids collisions, low-cost	Limited range, sensitive to angle
[2]	Pulse Sensor	S. S. Nayak, P. Gupta, A. B. W. Upasana	Heart rate monitoring	Health alerts, remote sharing	Requires finger placement
[3]	Camera Sensor	Usman Masud, Nawaf A. Almolhis et al.	Vision-based object detection	Real-time smart decision making	Demands high processing power
[4]	Accelerometer	Mradul Mehrotra, Narendra S. Pal et al.	Gesture tilt recognition	Intuitive directional control	Inaccurate with unstable hands
[5]	Temperature Sensor	Kaur P., Jain K.	Body heat monitoring	Medical application value	Calibration drift, slow reaction
[6]	Ultrasonic Sensors	Sahil Sharma, Kushi Tibrewala, Harshit Dhiman, Prof. Dimpal Khambhati	Integrated into joystick, IoT, and voice-controlled navigation modes	Joystick, voice, and mobile app-based control	Sensor performance may be affected by noise, lighting, or uneven terrain.

The ultrasonic sensor, as implemented by Deepak Kumar, Reetu Malhotra, and S. R. Sharma, is primarily used for obstacle detection. It emits high-frequency sound waves and calculates the time it takes for the echo to return from nearby objects. This allows the system to determine the distance to an obstacle and act accordingly, such as stopping or changing direction. The ultrasonic sensor provides a cost-effective safety layer, helping to prevent collisions. However, it suffers from a limited field of view and may give inaccurate readings on soft or angled surfaces that poorly reflect sound [1].

The pulse sensor, used by S. S. Nayak, P. Gupta, and A.B. W. Upasana, adds a biomedical monitoring feature to the wheelchair. Placed on the user's finger, this sensor detects blood volume changes using photoplethysmography (PPG) and calculates the user's heart rate in beats per minute. This functionality is useful for monitoring the user's well-being, especially for elderly or medically vulnerable individuals.

It enables real-time alerts in case of abnormal heart rate fluctuations. Its main drawback is that it requires consistent skin contact and can produce inaccurate results if the user moves excessively or if the sensor placement is poor [2].

A camera sensor is employed in the system designed by Usman Masud, Nawaf Abdulaziz Almolhis, and collaborators. This vision-based approach enables the wheelchair to process its surroundings using object detection, path recognition, and obstacle tracking. Cameras capture real-time visuals that are analyzed using image processing algorithms to provide a smart navigation interface. The major advantage of camera sensors is their ability to mimic human vision and react to dynamic environments. However, these sensors demand high processing power, and their performance can degrade significantly in low-light or high- glare conditions [3].

An accelerometer sensor, as demonstrated by Mradul Mehrotra, Narendra S. Pal, Kavisha Saxena, and Divyam Agarwal, enables gesture recognition by detecting tilts and movements of the user's hand or wrist. The sensor reads three-axis data, which is used to determine directional commands such as forward, reverse, left, or right. This allows users with speech impairments to control the wheelchair using intuitive hand gestures. Although it is highly responsive and consumes minimal power, its accuracy may be compromised by tremors or involuntary movements, especially in patients with motor disorders [4].

The system by Kaur P. and Jain K. incorporates a temperature sensor to measure the user’s body temperature. This feature is particularly relevant in health-monitoring wheelchairs for patients who are at risk of fever or heat-related illnesses. The sensor provides timely feedback and can be integrated with IoT platforms for remote alerts. While it adds valuable functionality, it requires precise placement and calibration to distinguish between body temperature and environmental fluctuations, which can otherwise affect the readings [5].

Lastly, the authors integrated three SRM04 ultrasonic sensors - two at the front and one at the rear—into the autonomous wheelchair system via the ATMEGA 2560 microcontroller. These sensors detect obstacles within 18–30 cm, triggering a buzzer to alert the user and automatically stop movement, ensuring safe navigation in crowded or unpredictable environments [6].

V. METHODOLOGY

The methodology for developing the Smart Wheelchair was designed in a structured and phased manner to ensure smooth integration of all components and successful execution of functionalities.

The project began with identifying the requirements for assisting elderly or physically disabled individuals with mobility, safety, and emergency communication. Based on this, the core features were finalized, which included wireless control via Bluetooth, obstacle detection, fall detection, emergency alerting through buzzer and email, and visual monitoring using a USB webcam.

The first step involved selecting appropriate hardware components. A Raspberry Pi was chosen as the central controller due to its ability to interface with multiple sensors and run Python code efficiently. For wireless communication, an HC-05 Bluetooth module was used, which connects the wheelchair to a mobile device. The wheelchair receives directional commands (1 for forward, 2 for backward, 3 for right, 4 for left, and 5 for stop) via a mobile application called Bluetooth Terminal. These commands are processed by the Raspberry Pi and then passed to the motor driver (L298N), which controls the movement of the motors accordingly.

To enhance safety, an ultrasonic sensor was integrated into the front of the wheelchair. This sensor continuously monitors for obstacles, and if anything comes within a set range, the Raspberry Pi immediately stops the wheelchair and activates a buzzer to alert the user. Additionally, an accelerometer is used to detect if the wheelchair tilts, flips, or falls. In such a situation, the buzzer is triggered again, and an emergency email is automatically sent to the caretaker or family member, indicating that the patient is in trouble.

Moreover, a USB webcam is connected to the Raspberry Pi to capture an image of the situation when a fall or tilt is detected. This image is then sent along with the email, so the caretaker can visually assess the condition of the patient and decide the next action. A 12V power supply is used to power all components, ensuring uninterrupted operation.

All the logic, sensor data handling, and communication tasks are programmed using Python. The code runs continuously on the Raspberry Pi to monitor all inputs and respond in real-time. This methodology ensured that the smart wheelchair is not only easy to operate but also safe and responsive to emergency situations, fulfilling the goals of the project effectively.

VI. SYSTEM IMPLEMENTATION

The implementation of the Smart Wheelchair system was carried out in a step-by-step manner to ensure proper integration of all hardware components and accurate functioning of the software. The system was built around a Raspberry Pi, which served as the main processing unit. All sensors, modules, and actuators were connected and interfaced with the Raspberry Pi GPIO pins according to the designed block diagram.

The first stage involved configuring the Bluetooth module (HC-05). It was paired with a smartphone using the"Bluetooth Terminal" application. The Raspberry Pi was programmed using Python to listen for incoming data from the Bluetooth module. Specific numeric commands (1 to 5) were assigned to control the movement of the wheelchair—forward, backward, right, left, and stop. These commands, once received by the Raspberry Pi, were processed and passed on to the motor driver (L298N), which in turn controlled the DC motors to drive the wheels accordingly.

Next, an ultrasonic sensor was mounted at the front of the wheelchair to detect obstacles. It continuously sent distance measurements to the Raspberry Pi. If an object was detected within a critical distance threshold, the system was designed to immediately halt the wheelchair's movement and activate the buzzer to alert the user of a potential collision.

To improve safety in case of accidents, an accelerometer sensor was integrated into the system. This sensor monitored the orientation of the wheelchair. If a sudden tilt or flip was detected, the Raspberry Pi responded by activating the buzzer and sending an emergency email alert to a preconfigured contact (typically a family member or caretaker). Simultaneously, the connected USB webcam captured an image of the scene and attached it to the email, giving the recipient visual insight into the incident.

A panic button was also installed, giving the user manual control to trigger emergency alerts whenever needed. The system ensured that all operations—movement, obstacle avoidance, fall detection, image capturing, and email alerts—ran smoothly in real time through Python scripts executed on the Raspberry Pi.

Power was supplied to the entire system using a 12V battery. Voltage regulation and power distribution were carefully managed to prevent overloads and ensure stable operation across all components.

In conclusion, the Smart Wheelchair system was successfully implemented using a combination of hardware integration and software logic. The entire unit was tested under various conditions to ensure its effectiveness in real- life scenarios. The result was a robust, intelligent, and safe mobility aid designed to enhance the independence and safety of disabled or elderly individuals.

VII. CONCLUSION

The Smart Wheelchair is an advanced and user-friendly system designed to make the lives of specially-abled individuals safer and more convenient. It incorporates features such as Bluetooth-based control, obstacle detection, tilt alert, emergency buzzer, camera integration, and real-time email notifications. This project demonstrates how modern technology can be applied to create practical and socially impactful solutions. In the future, additional features like GPS tracking, voice control, or AI-based navigation can be added to make the wheelchair even smarter and more efficient.

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