

STM32-Based Smart Electric Mobility Vehicle with Real-Time Monitoring and Safety Features

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Abstract: *Personal mobility devices can help users travel more independently, but safe operation requires responsive control, obstacle awareness and clear status information. This paper presents the design concept of an STM32-based smart electric mobility vehicle with real-time monitoring and safety features. The proposed system uses an STM32 microcontroller as the central control unit, ultrasonic sensors to estimate the distance to nearby obstacles, start/stop controls for user operation, an LCD for displaying status information, a motor driver and two drive motors. Sensor readings are processed by the controller and used to select a suitable movement response, such as forward motion, turning, slowing or stopping. The design separates low-voltage control electronics from the higher-current motor supply and emphasizes predictable operation, clear user feedback and an emergency stopping approach. A black-and-white system block diagram and an illustrative obstacle-response graph are included. The graph is a conceptual example rather than measured project data. Prototype evaluation should record obstacle-detection accuracy, stopping distance, response time, battery voltage, motor current and successful operation of the start/stop controls. The paper also reviews related embedded-control and smart-wheelchair work and outlines possible improvements. The actual performance and safety of the vehicle must be confirmed through controlled testing before practical use*

Keywords: STM32, electric mobility vehicle, ultrasonic sensor, real-time monitoring, motor driver, obstacle detection, safety control

I. INTRODUCTION

Affordable electric mobility systems combine embedded control, electric drive and sensing to support convenient movement. A basic vehicle can be driven with switches and a motor driver, but this arrangement provides limited information about nearby obstacles and system status. Adding sensors and a microcontroller allows the vehicle to respond to its surroundings and provide feedback to the user. These functions are especially relevant to low-speed mobility platforms where predictable movement and accessible controls are important [1], [2].

An ultrasonic sensor estimates distance by transmitting a sound pulse and measuring the time taken for its echo to return. When several readings are filtered and compared with calibrated thresholds, the controller can identify an obstacle in the sensing direction. Sensor placement, the shape and angle of the obstacle, surface material and environmental conditions can affect readings, so a single distance measurement should not be treated as infallible. A practical system should use conservative thresholds and a defined response when sensor data is missing or implausible. The STM32 family provides microcontroller options with timers, general-purpose input/output, communication interfaces and interrupt support. These peripherals can be used to read sensors, scan user controls, update an LCD and generate control signals for a motor-driver stage [3]. A motor driver is required because microcontroller pins cannot



supply the current needed by drive motors directly. The power design should therefore account for motor start-up current, voltage regulation, grounding, wiring protection and electrical noise.

This paper follows a literature-review structure similar to the supplied survey paper, but all application-specific discussion is adapted to the project titled “STM32-Based Smart Electric Mobility Vehicle with Real-Time Monitoring and Safety Features.” The paper describes the subsystems, reviews related approaches, proposes a system architecture and defines a test plan. Since measured prototype results were not provided, no experimental performance claims are made.

II. SYSTEM SUBSYSTEMS

A. STM32 Control Unit

The STM32 microcontroller is the central decision-making unit. It reads the ultrasonic sensor signals and start/stop inputs, updates the LCD, and sends logic-level commands to the motor driver. Firmware can be organized into repeated tasks: acquire sensor readings, validate the measurements, determine the requested motion, check safety conditions, update the motor outputs and refresh the displayed status. The exact pin assignment and peripheral configuration must match the selected STM32 model and its datasheet [3].

B. Obstacle Detection Sensors

Two ultrasonic sensors can provide distance information from different directions, depending on their physical mounting. The controller can compare each measured distance with a configurable safety threshold. If an obstacle is detected in the intended direction, the system can slow, stop or choose an alternate direction if the steering design supports it. Sensor readings should be time-limited; if an echo is not received or the value is outside the valid range, the safer response is to stop or enter a fault state rather than continue blindly.

C. Motor Driver and Drive Motors

The motor-driver module switches the higher current required by the DC motors and provides direction control. The STM32 sends control signals to the driver to support forward, reverse, left and right movement according to the vehicle’s mechanical arrangement. The motor supply must be sized for the motor voltage and stall/start-up current. The driver and controller should share a suitable signal reference, and decoupling, fuse protection and secure wiring should be considered. The actual driver IC and motor ratings should be added to the final version once confirmed.

D. User Controls and LCD Monitoring

Start and stop buttons provide a direct user interface. The firmware should define the state of the vehicle after powerup and after a stop command; a safe default is to keep the motors disabled until the user deliberately starts the system. The LCD can display operating state, measured distance, direction command and warnings such as “Obstacle Detected” or “Sensor Error.” The displayed information should be concise and readable while the vehicle is moving.

E. Power Supply and Safety Logic

The battery or DC supply must provide suitable voltage and current for the motor driver, while a regulated rail powers the STM32, sensors and display. Motor switching can create voltage dips and electrical noise, so power rails should be designed and tested under load. Safety logic should prioritize stop commands and sensor faults over movement requests. A physical emergency stop, if fitted, should interrupt motor drive independently of ordinary software commands. Water resistance, wiring insulation, mechanical stability and secure mounting also need to be considered for a real mobility platform.

III. REVIEW OF RELATED WORK

Research on smart wheelchairs and mobility aids has explored obstacle sensing, shared control and navigation support. Pu et al. studied a low-cost sensor network for obstacle avoidance in shared-control smart wheelchairs, illustrating the importance of combining sensor information with a control strategy [1]. A review of wheelchair navigation systems for disabled and older users discusses different approaches to navigation and assistive control, highlighting that the



appropriate design depends on user needs and the operating environment [2]. These works provide context for adding obstacle awareness to a mobility vehicle, but their results should not be assumed to apply directly to this prototype. Microcontroller documentation is also a key design source. The STM32 reference manual and datasheet should be used to verify GPIO electrical limits, timer functions, interrupt configuration, ADC or communication peripherals where needed, and operating-voltage requirements [3]. The final report should cite the exact STM32 part used by the team rather than relying on a generic family description.

TABLE I. COMPARISON OF CONTROL PLATFORM OPTIONS

Platform	Strengths	Considerations for this project
Arduino-class MCU	Simple development and basic motor/sensor control	Peripheral capability depends on board; may be adequate for a simple prototype
ESP32	Microcontroller control with integrated wireless options	Wireless features are not necessary for basic local safety; power and firmware complexity should be considered
Raspberry Pi	Useful for camera processing and high-level software	Operating system adds complexity; motor control still needs suitable driver hardware
STM32	Timers, GPIO, interrupts and PWM-capable peripherals across many models	Exact features depend on the selected STM32 variant and must be checked in its datasheet

IV. PROPOSED STM32-BASED MOBILITY VEHICLE

A. System Architecture

The proposed architecture contains sensing, control, user-interface, drive and power blocks. The ultrasonic sensors send distance-related signals to the STM32. Start/stop buttons provide user commands. The controller evaluates these inputs and generates motor-driver signals. The driver operates Motor 1 and Motor 2 to move the vehicle in the required direction. The LCD provides status and warning information. A regulated supply powers the controller and sensors, while the motor supply delivers the current required by the drive motors.

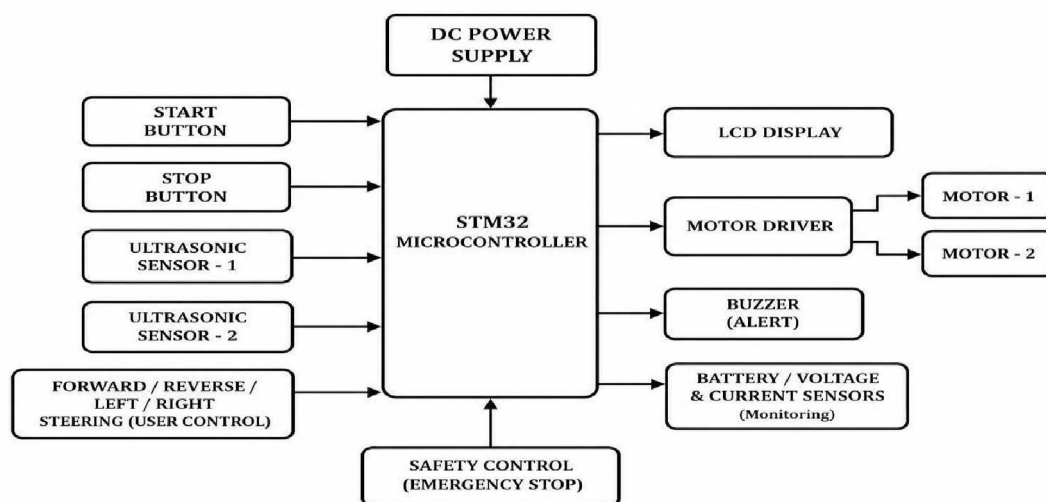


Fig. 1. Black-and-white block diagram of the proposed STM32-based smart electric mobility vehicle.



B. Operating Sequence

- 1) On power-up, initialize the STM32 peripherals, LCD and sensor interfaces while keeping the motor outputs disabled.
- 2) Wait for a valid start command. Continuously check the stop input and read the ultrasonic sensors using a defined timeout.
- 3) Validate the distance measurements and compare them with the configured safety zones. If a nearby obstacle or sensor fault is detected, prioritize stopping or a conservative response.
- 4) If the path is considered clear and the user has requested movement, command the motor driver to move the vehicle. Left/right turning must follow the actual motor wiring and chassis design.
- 5) Update the LCD with distance, motion state and warnings. A stop command must override all normal movement commands.

C. Real-Time Monitoring and Safety Features

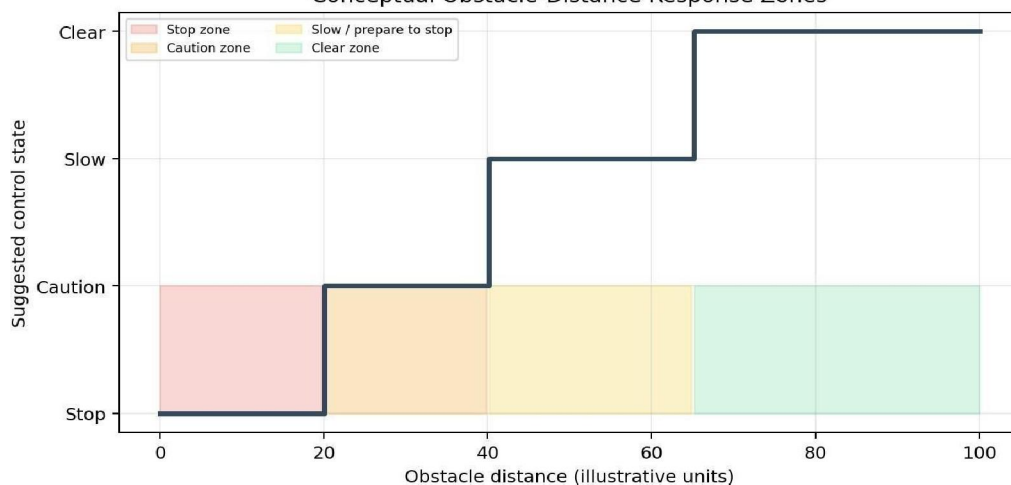
Real-time monitoring means that sensor measurements and the operating state are refreshed repeatedly during use, rather than only at start-up. The controller should use a predictable loop or scheduled tasks and avoid long blocking delays that could prevent a stop command from being processed. Sensor timeout detection, button debouncing, watchdog use where supported, and fault-state indication can improve robustness. The system should never be described as fully safe based only on the presence of ultrasonic sensors; the sensor coverage, braking behaviour, chassis stability and user-accessible stop mechanism must all be tested.

D. Difference from a Basic Mobility Vehicle

A basic switch-controlled vehicle generally relies on the user to judge the surroundings. The proposed design adds distance sensing and LCD feedback to support obstacle awareness. It also places stop handling and sensor validation within the control logic. Compared with a camera-based approach, ultrasonic sensing can keep the system simpler for low-speed proximity detection, although it does not provide detailed scene understanding. These are design intentions; comparative cost, reliability and safety advantages require testing.

IV. ILLUSTRATIVE GRAPH AND EVALUATION PLAN

Conceptual Obstacle-Distance Response Zones



Illustrative only — thresholds are placeholders, not measured prototype results.

Fig. 2. Conceptual obstacle-distance response zones; thresholds are illustrative and not experimental results.

Figure 2 presents an illustrative relationship between obstacle distance and a possible control state. It is included to explain how a threshold-based controller may be documented, not to claim that the prototype has been tested. The



example thresholds are placeholders and must be selected through risk assessment, sensor calibration and controlled trials. The actual control policy should also account for vehicle speed, braking delay and sensor blind zones.

TABLE II. PROPOSED PROTOTYPE TEST PLAN

Test	Measurement	Purpose
Distance sensing	Reference distance versus sensor reading	Estimate error and identify unreliable ranges
Obstacle response	Time from detection to motor stop	Check whether stop response is sufficiently fast
Start/stop control	Successful response over repeated trials	Verify that user commands are reliably recognized
Motor direction	Observed motion for each command	Confirm forward, reverse, left and right mapping
Power stability	Controller voltage and motor current under load	Identify resets, voltage drops or overheating
LCD status	Displayed distance, motion state and faults	Confirm that status updates are understandable

During testing, use a secured test area and a low speed. Record the actual STM32 model, motor driver, motor ratings, battery voltage, sensor positions and firmware thresholds. Repeat each test and report the number of successful trials and any failures. Do not place a person in the vehicle during early testing. Safety-related claims should be limited to the tests actually completed.

V. ADVANTAGES AND APPLICATIONS

Potential advantages include local embedded control, low-cost distance sensing, visible status feedback and the ability to stop movement when an obstacle is detected. The design may be useful as a student prototype for assistive mobility research, indoor transport demonstrations or a small electric platform. Suitability for a real user depends on load capacity, steering behaviour, braking, stability, battery endurance, accessibility and formal safety evaluation; these factors are outside what can be confirmed from the information currently supplied.

VI. LIMITATIONS AND FUTURE SCOPE

Limitations:

1. Ultrasonic sensors may miss narrow, angled, or soft obstacles and can produce unstable readings in some environments
2. Two ultrasonic sensors do not guarantee complete obstacle coverage around the vehicle.
3. Motor electrical noise may affect sensor readings or controller operation if wiring and power are not properly managed.
4. Battery voltage may drop during acceleration, which can affect motor performance and system stability.
5. The obstacle-response graph is illustrative; actual sensing accuracy and stopping performance must be confirmed through prototype testing.

Future Scope:

1. Wheel encoders can be added to provide wheel-speed feedback and improve motion control.
2. Battery voltage and current monitoring can be integrated to track power status and support low-battery warnings.
3. A buzzer can be added to provide audible alerts when an obstacle is detected.
4. A dedicated emergency-stop circuit can be implemented to improve safety.
5. Sensor position and orientation can be optimized, and additional sensors may be considered to improve coverage.
6. Speed limiting and data logging can be added to support safer operation and performance analysis.



7. Wireless monitoring or GPS may be considered only if required by the project scope and justified by the additional complexity.

VII. CONCLUSION

This paper presented an STM32-based smart electric mobility vehicle concept with real-time monitoring and safety oriented control. The proposed system integrates ultrasonic distance sensing, start/stop buttons, an LCD, a motor driver and two drive motors. The STM32 processes sensor and user inputs and coordinates movement while prioritizing stop commands and sensor faults. The block diagram and illustrative graph explain the intended architecture and threshold based response without presenting unmeasured results as experimental findings. The next stage is to build and validate the prototype through repeatable tests of sensing accuracy, stopping response, directional control, power stability and user-interface behaviour. The final report should include the actual circuit, selected component part numbers, firmware details and measured results.

VIII. ACKNOWLEDGMENT

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