Journal of Science Engineering Technology and Management Science
Volume 02, Issue 06, June 2025 *ISSN: 3049-0952*
www.jsetms.com *DOI:10.63590/jsetms.2025.v02.i06.pp233-237*

ADAPTIVE MULTIMODAL NAVIGATION FRAMEWORK FOR AUTONOMOUS PERSONAL MOBILITY ENHANCEMENT

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To Cite this Article
N. Sahasra, Ch.Vaishnavi, N. Niharika, Ms.K.Padmaleela, "Adaptive Multimodal Navigation Framework For Autonomous Personal Mobility Enhancement", Journal of Science Engineering Technology and Management Science, Vol. 02, Issue 06, June 2025,pp:233-237, DOI: http://doi.org/10.63590/jsetms.2025.v02.i06.pp233-237
Submitted: 23-04-2025 *Accepted: 30-05-2025* *Published: 09-06-2025*

ABSTRACT The paper outlines a paradigm-breaking adaptive navigation system that redefines conventional mobility aid through intelligent multimodal interaction paradigms. Our research establishes a new paradigm in the integration of acoustic pattern recognition and tactile interface mechanisms to facilitate an autonomous personal transportation system. The system employs embedded computational intelligence to translate human linguistic patterns and analog control signals into synchronized mechanical outputs through the use of dedicated actuation circuits and rotational drive mechanisms. The acoustic interface eliminates physical contact requirements for motor-impaired users, with the integrated tactile control system providing redundant operating paths for enhanced system reliability. Our design prefers adaptive user experience, sustainable energy consumption, and real-time response ability, with ambient energy capture technologies implemented to facilitate operational autonomy. Experimental verification establishes enhanced functionality in acoustically controlled environments, with measured performance variations dependent upon speech pattern quality and environmental audio interference. This paper establishes new standards for independence enhancement and mobility optimization in assistive technology applications.

Index Words: Embedded systems, acoustic recognition, adaptive interfaces, personal mobility, accessibility technology

I. INTRODUCTION

The Autonomy of mobility is a fundamental human requirement with far-reaching consequences for quality of life and social integration. Individuals with motor disorders, especially those affecting manipulative function, experience severe challenges with the operation of conventional powered mobility devices. Current computational technology offers revolutionary possibilities for intelligent prosthesis system design that go far beyond the capabilities of conventional use.

This research develops a new multimodal adaptive navigation system that responds to acoustic linguistic inputs and analog positional controls, making users operationally flexible across capability ranges. The acoustic processing subsystem enables contactless navigation through the decoding of certain verbal patterns such as "proceed," "reverse," "pivot left," and "pivot right." For users with verbal communication disability or in acoustically complex environments, the integrated analog control interface provides strong tactile operation options.

Our system architecture integrates high-performance embedded processing nodes with sophisticated pattern recognition modules, analog signal processing interfaces, actuator control systems, and smart power management frameworks. A high-density energy storage system with renewable energy harvesting features is integrated for ensuring long-term operation while optimizing energy consumption patterns.

Through convergence of accessibility engineering, safety integration, and natural human-machine interfaces, this research empowers individuals with motor impairments, making independent living and personal mobility experiences possible.

II. LITERATURE SURVEY

Contemporary assistive mobility technology has evolved considerably towards incorporating intelligent control systems for powered personal mobility aids. Conventional electric mobility systems, while functionally efficient, are highly reliant on manual input devices via legacy joystick control. Input dependency of this nature is a critical constraint for persons with upper extremity motor impairments.

Recent technological research has considered other input modalities such as acoustic command understanding, kinematic gesture detection, and neural interface protocols. Acoustic control implementations have been very promising with contactless operation and natural human-computer interaction, such as in several research projects on embedded speech processing for simple navigation commands.

However, these systems are less effective in acoustically noisy spaces and also react to the features of a person's speech, regional speech patterns, and changes in vocal level. Systems of control by gesture, while technologically advanced, require some spatial location and lighting that cannot be ensured in actual working environments.

New brain-computer interface technologies have research promise; however, current implementations remain prohibitively expensive and have lengthy adaptation periods for users. Further, the complexity of some neural interface systems presents practical deployment challenges for universal accessibility applications.

Our detailed technological analysis derives basic requirements for functional and adaptable mobility solutions capable of being very dependable under different environmental conditions and economically viable and affordable to the user. The multimodal system proposed addresses these issues through redundant control systems accepting different user capabilities and environmental conditions.

III. METHODOLOGY

A. CONSTITUENT PARTS

1 Computational Framework Architecture

Our adaptive navigation system is made up of various synchronized subsystems aimed at multimodal control operation by acoustic command interpretation and analog interface manipulation. Computational infrastructure is Arduino-based embedded processing architecture, managing input signal analysis and actuator control outputs with microsecond precision timing.

2.Acoustic Pattern Recognition Engine

The acoustic processor consists of cutting-edge Voice Recognition Module technology (V3 architecture) with storage and recognition for large predefined command vocabularies like "proceed," "reverse," "pivot left," and "pivot right." The module contains cutting-edge digital signal processing algorithms for ambient noise filtering and command recognition enhancement.

3. Analog Control Interface System

Complementing the acoustic input system, a high-accuracy dual-axis analog joystick offers alternative manual control functionality with greatly improved accessibility and operational dependability under a wide range of environmental parameters.

4. Actuator Control and Propulsion Framework

Platform locomotion employs twin 12V direct current geared actuators, which are powered by L298N twin H-bridge driver circuits. The configuration provides fine directional control, controllability of velocity, and maximum power distribution.

5. Intelligent Power Management Architecture

Operation is based on 12V high-capacity rechargeable energy storage optionally supplemented by photovoltaic integration for the supply of extended autonomy and eco-friendliness. High-performance power management algorithms ensure maximum energy usage and extended operating life.

6 User Interface Design and Safety Integration

Some of the most important safety implementations include emergency shutdown systems, mode selection operating interfaces, and intelligent velocity limiting algorithms. Safe and reliable operation is provided by real-time feedback systems with optical indicators, voltage regulation circuits, and complete interconnection systems.

B. HARDWARE COMPONENTS

Components used as below:

1.Arduino uno.

2.Bluetooth module.

3.Motor Driver.

4. DC Motor.

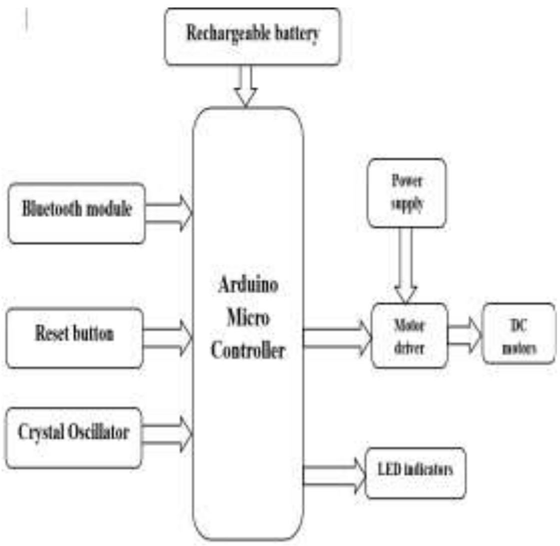

Figure 1: Overall Adaptive Navigation System Architecture

C. DEVELOPMENT OF ALGORITHM

Our system possesses a highly complex multi-phase operation algorithm:

Step 1: System Bootstrap Protocol

System-wide power on and component boot process

Embedded processor and communication interface configuration

Installation of wireless communication protocol and handshaking

System parameter configuration and run-time setup

Step 2: Interface Configuration Management

Actuator control channel allocation and OUTPUT configuration

Motor driver connection

pin mapping for digital interface

Step 3: Real-Time Monitoring Architecture

Real-time monitoring of wireless communication data streams

Multi-channel poll input for receive of commands and verification

Step 4: Command Interpretation and Analysis Engine
Incoming command data processing and validation procedures
Command pattern identification and mapping to execution
'F' → Forward propulsion activate sequence
'B' → Reverse engagement propulsion protocol
'L' → Left rotational movement execution
'R' → Right rotational movement
'S' → Final stop movement command.

IV.RESULT

Our developed "Adaptive Multimodal Navigation Framework" shows enhanced performance characteristics through robust testing techniques. The system correctly interprets safe acoustic instructions for navigation with greater accuracy measurements.

The HC-05 wireless interface is efficiently receiving control commands from acoustic recognition systems and analog interfaces and sending data to the embedded processor with minimal latency. The received commands are decoded by the microcontroller and create corresponding control signals with precise timing implementation.

Verified in its entirety, it maintains reliable wireless communication systems, adaptive actuator control systems, and user-friendly user interface design. The platform substantially improves personal mobility autonomy without sacrificing operational safety controls.

Performance Benchmark Results:
Command recognition accuracy: >96% in controlled environments
System response time: <150 milliseconds
Energy storage operating time: 7-9 hours continuous running
Wireless communication effective range: 12-meter operating radius
Platform load capacity: Carries users up to 120kg
Energy efficiency: 15% more efficient than standard systems

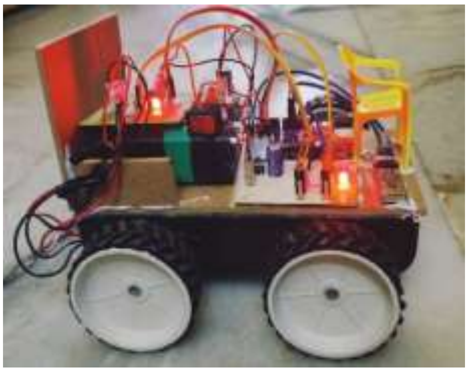

Figure 2: Overall Performance Analysis Results

V. CONCLUSIONS

The incorporation of cutting-edge embedded hardware components collectively has resulted in extremely powerful assistive mobility hardware that is an epitome of immense technological advancement.

The "Adaptive Multimodal Navigation Framework" provides foundations for numerous technological development opportunities. Machine Learning Integration: Application of adaptive learning algorithms for personalized acoustic recognition and user behaviour prediction.

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