Solar Powered Self-Balancing Hoverboard

Ch. Gayatri[1], G Karthikeya[2], G Thanush Kumar[3], M Adbhuta[4], N Bhanu Kiran[5]
[1,2,3,4,5,6]Dept of ECM, Vignan's Institute of Information Technology (A), Visakhapatnam, India.

Abstract: Self-balancing technology now plays a key role in personal transportation and robotics and industrial automation sectors because it delivers better mobility and stability. The proposed work brings forward a solar-powered self-balancing hoverboard system that supports weights up to 100 kilograms while replacing conventional electric mobility solutions with environmentally friendly technology. An MPU6050 Inertial Measurement Unit (IMU) serves as the central component for real-time tilt angle and angular velocity detection which the system utilizes for monitoring purposes. The Arduino microcontroller uses processed MPU6050 Inertial Measurement Unit data to generate control signals to BLDC motors for providing real-time balance adjustment and operational smoothness. The hoverboard makes use of pressure sensors that enable its users to control acceleration and deceleration based on their body position. The device includes warning buzzers that activate when tilt angles get extreme and when battery levels become too low and it also uses LED status signals to show operational readiness. The main innovation of this hoverboard includes a solar-powered backup power system that helps users avoid external charging requirements. The Li-ion batteries are being charged by a 5W solar panel using a charge controller to regulate the charging levels and also safeguard battery life spans. An inverter network is responsible for efficient transmission of power from solar sources in order to yield longer runtimes. The analysis of performance considers both Battery Performance Over Time to ensure maximum usage of energy and Tilt Angle vs. Speed Analysis to evaluate system response based on varying conditions. Bluetooth connectivity technology on the hoverboard enables wireless music streaming with voice instructions that guide users in the use of the device to attain a smart intelligent experience. The product combines self-balancing technology with renewable energy to provide a new idea of modern mobility that is very efficient and exhibits intelligence as well as energy-saving features.

Key Words: Self-balancing technology, solar-powered hoverboard, MPU6050 IMU, Arduino microcontroller, BLDC motors, pressure sensors, Li-ion batteries, charge controller, inverter system, Bluetooth connectivity, energy efficiency.

1. INTRODUCTION:

The developed project amalgamates solar-charged autonomous technology with hoverboard features to deliver power independence along with mobility advantages. Real-time balance management uses the MPU6050 IMU sensor paired with the Arduino microcontroller to process motion data but this design differs from standard hoverboards since they need frequent external power charging. Movement throughout the onboard application triggers automatic brake and accelerator sequences when the built-in pressure sensors detect user entry and exit actions while the BLDC motors adapt speed performance through angular tilt evaluation. The solar backup system operates without interruption due to its charging function enabled by inverter which operates independently of external power sources. The system operates stably due to weight-capable adaptive motors and real-time alert functionality through

LEDs and buzzing mechanisms.

Distance measurement between gyroscopes and tilt angles that is aim-controlled leads to enhanced balance control and generates stable operation and declines environmental footprint. Growing market needs for secure and exact self-balancing systems emerge from the expanding technological progress since these systems find extensive application in mechanical systems. The field of research continues to optimize control methods for autonomous robotic mobility systems because it improves both agility performance and system stability and real-time responsiveness. The paper addresses both the current advantages and obstacles of free-standing systems.

An Attitude Controller based on ADRC when combined with ROS enhanced the stability of self-balancing robots through superior disturbance management when contrasted to PID controllers. Real-time systems faced difficulties implementing the controller because its implementation needed complex processing requirements [1]. This project focuses on designing and fabricating an automated water-jet robot for cleaning photovoltaic (PV) panels using an Arduino-controlled system with an HC-05 Bluetooth module. The system enhances efficiency by enabling remote operation, ensuring optimal solar energy absorption with minimal manual intervention [2]. The study provides valuable insights into how top-loading modifications can be leveraged to improve the efficiency and adaptability of LPDA antennas for modern wireless applications [3].

A machine learning algorithm implemented to control the balance of an inverted pendulum platform managed changing weights. Implementation of this system faced difficulties because of its complicated training requirements [4]. This research focuses on the strategic placement of solar power plants and Interline Power Flow Controllers (IPFC) to enhance grid stability and prevent blackouts. By optimizing power distribution and flow control, the system improves energy reliability and resilience against disruptions [5]. Deep learning technology allowed humanoid robots to obtain increased environmental safety by using predictions about joint-space movements to maneuver safely within restricted areas. High computational requirements prevented embedded system usage of this approach [6].

This study analyzes the performance of a multi-user MIMO system utilizing a successive hybrid beamforming approach for simultaneous information and energy transfer. The model enhances spectral and energy efficiency, optimizing wireless communication and power harvesting in next-generation networks [7]. This paper presents an optimized design of a double-notch E-shaped inset-fed patch antenna with enhanced bandwidth and improved VSWR performance [8]. Autonomous robotic movement enhanced by AI allowed machines to balance more effectively in dynamic situations though robots maintained limited speed control and reaction capabilities in unforeseen circumstances [9].

Real-time video data calculations done by deep learning algorithms have brought much needed improvements to the navigation capabilities of the two-wheeled robot. The system performance degraded when used in situations where clear vision data was unavailable especially under low-light or visually unclear conditions [10]. The application of machine learning resulted in better humanoid robot stability on uneven surfaces because it provided real-time control capabilities which surpassed traditional PID controllers. The research showed that combining AI technology with traditional control approaches improves stability and adaptability when controlling self-balancing systems according to [11].

A pause-and-go control system utilized vision and ultrasound sensors to enhance stability but its control required sensor response synchronization to perform effectively in real-world conditions as reported in [12]. The wheel-leg robot achieved better balance and movement control through an uncertainty measurement system. Adjustments to variable conditions occurred in the system but the device struggled to function in real-time. The technology required further improvement to reach utilization standards in dynamic operational environments [13].

The path planning capabilities of multi-legged robots were enhanced by constraint modeling yet these robots had excessive computational expenses which hindered real-time operation, needed optimization [14]. The robotic cane assisted users with stability through intelligent motion by providing balance support. Accurate calibration processes for each user determined how well the system worked. Flexible control systems would increase customization capabilities and make the system easier to use [15].

2. Methodology:

Working Principle: An inverted pendulum system in hoverboards drives the stability mechanism which needs continuous adjustment to stay level. A system managed by an Arduino takes sensor input from MPU6050 to detect the tilt angle and angular velocity. After signal processing from the system the BLDC motor hub receives corrective signals that control motor speeds to balance the system.

The hoverboard controls motor speed by accelerating forward from user forward tilts and slowing down or reversing while the user tilts backward. Under no detection of tilt the system keeps itself stationary so it can maintain stability. A pressure sensor system tracks weight distribution while operating on signals that result from user actions.

The hoverboard includes a stellar solar charging system as one of its essential features. The external solar panel collects energy through a charge controller to feed into a battery thus sustaining operation independently from different power sources. This system enables users to experience increased operational times with efficient energy management.

User safety becomes more manageable because the hoverboard has a buzzer system to notify users about unstable conditions and battery depletion and extreme tilt angles. LED indicators serve the purpose of displaying real-time feedback which helps users maintain better system reliability as well as increased situational awareness.

3. System Design:

The self-balancing hoverboard consists of the following components:

- **MPU6050 (IMU Sensor) –** The device measures both balance tilt angles and angular velocity to activate balance adjusting functions.
- **Arduino Uno –** The device functions as the primary controller which processes sensor information before it manages motor operations.
- **BLDC Motors –** The device propels itself and maintains stability through speed control which depends on the tilt angle.
- **BLDC Motor Driver Hub –** The DC motor receives control signals from the microcontroller for adjusting its operational speed.
- **Pressure Sensors –** The device detects user weight distribution which supports control of movements through mobility aids.

- **LiPo Battery –** The hoverboard receives electric power through the power storage systems which enable its continued operation.
- **Solar Panel –** The device enables solar energy capture through self-charging functions which improve battery longevity.
- **Inverter with Plug Board –** An essential component that converts solar power into a format that can recharge the hoverboard battery.
- **Li-ion Batteries –** Extended operation under low sunlight is possible because the device stores additional solar energy during charging.
- **Buzzer –** The device warns users about system instability as well as alerts them for both high chair tilt levels and battery power depletion.
- **LEDs and LED Strips –** Mechanisms to display system performance alongside safety alerts should be present on the interface visually.
- **Bluetooth Module –** The device provides hands-free music streaming along with spoken instructions from the phone.
- **Jumper Wires & Connectors –** The devices use electrical connections for connecting diverse parts and components.

Different elements within the hoverboard system create balanced movement and optimized usage of energy to achieve both operational stability and sustainable operation.

4. Components Explanation:

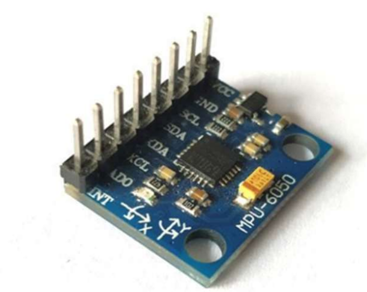

Fig 4.1: MPU 6050

Fig 4.2: ARDUINO UNO

Fig 4.3: BLDC MOTORS

Fig 4.4: BLDC MOTOR DRIVER HUB

Fig 4.5: PRESSURE SENSOR

Fig 4.6: BATTERY

Fig 4.7: SOLAR PANEL

Fig 4.8: INVERTER WITH PLUG BOARD

Fig 4.9: LI-ION BATTERIES

Fig 4.10: BUZZER

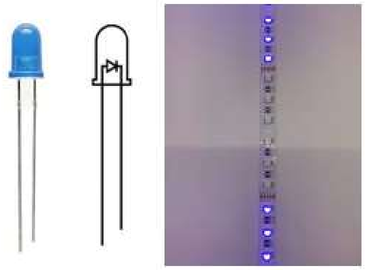

Fig 4.11: LEDS AND LED STRIPS

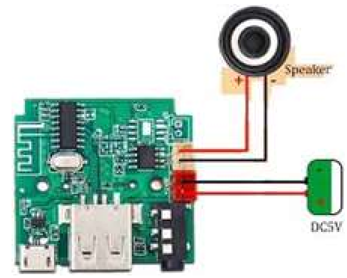

Fig 4.12: BLUETOOTH MODULE

Fig 4.13: JUMPER WIRES

Description:

The MPU6050 module as presented in Fig. 4.1 functions as the basis for self-balancing operations through accelerometer and gyroscope integration that provides precise orientation and movement and tilt angle measurements. The hoverboard obtains real-time data that leads to more precise balance control thus improving its stability throughout various terrain surfaces. The main processing tasks which include sensor interpretation and movement command execution take place through the Arduino Uno system shown in Fig. 4.2. Reacting smoothly to user commands is possible through BLDC motor operation which generates adequate torque to keep hoverboard equilibrium in Fig. 4.3. Hoverboard systems choose BLDC motors because they reduce power usage while providing high torque output which suits self-balancing needs.

As presented in Fig. 4.4 the BLDC motor driver hub distributes power through safety protocols that protect against voltage spikes and heat-related breakdowns to achieve continuous operation. The pressure sensor presented in Fig. 4.5 improves operational control by monitoring user presence and weight distribution which allows smooth acceleration and deceleration. A high-performance Li-ion battery pack shown in Fig. 4.6 offers both excellent energy density and rechargeable abilities for system power supply. Green energy charging through sunlight collection by solar panels is illustrated in Fig. 4.7 which decreases our dependence on external power electricity. This inverter depicted in Fig. 4.8 contains a plug board which enables smooth DC to AC power conversions for maintaining continuous energy supply. The Fig. 4.9 of the backup Li-ion batteries enables the storage of excess solar energy for maintaining power supply during periods of low sunlight.

The hoverboard receives extra functionality through its built-in safety features. The security buzzer in Fig. 4.10 warns users about vital tilt angles and low power while stopping unsafe use of the device. Fig. 4.11 demonstrates the advantages of the LED indicators and LED strips which enhance viewing capacity during darkness as they notify users about battery power and warning signals as well as security alerts. The Bluetooth module added in Fig. 4.12 allows wireless music streaming alongside voice-guided navigation features which enhance both user experience and convenience. Flex jumper wires in Fig. 4.13 enable easy component communication without soldering thus granting users greater access to maintain and modify the hoverboard system.

5. Software Used

1. **Arduino IDE**: Used for programming the Arduino microcontroller to process step counts and manage energy storage.

2. **Proteus**: Designers use this program for circuit testing as well as electronic component assessment before actual hardware development.

6. WORKFLOW/WORKING:

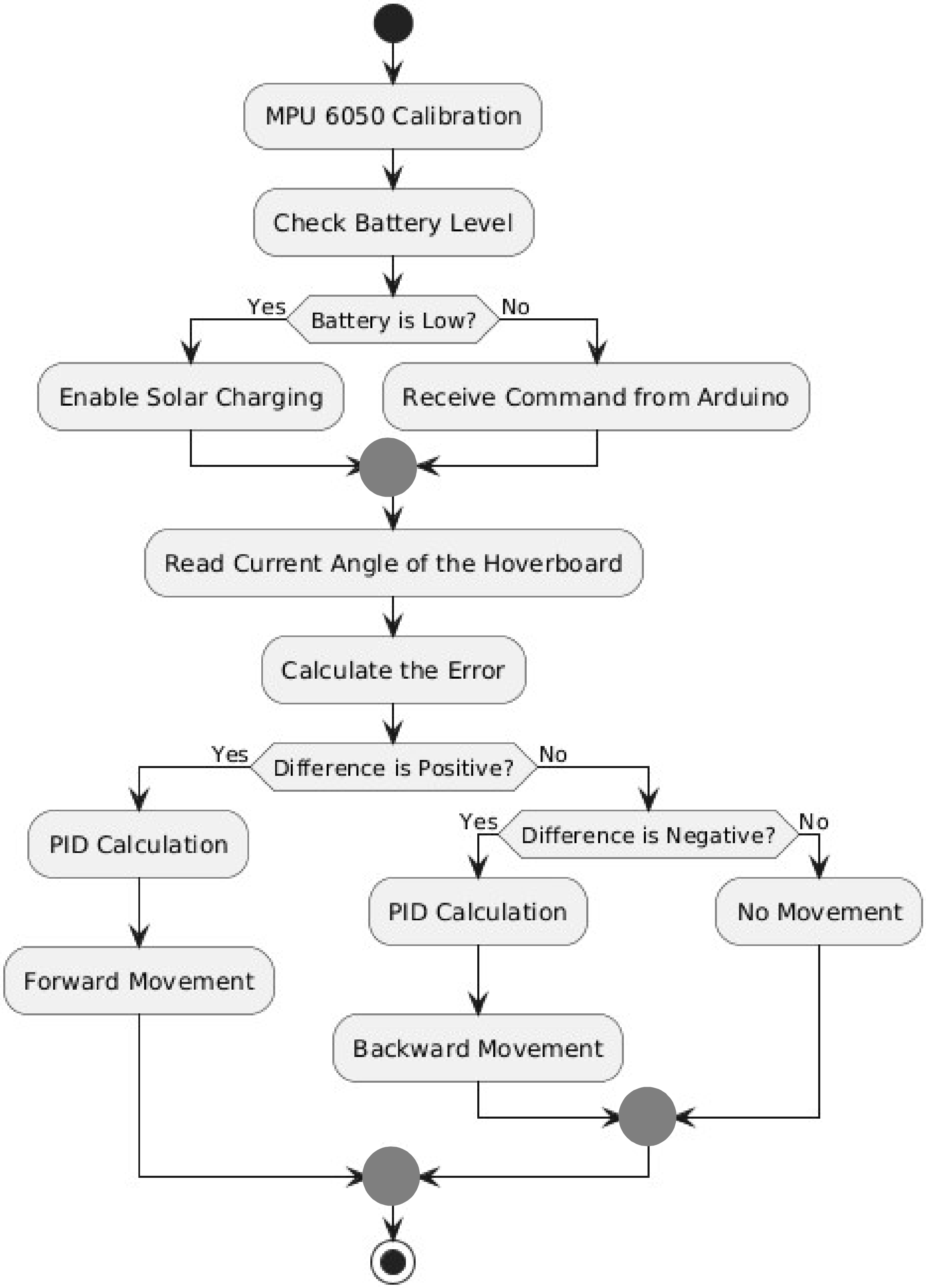

Fig. 6.1: Flowchart

7. Implementation:

Through constant sensor input the MPU6050 IMU detects balance disturbances by monitoring both tilt angles and angular velocity obtained during hoverboard motion. Real-time data processing on the Arduino Uno device produces signals which guide the BLDC motor drivers to alter motor speeds for maintaining stability.

The pressure sensor monitors how weight is distributed on the hoverboard so it can identify which movements the user plans to perform. The hoverboard moves forward under forward leaning pressure and slows or stops when the user leans backward. The control mechanism lets users extend operating times by connecting solar power to a system that is powered by charging Li-ion batteries.

A buzzer alerts users to unsafe tilt angles, low battery levels, and system instability. The system displays its operational status by using LED indicators as well as LED strips. Built-in Bluetooth allows users to stream audio wirelessly yet voice assistance delivers route directions to users. The device binds to green energy systems to achieve operational efficiency and balanced movement.

8. Results and Discussion:

The hoverboard provided permanent stability irrespective of 100-kilogram loads through its consistent processing of sensor data as well as self-regulation of motor speeds. Its prolongation of battery life by the self-charging solar system varied with the level of sunlight in effect to its power source. The pressure sensor continually detected the presence of users in addition to detecting changes in body weight to provide smooth acceleration as well as braking of the vehicle. With buzzer notification and LEDs, users received essential alerts signaling unstable states of operation and battery low levels that enhanced their safety experience. Renewable power integration meant better energy efficiency along with reliable self-balancing functionality.

This device obtains balance control after speed adjustment from solar-powered charging systems. The final product design as a whole and the major components of it can be viewed through photographs.

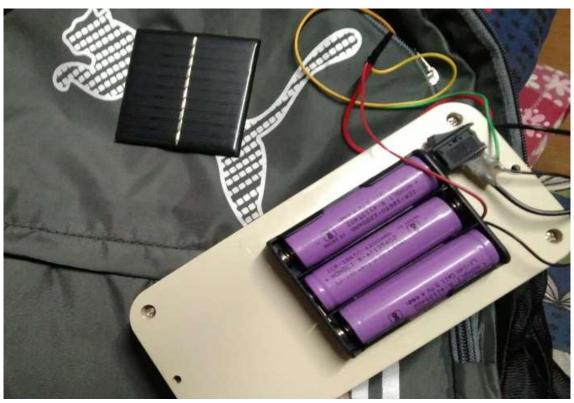

Fig 8.1: Solar Backup

Fig 8.2: Self-Balancing Hoverboard

Tilt Angle vs. Speed Analysis:

This analysis shows how speed changes with tilt angle in order to achieve stability and controlled movement.

Table: Tilt Angle vs. Speed Performance

Tilt Angle (Degrees)	***Speed Achieved (m/s)***
0°	0.0
5°	0.5
10°	1.0
15°	1.8
20°	2.5
25°	3.2
30°	4.0

Table 8.1: Tilt Angle vs Speed

Graph: Tilt Angle vs. Speed

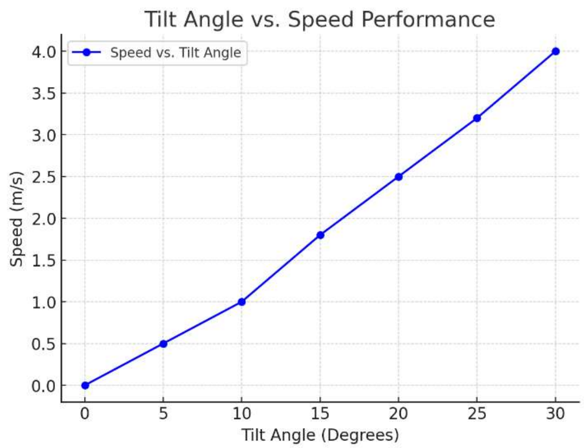

Fig 8.3: Graphical Representation of Tilt vs Speed

Battery Performance Over Time:

During the battery performance analysis, the materials discharged steadily during 1.5 hours to maintain operational stability.

Table: Battery Performance Over Time

Time (Minutes)	***Battery Level (%)***
0	100
15	85
30	70
45	55
60	40
75	25
90	10

Table 8.2: Battery Performance Over Time

Graph: Battery Performance Over Time

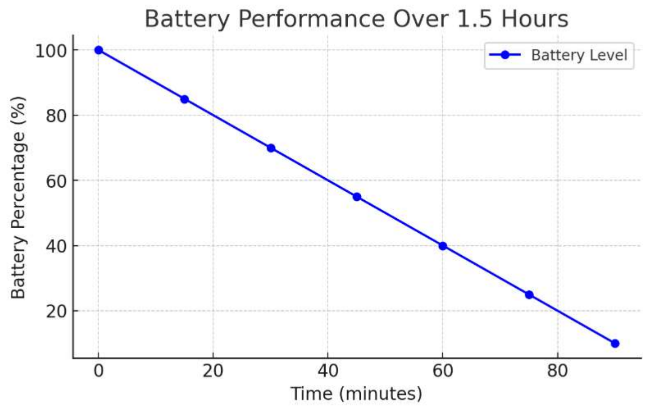

Fig 8.4: Graphical Representation of Battery Performance

9. Limitations and Future Scope:

Operational performance of the hoverboard is solar power charging based with normal sunshine conditions still required for system operation. For poor reception of solar power, the equipment takes longer to charge that reduces its operational time. Proper regulation of hoverboard operations depends on effective balance optimization alignments since they enable safe operation of quick movements.

The most important operational constraint arises from increased battery efficiency achieved as a result of improved management systems to provide more operating time for the hoverboard. A novice rider will need to get used to the self-driven mechanism of the hoverboard first before he/she can direct the hoverboard for accurate movement. Even movement of the hoverboard depends on proper weight distribution since weights above 100 kg trigger unstable performance. Solar-powered energy storage systems and power storage systems will render next-generation hoverboards more efficient and versatile. Advanced balance hoverboard systems and advanced control algorithms allow the drivers to have control over how responsive and quick they are as improved regenerative braking guarantees maximum recycling of energy in an attempt to enhance hoverboard usage time before recharging.

The users should be able to view their speed and battery power information through expert features in all mobile app sessions. The AI security system utilizes perception technology to detect potential dangers that trigger its route planning for defensive purposes. The security technologies will be upgraded after the incorporation of light materials with more efficient control systems that offer stable hoverboards.

10.Conclusion:

The research designs a hoverboard system and self-balancing control with a focus on green personal mobility, all powered by solar energy. The system can provide natural smooth motion with robust stability by real time balance correction sensors and BLDC motors. The equipment has an environmental aspect through the solar charging technology which enables it to power grid free standalone mode than conventional hoverboards. The system integrates the pressure sensors into the system to be able to implement automatic speed control functions in an attempt to reduce risks and increase customer satisfaction. Regenerative braking measurement enhances power saving and thus the battery efficiency and the working time of the system. The sensitivity to the rapid movement is enhanced in the AI powered hoverboard that learns from the time it is used to make its stability measurements. Enhanced user experience will be a result of future smart connectivity tools that add remote monitoring diagnostics capabilities to this system. Future developments in lightweight construction together with advanced material science offer improvements that make the device portable with maintained durability. The hoverboard has a strengthened structure that keeps users up to 100 kg safe while providing stable operations. The hoverboard will progress from a reliable and flexible mobility platform because of ongoing advancements in energy storage technology and motor efficiency and control algorithm development. The integration of renewable energy systems with intelligent automatic systems makes this project help create sustainable along with efficient urban transport solutions.

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