Low-Cost SLAM Robot Using TB6612 gyro sensor and ESP32

Dr Rekha Sonune[1], Nikhil Mokale[2], Shivam Jaiswal[3], Yash Patil[4], Sairaj Tatkare[5]
[1]*Guide, Department of Electrical Engineering, Lokmanya Tilak College of Engineering, Mumbai University, India*
[2,3,4,5]*Department of Electrical Engineering, Lokmanya Tilak College of Engineering, Mumbai University, India*

Abstract- This paper presents the design and development of a low-cost Simultaneous Localization and Mapping (SLAM) robot using LiDAR simulation and embedded hardware implementation. The proposed system combines MATLAB-based simulation for environment mapping with a practical prototype built using an ESP32 microcontroller, gyroscope sensor, and motor driver. The simulation phase focuses on accurate mapping and localization using LiDAR data, while the hardware implementation aims to achieve cost-effective real-time navigation. The integration of sensor data allows the robot to estimate its position and generate a map of unknown environments. The proposed approach reduces system cost while maintaining acceptable performance for indoor navigation applications. Experimental and simulation results demonstrate the effectiveness of the system in terms of mapping accuracy and stability. This work provides a foundation for developing affordable SLAM-based robotic systems for educational and practical applications.

I. INTRODUCTION

Simultaneous Localization andMapping (SLAM) is a fundamental problem in robotics, where a robot must build a map of an unknown environment while simultaneously determining its position within that environment. SLAM is widely used in applications such as autonomous vehicles, robotics, and indoor navigation systems.
However, most SLAM systems are expensive due to the use of high-end sensors and processing units.

In recent years, there has been a growing interest in developing low-cost SLAM systems for educational and research purposes. This paper focuses on designing a cost-effective SLAM robot using LiDAR-based simulation in MATLAB along with a hardware prototype built using an ESP32 microcontroller, gyroscope sensor, and motor driver. The use of MATLAB allows easy visualization and testing of SLAM algorithms, while the ESP32 enables real-time implementation at a lower cost.

The main objective of this work is to develop a hybrid system that combines simulation and hardware implementation to achieve efficient mapping and localization. The proposed system aims to reduce cost without significantly compromising performance, making it suitable for students and small-scale robotics applications.

II. LITERATURE REVIEW

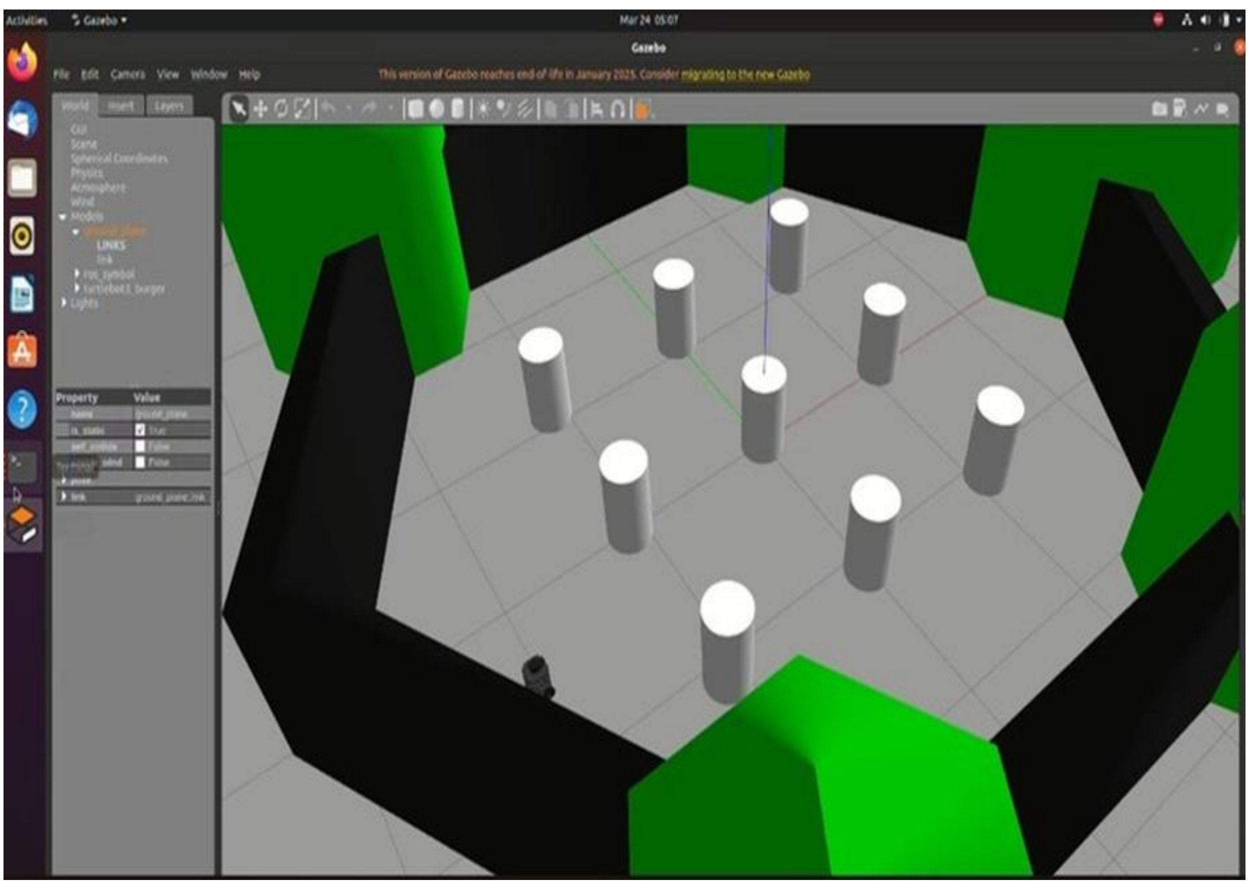
Simultaneous Localization and Mapping (SLAM) has been extensively studied using various sensing and computational approaches. One advanced method, SLAM++, focuses on object-level mapping, where the environment is represented using high-level features instead of raw sensor data. This approach improves computational efficiency and mapping accuracy, making it suitable for complex environments

Radio-based SLAM techniques have also been explored as an alternative to traditional sensor-based methods. These approaches utilize radio signals for localization and mapping, providing a cost-effective solution. However, they are often affected by signal interference and environmental noise, which can reduce accuracy WiFi-based SLAM systems, such as P2SLAM and RWiFiSLAM, use signal strength and ranging techniques to estimate the position of a robot in indoor environments. These systems are relatively low-cost and easy to implement, but they generally provide lower accuracy compared to LiDAR-based SLAM methods

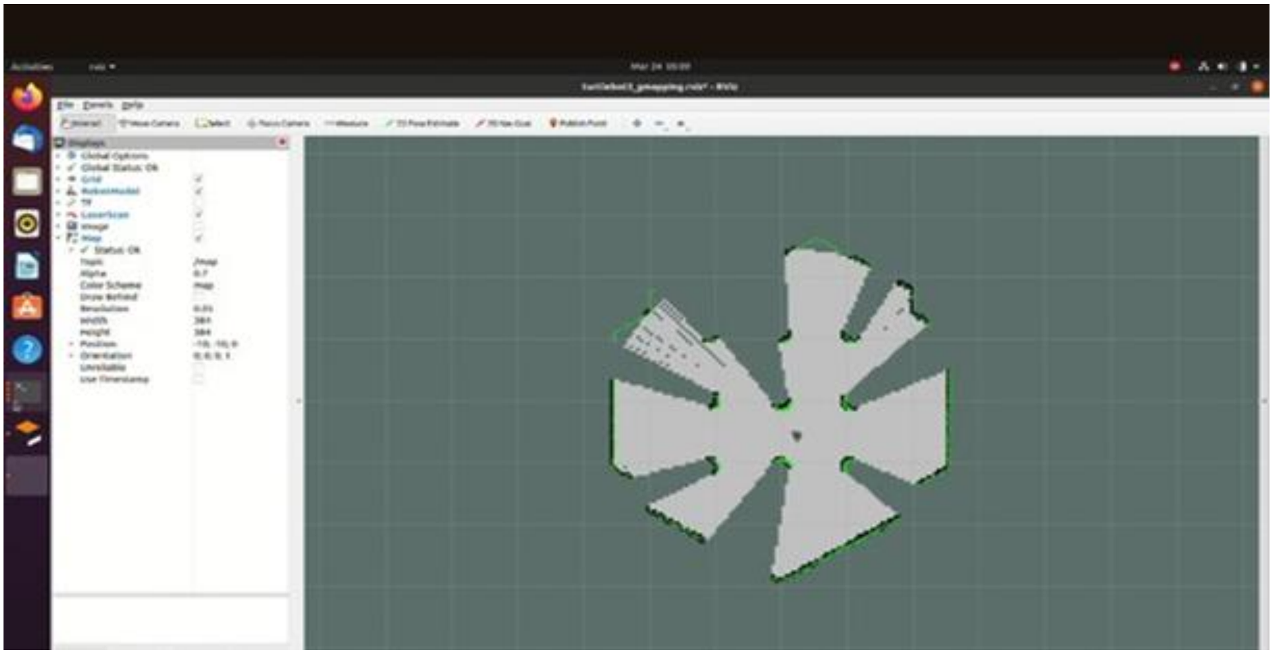
Recent research has focused on hybrid approaches that combine SLAM with WiFi-based positioning and machine learning techniques. These systems improve localization and tracking performance in indoor spaces, but they increase system complexity and computational requirements From the above studies, it is observed that LiDAR-based SLAM offers high accuracy and robustness, while WiFi and radio-based methods provide cost advantages. Therefore, this work proposes a hybrid system that combines LiDAR-based simulation using MATLAB with a low-cost hardware implementation using ESP32, gyroscope, and motor driver to achieve an optimal balance between performance and affordability.

[1] R. F. Salas-Moreno, R. A. Newcombe, H. Strasdat, P. H. J. Kelly, and A. J. Davison, “SLAM++: Simultaneous Localization and Mapping at the Level of Objects,” IEEE Conference, 2013.
[2] B. A. Zekavat and R. M. Buehrer, “Radio SLAM: A Review on Radio-Based Simultaneous Localization and Mapping,” IEEE Communications Surveys & Tutorials, 2019.
[3] A. Nour, R. Koubâa, “P2SLAM: Bearing Based WiFi SLAM for Indoor Robots,” IEEE, 2018.
[4] B. Wang, S. Fang, H. Cheng, J. Chen, W. Yang, and J. Zhang, “RWiFiSLAM: Effective WiFi Ranging SLAM System in Ambient Environments,” IEEE, 2017.
[5] G. Lee, B. Moon, S. Lee, and D. Han, “Fusion of SLAM with Wi-Fi-Based Positioning Methods for Mobile Robot-Based Learning Data Collection, Localization, and Tracking in Indoor Spaces,” IEEE Access, 2020.

III. SIMULATION AND PICS



3D view of background



IV. HARDWARE IMPLEMENTATION

The hardware implementation of the proposed low-cost SLAM robot is designed using compact and efficient components to achieve real-time navigation and localization. The system integrates a microcontroller, sensors, motor driver, and power supply to perform robotic movement and data acquisition.

The main controller used in this system is the ESP32-CAM Module, which is a low-cost microcontroller with integrated Wi-Fi and camera capabilities. It operates at a voltage of 5V and is powered by an ESP32-S chip with a clock frequency of up to 240 MHz. It has 4 MB flash memory and supports UART, SPI, and I2C communication protocols, making it suitable for sensor interfacing and wireless communication.

For motor control, the TB6612FNG Motor Driver is used. It operates within a motor supply voltage range of 4.5V to 13.5V and can deliver a continuous current of 1.2A per channel, with a peak current of up to 3.2A. It provides high efficiency and supports PWM-based speed control along with bidirectional motor operation.

The orientation and motion sensing is performed using the MPU6050 Sensor, which is a 6-axis sensor combining a 3-axis gyroscope and a 3-axis accelerometer. It operates at 3.3V to 5V and communicates using the I2C protocol. The gyroscope has a sensitivity range of ±250 to ±2000 degrees per second, while the accelerometer has a range of ±2g to ±16g.

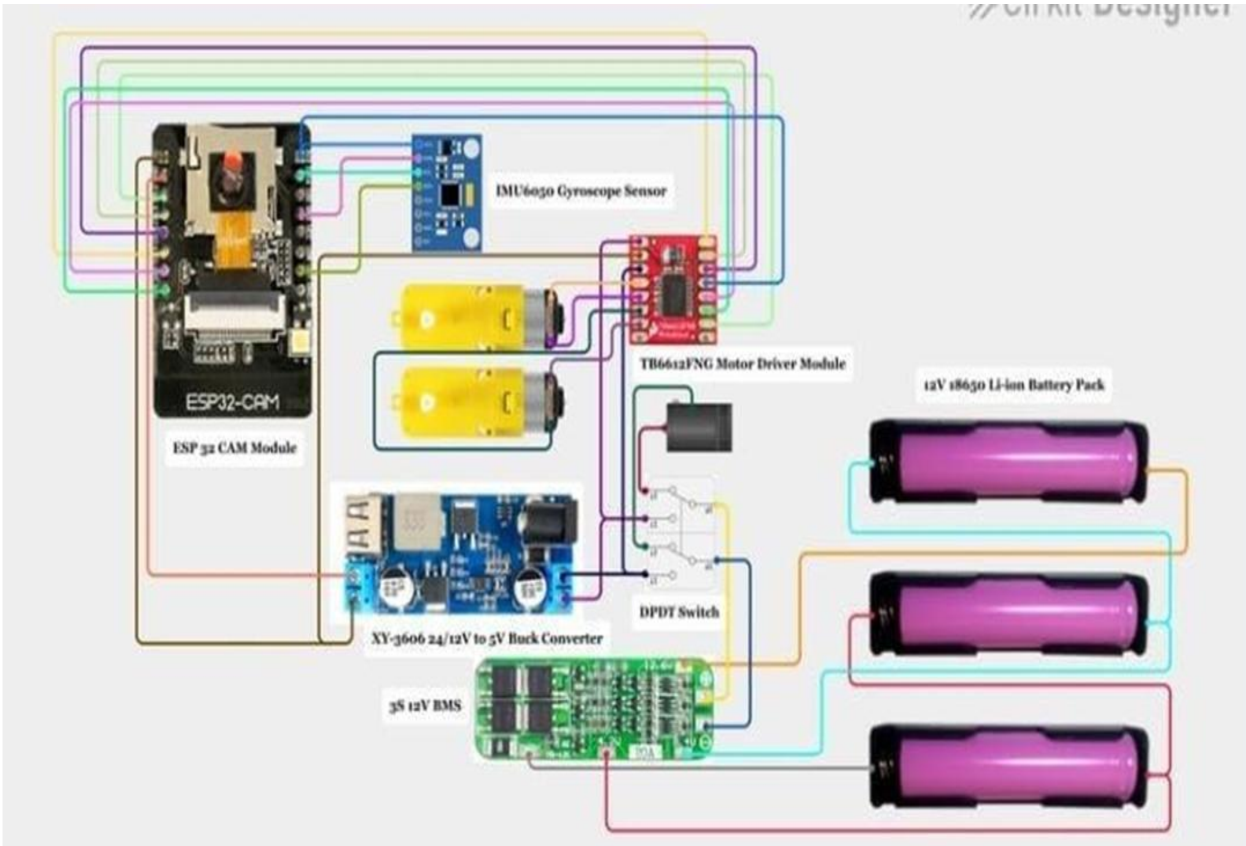
The robot uses BO geared DC motors coupled with rubber wheels to achieve locomotion. These motors typically operate at 6V to 12V and provide sufficient torque for low-speed robotic applications. The rubber wheels enhance grip and stability during movement.

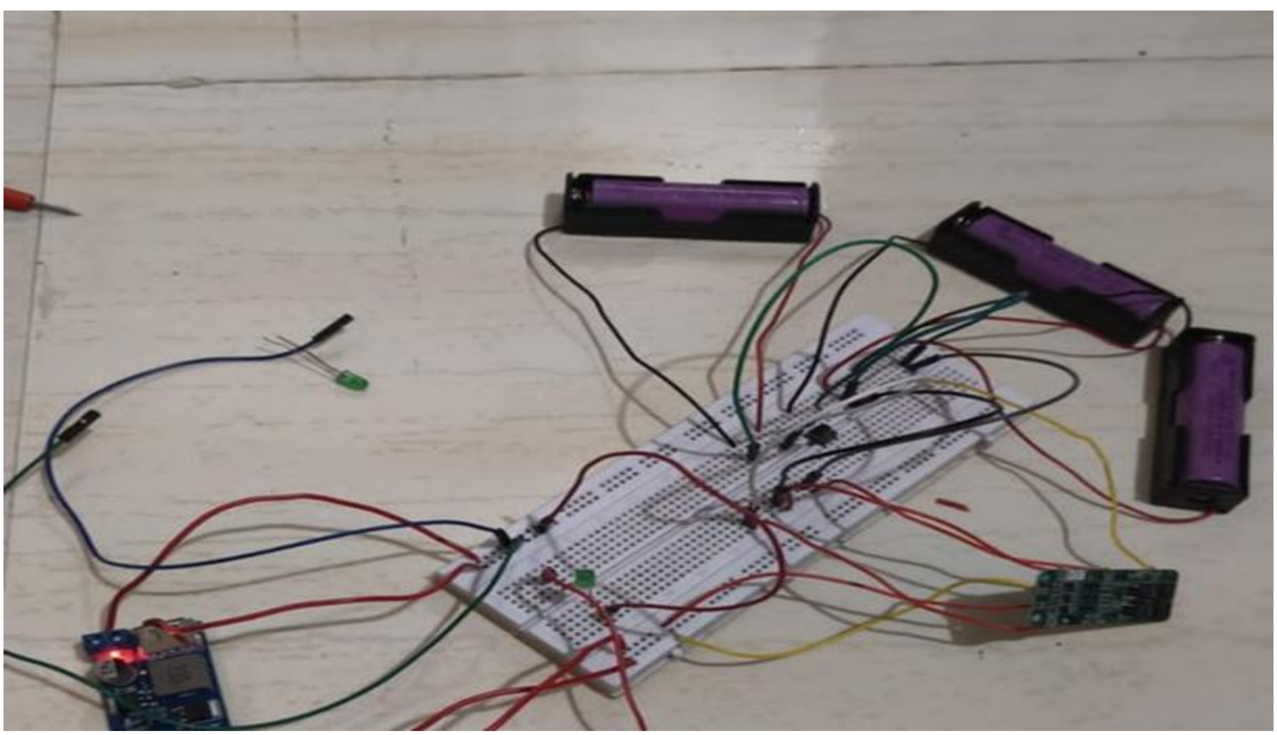
A 12V battery pack is used as the primary power source to drive the motors and provide sufficient energy to the system. Since different components require different voltage levels, a XY-3606 DC-DC Buck Converter is used to step down the voltage. This converter supports an input voltage range of 4V to 40V and provides an adjustable output voltage between 1.25V and 35V with high efficiency.

All components are interconnected using a breadboard and jumper wires, allowing easy prototyping and modification. The ESP32-CAM collects sensor data from the MPU6050, processes it, and controls motor movement via the motor driver. This hardware system works in coordination with MATLAB-based LiDAR simulation to perform mapping and localization tasks.

The use of these low-cost components ensures that the overall system remains affordable while still achieving acceptable performance for SLAM-based robotic applications.

Circuit diagram





VI RESULT AND PROBLEM FACED

6.1 Overall System Performance

The SLAM system implemented using ESP32 and IMU sensor successfully demonstrated the basic concept of localization and mapping. The system was able to track motion and estimate position in a controlled environment. Although the accuracy is limited due to sensor constraints, the project proves that SLAM can be implemented on low-cost embedded hardware.

6.2 Localization Accuracy

The IMU sensor provided real-time data for motion tracking, including acceleration and angular velocity. The system was able to estimate orientation effectively; however, position estimation showed gradual drift over time due to cumulative sensor errors. This highlights the limitation of using only IMU for SLAM.

6.3 Mapping Results

The generated map represents the movement path of the system rather than a highly detailed environmental map. The mapping performance is basic but sufficient to demonstrate the working principle of SLAM. Accuracy can be improved by integrating additional sensors such as LiDAR or cameras.

6.4 System Efficiency and Limitations

The ESP32 microcontroller handled data processing efficiently within its hardware limits. The system operates in real-time but is constrained by memory and processing power. Major limitations include sensor drift, lack of external correction, and reduced mapping precision.

6.5 Conclusion

The project successfully achieves its objective of implementing a SLAM-based system using ESP32 and IMU sensor. It demonstrates a cost-effective approach for localization and mapping in indoor environments. While the current system has limitations in accuracy, it provides a strong foundation for future improvements such as sensor fusion, advanced algorithms, and integration with additional hardware components