Smart Patrol Bot

Project Exhibition II

Submitted in partial fulfillment for the award of the degree of

Bachelor of Technology

In

ELECTRONICS AND COMMUNICATION ENGINEERING

(AI & CYBERNETICS)

Submitted to

VIT BHOPAL UNIVERSITY (M. P.)

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DECLARATION

I hereby declare that the Dissertation entitled "*Smart Patrol Bot*" is my own work conducted under the supervision of *Dr. Anirban Bhowmick, Assistant Professor , School of Electrical and Electronics Engineering* at VIT Bhopal University, Bhopal.

I further declare that to the best of my knowledge this report does not contain any part of work that has been submitted for the award of any degree either in this university or in another university / Deemed University without proper citation.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: 15.04.2025

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CERTIFICATE

This is to certify that the work embodied in this Project Exhibition-2 report entitled **"Smart Patrol Bot"** has been satisfactorily completed by **Ms.Sarala Florence K (23BAC10007) , Ms. Ankita Soni (23BAC10032) , Mr. Shivaraman T (23BAC10009)** in the School of Electrical & Electronics Engineering of AI and Cybernetics at VIT Bhopal University, Bhopal. This work is a bona fide piece of work, carried out under our guidance in the School of Electrical and Electronics Engineering for the partial fulfilment of the degree of Bachelor of Technology.

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Abstract

The project “Smart patrol bot” , Detects Motion and Intrusions using PIR sensors to identify movement. Gives the Real-Time Surveillance using the ESP32-CAM for video streaming and capturing images. Also detects Object/Person by python flask to detect and track people or objects. It navigates around the premises using a chassis with wheels and motors controlled by the L298N motor driver. Additionally it provides Alerts and Notifications, Sending alerts or images to the owner or the user in case of suspicious activity.

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Symbol	Description
CAM	Camera module
DC	Direct Current
DL	Deep Learning
ESP32	Embedded Serial Processor 32-bit microcontroller
FTDI	Future Technology Devices International (USB to Serial Communication IC)
GPIO	General Purpose Input Output
IDE	Integrated Development Environment
IoT	Internet of Things
LED	Light Emitting Diode
PIR	Passive Infrared Sensor

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INTRODUCTION

With the increasing demand for intelligent security systems, the integration of robotics and automation in surveillance has become a promising approach. The **Smart Patrol Bot** is an autonomous mobile surveillance system designed to enhance security by combining motion detection, live video streaming, and smart navigation.

This project aims to develop a compact, mobile robot capable of patrolling an indoor environment, detecting unauthorized motion using **PIR (Passive Infrared) sensors**, and streaming real-time video through the **ESP32-CAM module**. The bot is powered by four gear motors connected to an **L298N motor driver**, enabling forward, backward, and directional movements. All components are interfaced using a setup and programmed through the **Arduino UNO**, with serial communication managed via the **FTDI programmer**.

What makes this project special is it enables basic object or person detection directly on the ESP32 without the need for external processing units. This allows the robot to recognize and take specific pictures of individuals or respond to unknown presence, making it a cost-effective and intelligent security solution. The pictures which are taken can be seen in telegram Bot .

The primary goal is to create a real-time, responsive system that can operate independently without the need for constant human intervention or large-scale infrastructure. This approach enhances security, especially in the absence of the occupants, and showcases the power of embedded systems combined with machine learning for practical applications

LITERATURE REVIEW

[1] IOT Surveillance Robot Using ESP-32 Wi-Fi CAM & Arduino Venu DN.
IOT Surveillance Robot Using ESP-32 Wi-Fi CAM & Arduino.
IJFANS International Journal of Food and Nutritional Sciences. 2022;11(5):198-205.

Abstract :

An advanced spy robot has been developed using a Raspberry Pi, night vision camera, and multiple sensors to enhance modern security measures. Capable of autonomous operation, the robot monitors its environment, detects intrusions, captures images, and sends real-time alerts via a web server. Its night vision capabilities ensure effective performance even in low-light conditions. Additionally, the robot can be remotely controlled through a user-friendly web interface and is equipped with obstacle detection sensors for smooth navigation, making it suitable for diverse surveillance scenarios like industrial sites, banks, and malls.

This project addresses the growing demand for intelligent, around-the-clock surveillance solutions in response to evolving security threats. The robot offers key advantages such as real-time monitoring, remote access, and reliable performance in all lighting conditions. It reduces reliance on human security personnel and enhances safety. Future upgrades may include AI for decision-making, facial recognition, and better integration with emergency systems, making this robot a valuable component in next-generation smart security infrastructure.

[2] Development of a Patrol Robot for Home Security with Network Assisted Interactions
Chen Jin, Xinggang Fan, Liyan Chen, Shujia Qin, "Design of a Patrol Robot Based on the Plug-In Service Architecture", 2021 IEEE International Conference on Robotics and Biomimetics (ROBIO), pp.528-532, 2021.

Abstract **:**

This paper presents the development of a patrol robot system for home security with some considerations on its interaction functionalities. The system integrates a variety of sensors to gather environmental information and detect abnormal events including fire alarm, intruder alert and lethal gas leakage. By continuously monitoring its surroundings, the robot acts as a vigilant guardian, capable of identifying potential dangers in real time. This comprehensive sensory integration allows it to respond quickly and effectively to a variety of home security threats.

To ensure the patrol robot can coexist naturally with people in a home setting, the system incorporates advanced human-robot interaction features. These include a face mask capable of displaying multiple facial expressions to enhance emotional communication and user comfort, as well as a force-feedback steering wheel controller for intuitive manual operation. These elements contribute to a more user-friendly and interactive experience, encouraging trust and ease of use among residents. Additionally, all sensor data and interaction feedback can be accessed remotely via the Internet, enabling homeowners or security personnel to monitor and control the system from anywhere in the world.

This patrol robot system holds significant value in the field of home automation and smart security. Its advantages lie in its ability to autonomously patrol, avoid obstacles, and navigate intelligently using a fusion of ultrasonic and vision-based data. The implementation of a dedicated patrol algorithm allows it to move randomly or follow a wall-baseline pattern, ensuring thorough coverage of the surveillance area. In real-world applications, the system was successfully tested on the second floor of the EE building on campus, proving its effectiveness. Looking ahead, the system could be enhanced with AI-based behavior analysis, voice control, and machine learning for predictive threat detection. With continued advancements, this type of robotic system could play a vital role in transforming how security is managed in homes, offices, and institutional buildings.

PROBLEM FORMULATION

In recent times, there has been a significant rise in the demand for intelligent and affordable security systems. Conventional security solutions such as static CCTV cameras or manual patrolling methods often fall short in providing real-time, autonomous, and proactive surveillance. These systems are generally reactive rather than preventive ,they record events but lack the ability to act or adapt to dynamic situations such as unauthorized entry or suspicious activity. This creates a critical need for a smart, mobile, and self-sufficient security bot that can operate autonomously, detect motion, and monitor environments effectively.

The proposed **Smart Patrol Bot** addresses this problem by integrating multiple technologies into a single mobile platform. It aims to provide real-time surveillance using an ESP32-CAM module, which takes pictures of its surrounding environment to users over Hotspot, while simultaneously detecting motion through PIR sensors. The bot can move around a designated area using gear motors and an L298N motor driver, allowing it to patrol and reposition itself based on sensor inputs. This eliminates the limitations of static surveillance systems and enables active monitoring.

Furthermore, most existing low-cost security systems do not incorporate artificial intelligence or machine learning due to computational and power constraints. This project attempts to overcome this barrier by implementing a lightweight ML framework capable of running on microcontrollers like the ESP32. The goal is to enable basic object or face detection and future capabilities such as human following or threat identification. This adds a layer of intelligence to the patrol bot, making it context-aware and adaptable to various security scenarios.

Therefore, the central problem this project aims to solve is the lack of a compact, intelligent, and autonomous surveillance solution that can be deployed in homes or small-scale facilities without the need for expensive infrastructure, constant power supply, or continuous human monitoring. The Smart Patrol Bot intends to bridge this gap through an affordable, energy-efficient, and AI-powered robotic system.

METHODOLOGY

The development of the Smart Patrol Bot was approached in a structured and modular manner. Initially, the core requirements were identified as autonomous mobility, real-time surveillance, and motion detection. Based on these goals, key components were selected, including the ESP32-CAM module for video streaming, L298N motor driver for controlling the four gear motors, PIR sensors for motion detection, and an FTDI programmer for uploading code to the ESP32. The hardware was assembled on a four-wheeled chassis, where each gear motor was connected through the motor driver. The ESP32-CAM was programmed using the Arduino UNO to connect to Bluetooth Along with the hotpot and when the server is on and the motion is detected it captures pictures, and receives sensor input. The PIR sensors were configured to detect human movement and send signals that trigger the bot's movement in specific directions. Basic GPIO controls were implemented to manage the motor driver through PWM signals.

The software logic of python flask, allowed the bot to respond dynamically moving forward when motion was detected and stopping or changing direction based on sensor input. Python flask was optionally explored to integrate basic object detection capabilities into the ESP32-CAM, using a quantized, pre-trained model to identify faces or objects in real time. After individual testing of each module, the system was fully integrated and tested in a controlled indoor setting. Calibration was performed to adjust motor direction, sensor sensitivity, and camera stability. The final result was a mobile robot capable of autonomously patrolling an area, detecting motion, and broadcasting live video, offering a cost-effective and intelligent solution for surveillance.

BLOCK DIAGRAM

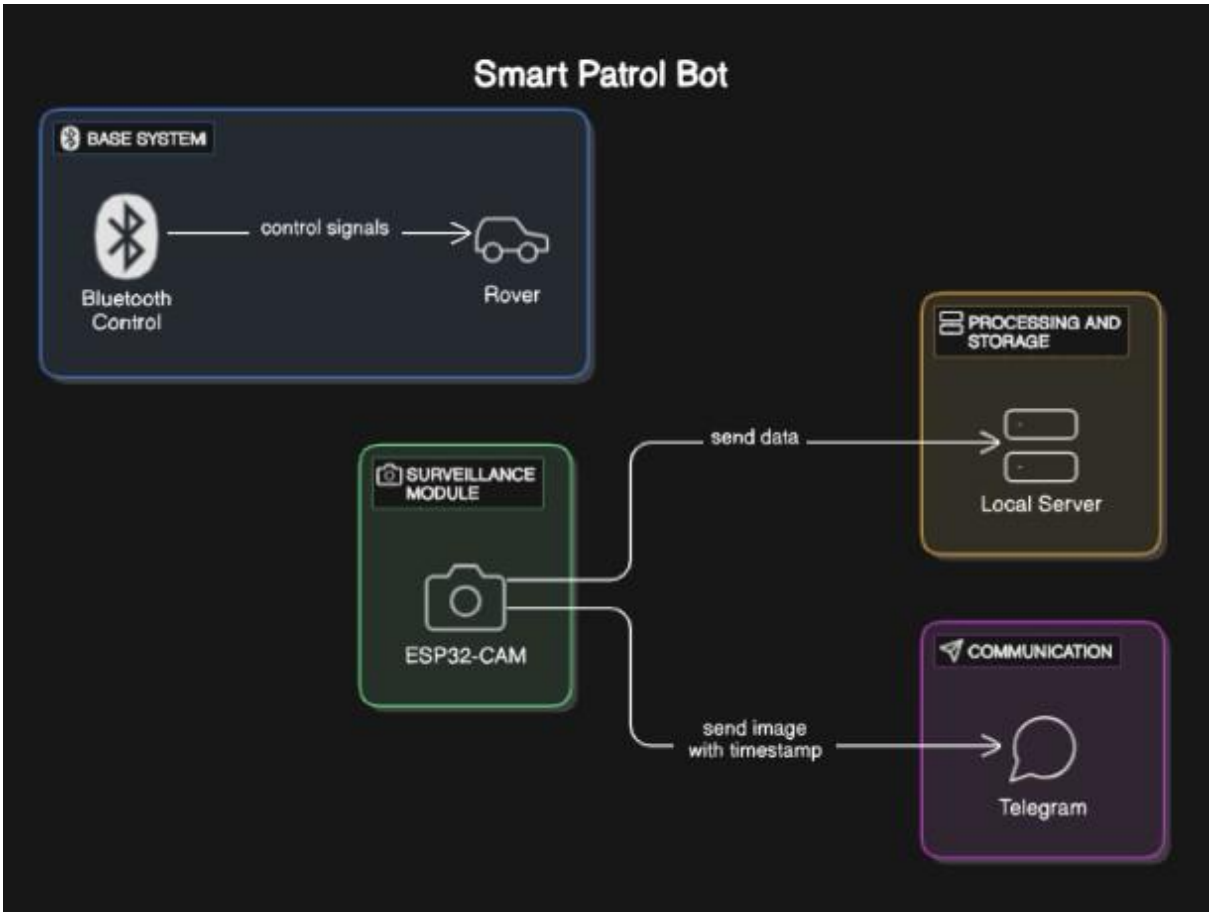


Fig.1.Block Diagram

CIRCUIT DIAGRAM

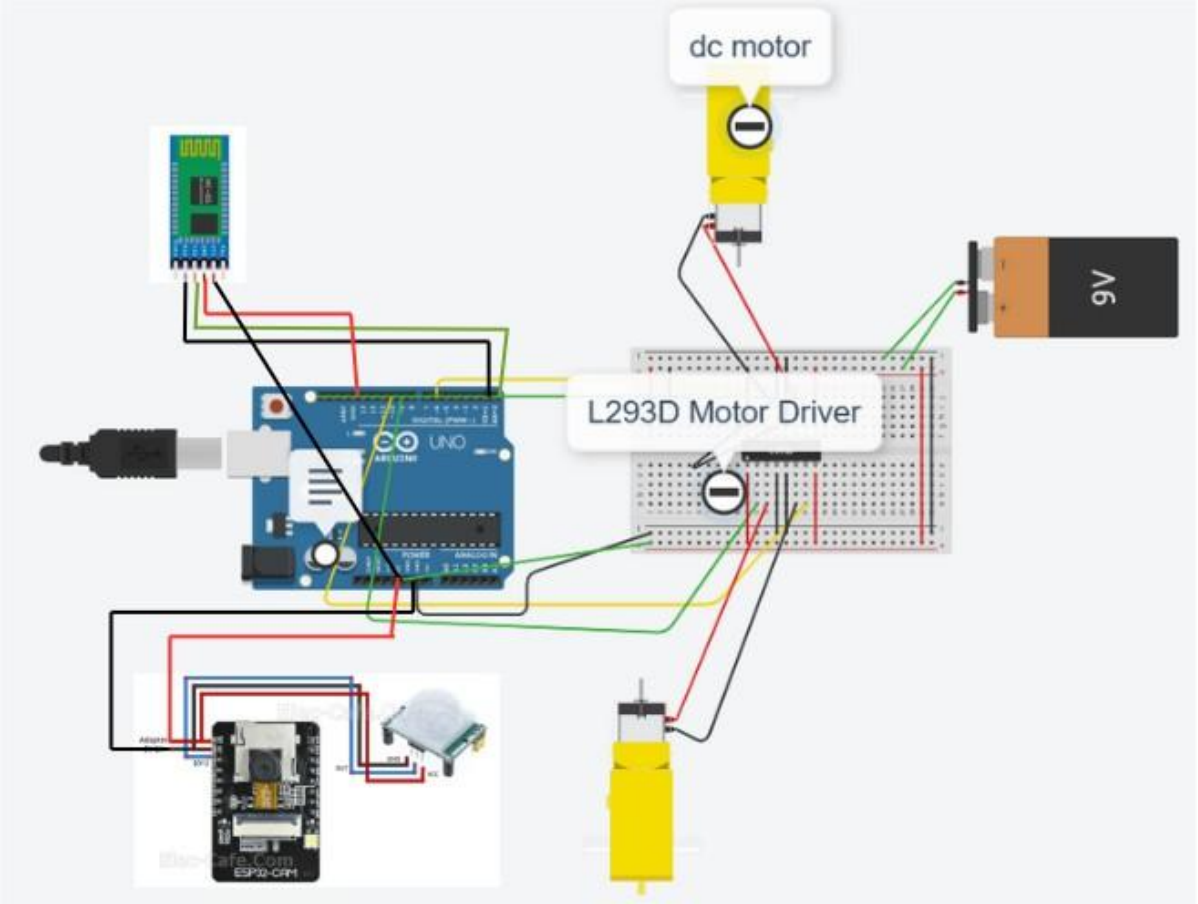


Fig.2.Circuit Diagram

COMPONENTS DESCRIPTION

ESP32 CAMERA MICROCONTROLLER

This is like the brain of the module. It has built-in Wi-Fi and Bluetooth, so it can connect to your phone, laptop, or the internet without needing extra parts.
Camera (OV2640) , This tiny camera can capture pictures and stream live video.

Specifications :

- Operating Voltage: 5V (via FTDI)
- Flash Memory: 4 MB
- Camera Sensor: OV2640 (2 MP)
- Maximum Image Resolution: 1600×1200
- Wi-Fi: 2.4 GHz and Bluetooth
- Digital I/O Pins: 9
- Clock Speed: Up to 240 MHz
- Power Consumption: 160–260 mA (during Wi-Fi operation)
- Programming Interface: UART (via FTDI)
- Board Dimensions: 27 mm x 40.5 mm
- Onboard Flash: LED Flashlight

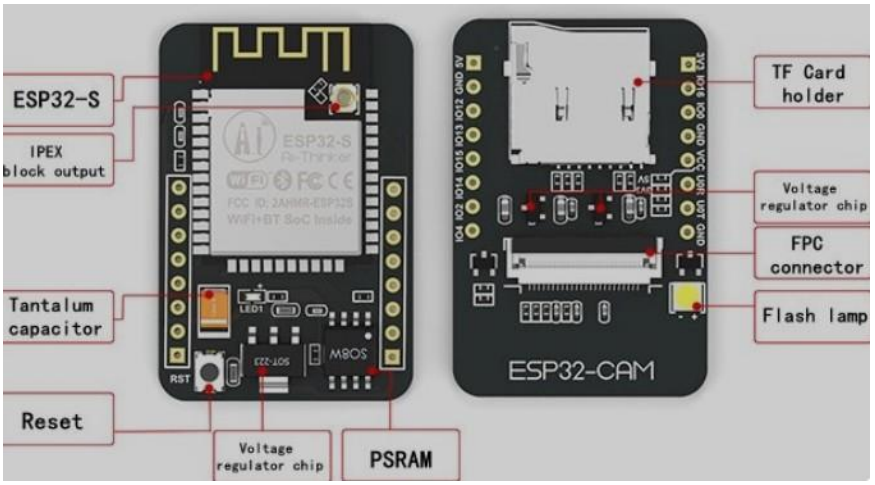


Fig:3.2.1.1 ESP32 Inbuilt camera Module

Arduino UNO Microcontroller :

The Arduino Uno is a microcontroller development board based on the ATmega328P chip. It is used for building various digital and analog projects, including robotics, automation, and IoT applications.

Specifications:

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Digital I/O Pins: 14 (6 can be used as PWM outputs)
- Analog Input Pins: 6
- Flash Memory: 32 KB (0.5 KB used by bootloader)
- Clock Speed: 16 MHz
- USB connection for programming

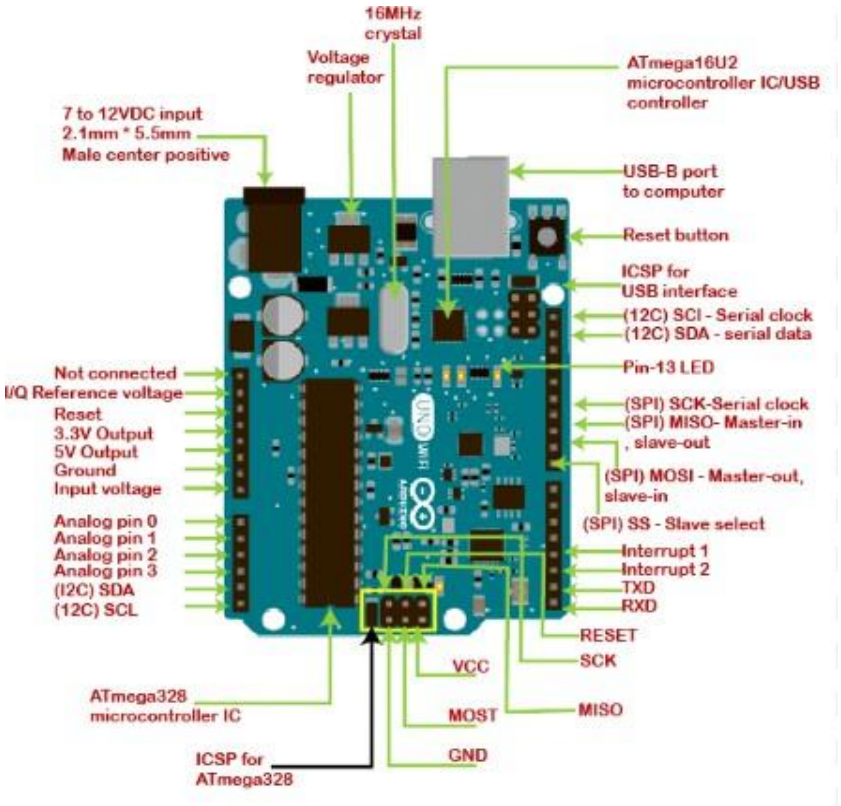


Fig:3.2.1.2 Arduino UNO Microcontroller

L298N Motor Driver :

The L298N is a dual H-bridge motor driver IC that allows control of the direction and speed of DC motors, stepper motors, and other inductive loads. It is commonly used in robotics for driving motors with low to moderate power requirements.

Specifications:

- Operating Voltage: 4.5V - 46V
- Output Current: 2A per channel (with proper heat sinking)
- Control Pins: 4 (for controlling direction and speed)
- Maximum Power Dissipation: 25W (with proper heat sinking)
- Logic Voltage: 5V
- Features: Over-temperature and over-current protection, thermal shutdown, and overload protection

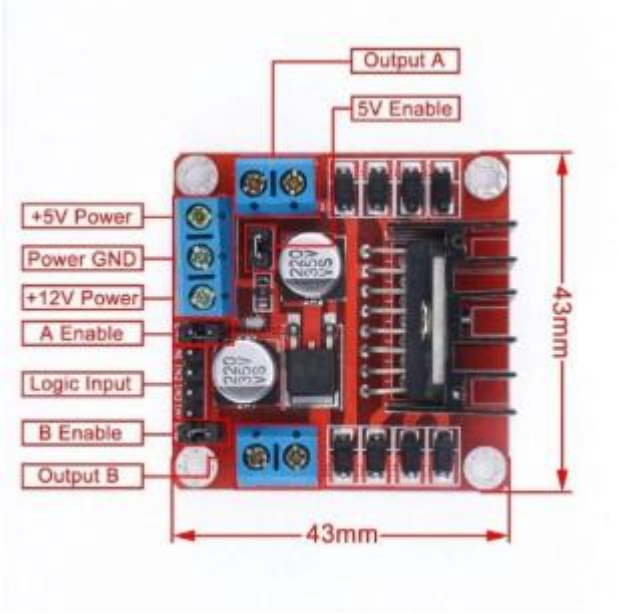


Fig:3.2.1.3 Motor Driver L298N

PIR Sensor :

The PIR, which is a Passive Infrared sensor ,detects motion by measuring changes in infrared radiation from objects in its environment. It is commonly used in motion detection systems.The sensor operates by detecting infrared radiation emitted from warm objects (like humans) and triggering a signal when a change is detected in the environment.

Specifications:

- Operating Voltage: 5V
- Output: Digital (high or low)
- Detection Range: 3-7 meters
- Detection Angle: 120 degrees
- Current Consumption: 20mA
- Trigger: Active-high logic output

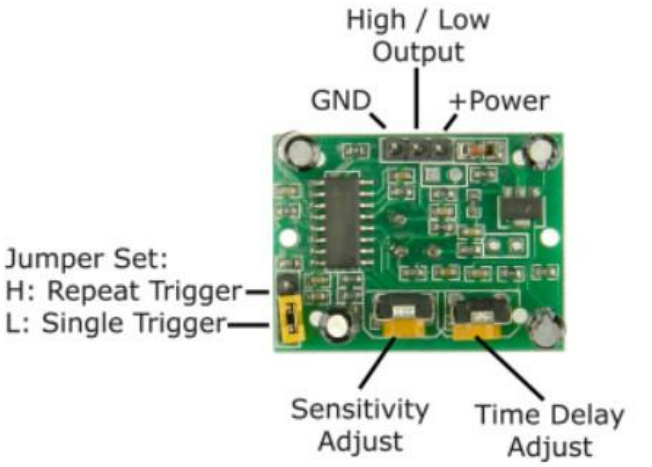


Fig:3.2.1.4 PIR Sensor

Bluetooth Module HC-05 :

The HC-05 is a wireless Bluetooth module that enables serial communication between microcontrollers and other devices. It supports both master and slave modes. The module communicates using UART (Universal Asynchronous Receiver-Transmitter) protocol to send and receive data wirelessly.

Specifications :

- Operating Voltage: 3.3–5V
- Communication Protocol: UART
- Default Baud Rate: 9600
- Range: Up to 10 meters (Class 2 device)
- Modes: Master/Slave

Fig:3.2.1.5 Bluetooth Module HC-05

FTDI Programming Module :

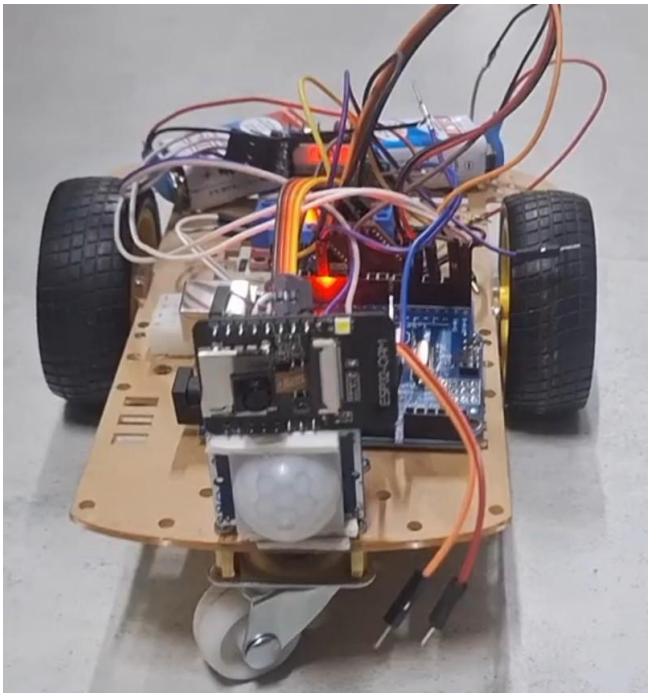
The FTDI programmer is a USB-to-serial adapter that enables communication between a computer and a microcontroller, such as the ESP32, via a UART interface. It is commonly used for flashing firmware to microcontrollers or for serial communication in embedded systems. The FTDI programmer simplifies the process of transferring data between a computer and a microcontroller, making it an essential tool for embedded systems development.

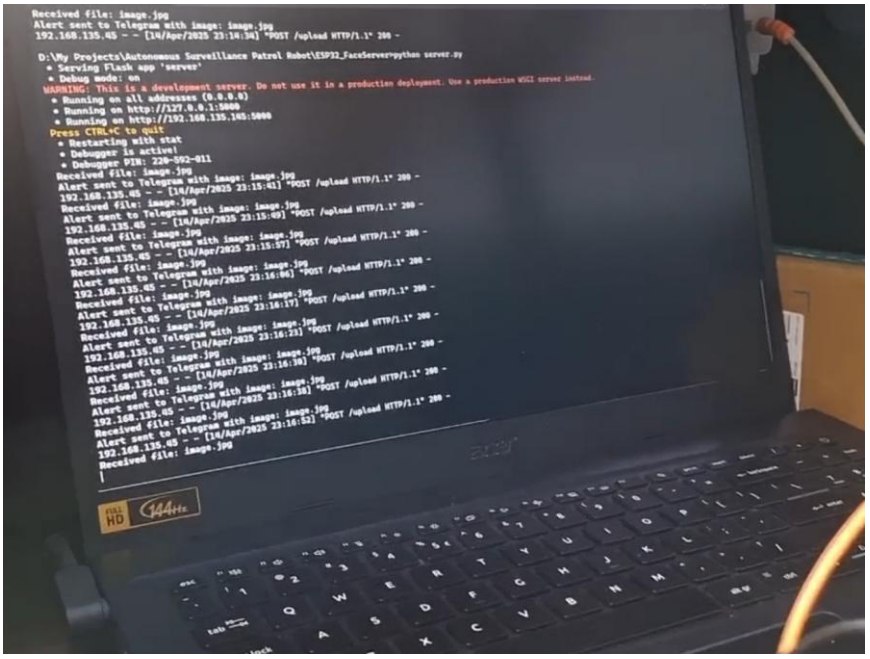
Specifications:

- Operating Voltage: 5V/3.3V
- Data Transfer Rate: Up to 1 Mbps
- Interface: USB to TTL Serial
- Connector Type: 6-pin or 5-pin header

Fig:3.2.1.6 FTDI Programming Module

SMART PATROL BOT





RESULTS AND DISCUSSIONS

After successfully assembling and programming the Smart Patrol Bot, several tests were conducted to verify its functionality. The bot was able to patrol a predefined area using its four gear motors controlled by the L298N motor driver. Upon detecting motion via the PIR sensors, the bot initiated movement in the direction of the detected activity, simulating autonomous patrolling behavior. The movement was smooth and responsive under indoor conditions with sufficient lighting and obstacle-free paths.

Observation Table :

Test No.	Motion Detected	Bot Reaction	Status of Video Stream	Remarks
1	Trigger Left PIR	Turned Left and moved	Streaming	Accurate
2	Trigger Right PIR	Turned Right and moved	Streaming	Slight delay
3	No motion	Stopped	Streaming	Idle mode
4	Trigger Front	Moved forward	Streaming	Quick and smooth response

The above observation table shows the Bot’s movement according to the instructions given by the user . When the user triggers the Left PIR sensor , the Bot turns to left and moves in the left direction . Likewise , it goes to the right side when it is triggered to the right PIR . At this point , we can observe the streaming of the bot in a video from the mobile which is connected through bluetooth to the ESP32 Camera Module. When there is no motion to the Bot , it stays constant with no movement and the video streaming works but there is no movement instead the video stays in idle mode until and unless the motion is detected from the Bot by the user .

CONCLUSION AND FUTURE SCOPE

By this project , we have achieved real-time pictures capturing with minimal false alarms .Autonomous patrolling with effective motion detection using PIR sensors. Low-cost and efficient solution using affordable components like ESP32-CAM and L298N motor driver. Successfully integrated AI-based surveillance using Python flask on ESP32-CAM. Easy to expand with additional features like alarm systems and remote monitoring through IoT. This project aims to be cost effective and affordable . It can be widely useful in the utmost security systems enhancing its ability to achieve a smart process .

Future Scope : The Smart Patrol Bot, successfully performs basic surveillance and patrolling tasks using motion detection, video streaming, and autonomous movements.The major area of improvement lies in incorporating GPS and obstacle-mapping sensors (like LiDAR or IR sensors) to allow for outdoor navigation and smart route planning. Additionally, implementing a rechargeable battery system with solar charging could make the bot energy-efficient and reduce manual maintenance.

On the software side, advanced AI models can be trained and integrated using TensorFlow Lite or cloud-based services to recognize specific intruders, suspicious behaviors, or even fire and smoke detection. The ESP32-CAM can be enhanced to include cloud storage or real-time alerts sent via email or messaging platforms. Furthermore, integration with smart home systems (like Alexa, Google Home, or MQTT-based dashboards) can transform this bot into a complete home automation and security companion. Expanding the robot’s functionality into industrial or military surveillance applications could also be explored, offering a low-cost, intelligent solution for sensitive and large-scale areas.

REFERENCES

[1] IOT Surveillance Robot Using ESP-32 Wi-Fi CAM & Arduino Venu DN. IOT Surveillance Robot Using ESP-32 Wi-Fi CAM & . IJFANS International Journal of Food and Nutritional Sciences. 2022;11(5):198-205.

https://www.researchgate.net/publication/367380053_IOT_Surveillance_Robot_Using_ESP-32_Wi-Fi_CAM_Arduino

[2] Development of a Patrol Robot for Home Security with Network Assisted Interactions Chen Jin, Xinggang Fan, Liyan Chen, Shujia Qin, "Design of a Patrol Robot Based on the Plug-In Service Architecture", 2021 IEEE International Conference on Robotics and Biomimetics (ROBIO), pp.528-532, 2021.

https://www.researchgate.net/publication/224300583_Development_of_a_patrol_robot_for_home_security_with_network_assisted_interactions