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VIRO: 360 Degree Real-Time Surveillance

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Abstract – VIRO: 360 Degree Real-Time Surveillance is a compact mobile surveillance system that combines robotics with IoT-based video monitoring to enhance real-time security. The system features TT gear motors for smooth navigation in all directions and a caster wheel for added stability. An ESP32 camera captures live video, while the L298N motor driver controls movement, making VIRO agile and responsive. LED bulbs mounted on the chassis improve visibility in low-light conditions, enabling efficient operation during nighttime. The ESP32 module hosts a local web server accessible through Wi-Fi (IP: 192.168.4.1), allowing users to remotely control the robot and stream real-time video on mobile devices. The user interface is developed using HTML and Arduino libraries such as esp_camera.h and ESPAsyncWebServer.h, ensuring smooth and interactive control. Powered by dual 18650 batteries, the system is portable and energy-efficient. VIRO is ideal for applications in home security, industrial monitoring, and event surveillance, providing flexibility, mobility, and real-time situational awareness. This project demonstrates the effective integration of robotics, wireless communication, and embedded systems, highlighting the potential of IoT in modern surveillance technology. It offers an innovative, scalable solution to evolving security challenges in both personal and professional environments.

***Key Words*:** VIRO, real-time surveillance, robotics, mobile surveillance unit, TT gear motors, ESP32 camera, L298N motor driver, web server, remote control, live feeds, LED bulbs, low-light visibility, Arduino libraries, user-friendly interface, dual 18650 batteries, security monitoring, Internet of Things, IoT solutions, intelligent surveillance systems, technological advancements.

1. INTRODUCTION

The growing need for advanced security systems has accelerated innovations in technology, particularly through the integration of robotics and the Internet of Things (IoT). Traditional surveillance setups, which often rely on stationary cameras and manual supervision, fall short in dynamic and wide-area monitoring. Addressing these limitations, the VIRO – 360 Degree Real-Time Surveillance system offers a mobile solution that merges real-time video streaming with robotic movement, providing a flexible and responsive platform for surveillance across various settings such as residential areas, workplaces, and public zones. The system is powered by a strategic combination of TT gear motors for smooth navigation, an ESP32 camera for real-time image capture, and an L298N motor driver for motor control. This assembly enables the robot to move fluidly while streaming live visuals to connected mobile devices. Equipped with LED lighting, the unit maintains visibility even in low-light conditions, making it suitable for night-time or indoor surveillance.

The software framework of VIRO is designed for ease of use, offering control via a mobile interface connected through a locally hosted web server. Users can connect to the system over Wi-Fi, access live video feeds, and maneuver the robot using an interface built with HTML and Arduino-compatible libraries. Central to the system's functionality is the ESP32 microcontroller, developed by Espressif Systems. This low-cost, energy-efficient chip is equipped with dual-core processing and built-in Wi-Fi and Bluetooth, enabling robust multitasking and real-time communication. It is widely adopted in both DIY and industrial projects due to its powerful features and flexibility. In industrial applications, the ESP32 is employed for smart automation, remote monitoring, and predictive maintenance, supporting seamless communication between devices and cloud services.

With its adaptable architecture and user-centric design, VIRO represents a leap forward in mobile surveillance technologies. By combining compact robotics, efficient communication, and real-time video analytics, it offers a modern approach to ensuring safety and situational awareness. The use of the ESP32 exemplifies the expanding role of IoT components in shaping intelligent, responsive systems capable of transforming how we perceive and manage security in an increasingly connected world.

1.1. WORKING OF VIRO

Power Supply:
VIRO is powered by one or two 18650 lithium-ion batteries, connected through appropriate holders. The batteries provide the necessary voltage to the ESP32-CAM, L298N motor driver, and other components, ensuring smooth operation.
Motor Control:
The L298N motor driver acts as a bridge between the ESP32-CAM and the TT gear motors. The driver receives control signals from the ESP32 and regulates the direction and speed of the motors based on these signals. The connections from the ESP32-CAM to the motor driver enable the control of two motors: one for each wheel. This allows VIRO to move forward, backward, and turn left or right.
Camera Functionality:
The ESP32-CAM module captures real-time video and images using its integrated OV2640 camera. It streams this footage over Wi-Fi, allowing users to view live feeds on their mobile devices. The camera's settings, such as resolution and frame rate, can be adjusted in the code to optimize performance based on the user's requirements.

Web Server Setup:
A web server is created on the ESP32-CAM using Arduino libraries like ESPAsyncWebServer. This server runs on a local network with an IP address, typically 192.168.4.1. The user connects to the server via a mobile device's web browser, where they can access a control interface to operate VIRO and view the live video feed.
Mobile Control:
The control interface consists of buttons for navigating VIRO. When a button is pressed on the mobile device, a command is sent to the ESP32-CAM via HTTP requests, directing the motors to move in the desired direction. For example, pressing the "forward" button sends a signal to the L298N driver to rotate both motors in the same direction, propelling VIRO forward.
LED Functionality:
LED bulbs are integrated into the chassis to provide illumination, especially in low-light conditions. These LEDs can be activated based on user commands through the web interface, enhancing visibility during surveillance.
Real-Time Streaming:
The ESP32-CAM uses the MJPEG format to stream video, which is efficient for low-bandwidth connections. Users can view the live feed with minimal lag on their mobile devices. The streaming function is initiated in the setup code of the ESP32-CAM, allowing it to continuously capture and transmit video data.

1.2. Redundancy and Reliability in VIRO

Ensuring redundancy in system design is crucial for reliable surveillance and monitoring, particularly in projects like VIRO. One essential aspect is power supply redundancy, where the system utilizes 18650 lithium-ion batteries configured in parallel. This setup guarantees continuous operation, as an alternate battery takes over if one runs low or fails. Similarly, communication redundancy enhances reliability by supporting multiple protocols. While Wi-Fi is the primary method, alternative connections like Bluetooth can be integrated to maintain control in case of network failures. Additionally, sensor and component redundancy play a vital role in minimizing disruptions. Incorporating extra cameras or backup motor drivers ensures that the system remains functional even if a key component malfunctions.

Reliability is another cornerstone of VIRO's design, ensuring consistent performance over time. The use of robust hardware components, such as TT gear motors and the L298N motor driver, allows the system to withstand environmental stress and mechanical wear, thereby reducing failure risks. Software stability is reinforced by implementing error detection and recovery mechanisms, allowing automatic reconnection or communication switching when necessary. Thermal management further enhances reliability by preventing overheating of critical components like the ESP32-CAM and motor drivers, with heat sinks or fans incorporated as protective measures. Field testing in diverse environments helps identify weaknesses, enabling refinements to improve both hardware and software performance. Combining redundancy and reliability ensures that VIRO remains operational under various conditions, instilling user confidence and expanding its applicability across multiple sectors.

1.3. Classifications of VIRO

VIRO represents a versatile robotic system that can be categorized through multiple lenses, such as its functional capabilities, structural design, intended applications, technological framework, and mobility features. Functionally, it serves as both a surveillance and mobile robot, designed to deliver real-time video monitoring while navigating different terrains, making it ideal for security and exploration tasks. In terms of design, VIRO is structured with a wheeled chassis that allows smooth and agile movement, while its modular configuration ensures that parts can be easily upgraded or replaced, supporting long-term adaptability. The structural framework commonly employs lightweight plastic for housing electronics, and in some cases, incorporates hybrid or eco-friendly materials like cardboard or recycled components, reflecting both innovation and sustainability in design choices.

When viewed through the lens of application, VIRO demonstrates remarkable flexibility. It is deployed in security systems across residential, commercial, and public environments, while also serving as a hands-on educational tool for students and researchers exploring robotics and IoT technologies. Industrial sectors can leverage VIRO for inspection and safety compliance monitoring, and its unobtrusive presence makes it suitable for wildlife observation without disturbing natural behaviors. From a technological standpoint, VIRO integrates the ESP32-CAM module for live video streaming and image capture, along with L298N motor drivers for precise movement control. The use of Wi-Fi enables seamless remote operation, and there remains scope for integrating Bluetooth in future updates to further enhance connectivity options.

Mobility-wise, VIRO supports both dynamic and stationary configurations. Its gear motors and additional caster wheel allow omnidirectional movement, which is essential for exploring complex environments. At the same time, it can function effectively as a stationary surveillance unit when fixed in a particular spot. Altogether, these classifications underscore VIRO's capacity to meet diverse operational demands. By analyzing its various features and possible applications, developers and users alike can pinpoint its ideal usage scenarios and envision future improvements that align with emerging technological trends and user needs.

1.4. Motivation for the VIRO Project

The development of the VIRO 360-degree real-time surveillance system is driven by a blend of technological progress, growing societal needs, and personal enthusiasm for innovation. In recent times, the demand for effective surveillance systems has surged, largely due to rising concerns about security in both public and private spaces. VIRO emerges as a timely response to these concerns, offering a mobile and responsive solution capable of real-time monitoring across diverse environments. Its ability to function remotely suits the modern shift toward remote work and home-based lifestyles, enabling users to maintain awareness of their surroundings or property from virtually anywhere. The project capitalizes on the increasing availability and affordability of Internet of Things (IoT) components like the ESP32-CAM and the L298N motor driver, allowing for the creation of sophisticated yet cost-effective systems.

Moreover, the integration of such technology lays the groundwork for future enhancements, including artificial intelligence features like facial recognition and anomaly detection, thereby positioning VIRO as more than just a conventional surveillance tool. Beyond its functional value, VIRO plays a significant educational role. It offers a hands-on learning platform for students, hobbyists, and aspiring engineers to delve into areas such as electronics, coding, and robotics, bridging the gap between theoretical knowledge and real-world applications. Simultaneously, it provides a testbed for further research and experimentation, encouraging the exploration of cutting-edge technologies and innovative implementations within the IoT ecosystem.

From an environmental and social perspective, VIRO promotes safety while incorporating sustainability into its design. The use of recyclable materials in its chassis not only reflects environmental consciousness but also sets a precedent for eco-friendly engineering practices. On a personal level, the project is fueled by a deep interest in robotics, automation, and smart technology, serving as a channel for creative expression and technical growth. This fusion of curiosity and determination underscores a strong desire to innovate and contribute meaningful solutions to real-world challenges. Altogether, VIRO stands as a testament to how personal passion, educational goals, and social relevance can converge in the development of impactful technological systems.

1.5. Problem Statement for the VIRO Project

The rise in incidents related to security breaches, accidents, and safety violations across a range of environments underscores the urgent demand for more efficient and responsive surveillance systems capable of real-time monitoring. Traditional surveillance solutions, while widely used, often prove inadequate due to their static nature, high installation and maintenance costs, and inability to offer immediate situational awareness or intervention. Fixed-position CCTV cameras, for instance, are limited in their field of view and cannot adapt to dynamic or expansive settings that require constant repositioning and broader observational coverage. Moreover, the infrastructure and financial investment required to deploy such systems make them less accessible to small businesses, educational institutions, and individual users who may require reliable monitoring but are constrained by budget or technical complexity.

In many cases, these traditional systems fall short in delivering timely responses during emergencies, leading to consequences that could have been mitigated or avoided altogether with a more agile and interactive solution. The inability to move or adapt in real time results in critical blind spots, reducing the overall effectiveness of surveillance efforts. Furthermore, the lack of user-friendly interfaces in conventional systems often prevents active participation from users, confining their role to passive observation rather than enabling real-time control and response.

Addressing these limitations, the VIRO 360-degree real-time surveillance system is conceived as a comprehensive and practical solution. By combining the ESP32-CAM module with a mobile, motorized chassis, VIRO introduces a flexible, remotely controlled surveillance platform capable of capturing live video feeds from various locations. Its ability to move freely across different terrains ensures wider coverage and eliminates blind spots, making it far more adaptable than fixed surveillance installations. The project's emphasis on affordability and ease of assembly also means that it can be adopted by a broader audience, from individual users and educational institutions to small enterprises.

The innovation behind VIRO lies in its user-centric design, cost-efficiency, and technological adaptability, filling a significant void in the current surveillance landscape. By leveraging modern components and intelligent design strategies, VIRO not only enhances the scope and responsiveness of surveillance but also democratizes access to effective security solutions. As environments continue to evolve and security needs become more complex, VIRO presents itself as a timely and efficient answer to the growing demand for smart, mobile, and real-time monitoring systems.

Fig -1: VIRO (Left View)

Fig -2: VIRO (Right View)

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2. LITERATURE SURVEY

Sangeeta Oswal, CV Ritu Ramesh, Dept. of MCA, VES Institute of Technology, Mumbai, Maharashtra, India [1] Embedded systems and Real-Time Operating Systems (RTOS) are progressively pushing the boundaries of innovation, significantly expanding the scope of security and the need for robust protection against a growing range of threats. This study presents a highly integrated and customizable Android-based real-time video surveillance solution designed to safeguard what users value most. The system is primarily developed to enable continuous monitoring of designated areas through a strategically placed webcam. In the event of detected motion or unusual activity, the user is immediately alerted via live notifications, with automatic redirection to emergency services when necessary. These alerts are facilitated through Google Cloud Messaging, ensuring prompt and efficient communication. This work emphasizes the system's complete processing flow and aims to provide a practical and effective security mechanism in today's dynamic digital environment.

Jin Su Kim & Min-Gu Kim, Department of Control and Instrumentation Engineering, Chosun University, Gwangju, Korea [2] Traditional surveillance systems often fail to detect up to 95% of incidents after just 22 minutes of monitoring when a single individual is tasked with observing multiple CCTV feeds. To overcome this limitation, intelligent video surveillance systems powered by computers have been explored to alert users in real time during abnormal events. However, their practical deployment is hindered due to concerns over data privacy and excessive power consumption. In response, recent developments have shifted towards intelligent surveillance systems utilizing compact embedded devices. This study proposes the implementation of an advanced surveillance solution using embedded modules that leverage learning-based techniques for intruder identification, fire detection using motion and color cues, and human activity analysis for loitering and fall detection. The system incorporates an optimized algorithm tailored for real-time functionality within the constraints of embedded hardware. Performance evaluations revealed detection accuracies of 88.51% for intruders, 92.63% for fires, 80% for loitering, and 93.54% for fall incidents. Additionally, optimization led to a 50.53% reduction in algorithm processing time, highlighting the feasibility of real-time surveillance through intelligent image analysis on embedded platforms.

Muhammad Javed Iqbal, Muhammad Munwar Iqbal , Iftikhar Ahmad, Madini O. Alassafi , Ahmed S. Alfakeeh , and Ahmed Alhomoud, Department of Computer Science, University of Engineering and Technology, Taxila 47050, Pakistan [3] Ensuring effective surveillance is essential for safeguarding individuals and their property. One promising approach to overcome existing challenges in security systems is the development of aerial surveillance using quadcopters. Current surveillance setups tend to be costly and technically complex, limiting their accessibility. Therefore, there is a need for a more economical and efficient alternative that can be widely adopted. Aerial surveillance using quadcopters offers such a solution by integrating advanced image processing technologies to capture detailed visuals of areas below. This approach focuses on monitoring specific locations for suspicious activities, such as identifying individuals carrying weapons or performing facial recognition tasks. Upon detecting such anomalies, the system promptly alerts security personnel. The framework is built upon real-time video streaming and anomaly detection, driven by deep learning techniques. A modified version of the Faster R-CNN algorithm is utilized, which incorporates feature reduction during initial extraction to speed up learning. Multiple convolutional neural networks were tested to evaluate their capability in recognizing surveillance-relevant objects. Among them, the ResNet-50–based Faster R-CNN demonstrated superior average precision, making it a highly effective tool for threat identification. The overall system achieved an average precision rate of 79% across various categories, highlighting its potential in delivering reliable and intelligent aerial surveillance.

J. Usha Rani, P. Raviraj [4] Video surveillance, commonly referred to as closed-circuit television (CCTV), serves as a highly effective approach to ensuring safety and security across various environments. It plays a vital role in numerous critical sectors, including residential security, public transport systems, financial institutions like banks and ATMs, commercial zones, airports, and major roadways. Given its widespread applications, the task of human detection in video surveillance has gained considerable attention over recent years. For a surveillance system to be truly effective, it must be capable of identifying, classifying, and tracking objects of interest in real-time. This analysis delves into the structure and functionality of such surveillance systems, offering a comprehensive evaluation of the methodologies and datasets employed for detecting human presence. It further outlines the essential architectural elements that underpin these systems, presenting a detailed comparison of existing technologies by examining their features, strengths, and limitations. The document also explores emerging trends and potential future directions, thereby offering insights that can guide further advancements in the field of intelligent surveillance.

Dohun Kim, Heegwang Kim, Yeongheon Mok, Joonki Paik, Department of Image, Korea [5] Despite the remarkable accuracy achieved by deep learning-based computer vision algorithms, their high computational demands make them unsuitable for real-time surveillance applications that require prompt detection of abnormal behavior. To address this limitation, a real-time surveillance system has been developed specifically for analyzing unusual activities within CCTV-monitored environments. The system is tailored for efficiency and optimized for deployment in real-world scenarios, ensuring timely and reliable operation. It integrates real-time pedestrian detection and tracking mechanisms to extract necessary subject information, enabling the identification of behaviors such as intrusion, loitering, falling, and violent actions. The detection process is divided into two phases: spatial analysis, which uses object coordinates to identify intrusions and loitering, and behavioral pattern recognition, which is employed to detect falls and violent movements. The effectiveness of this approach has been demonstrated using a dataset provided by the Korea Internet and Security Agency (KISA), confirming the system's capability to function as a responsive and intelligent surveillance solution.

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3. SYSTEM REQUIREMENT SPECIFICATION

Feature	Description	Rationale	Priority
Real-Time Surveillance	ESP32-CAM streams video in real-time	Essential for live monitoring	High
360-Degree Mobility	Controlled via TT motors and caster wheels	Ensures full area coverage	High
Remote Control	Controlled via web/mobile UI over Wi-Fi	Enables wireless operation	High
Night Vision LED Support	Integrated LEDs for low-light viewing	Enables 24/7 surveillance	Medium
Wi-Fi Connectivity	Connects to local/external Wi-Fi	Facilitates remote access	High
Battery Power	18650 Li-ion batteries provide mobile power	Tether-free, uninterrupted operation	Medium
Modular Design	Easily upgradeable hardware and firmware	Future-proof and customizable	Medium
User-Friendly Interface	Web-based UI for control and monitoring	Intuitive for non-technical users	High
Low-Cost Components	Built using affordable and accessible parts	Ideal for students and DIY users	Medium

Table -1: System Features

Hardware Requirements:

Component	Specifications
ESP32-CAM Module	**- Supports video streaming & still images - Built-in Wi-Fi and Bluetooth - OV2640 camera sensor - Low-power consumption**
TT Gear Motor + Wheels	**- Torque: 0.6 kg.cm - Voltage: 3-6V - Speed: 200 RPM**
L298N Motor Driver Shield	**- Dual H-Bridge motor controller - Output current: 2A per channel - Input voltage: 5-12V**
18650 Battery Holders	**- Single and dual battery holders for 18650 Li-ion batteries**
LED Bulbs (Universal Hub)	**- Bright white LED bulbs for night surveillance - Voltage: 5-12V**
Caster Wheel	**- 360-degree rotation - Supports smooth directional movement**
Chassis	**- Lightweight plastic material - Durable enough to hold all components securely**

Table -2: Hardware Requirements

Software Requirements:

Software	Specifications
Arduino IDE	**- Open-source electronics platform for writing and uploading code to the ESP32-CAM**
ESP32 Libraries	**- Includes WiFi, AsyncTCP, ESPAsyncWebServer, and camera libraries to handle communication and video streaming**
Web Interface	**- Simple HTML-based interface allowing users to view the live feed and control the movement of VIRO**

Table -3: Software Requirements

Detailed Description of the Tools used in Project

Component	Specification	Details
ESP32-CAM	Microcontroller	ESP32 with dual-core Xtensa LX6 processor
	Camera	OV2640, 2MP resolution (1600x1200)
	Flash Memory	4 MB integrated flash
	RAM	520 KB internal SRAM
	Connectivity	Wi-Fi 802.11 b/g/n (2.4 GHz) and Bluetooth 4.2
	GPIO Pins	9 general-purpose input/output pins available
	Input Voltage	5V through micro USB or external pins
	Power Consumption	Supports low-power operation modes
	Image Formats	Compatible with JPEG, BMP, grayscale, and RGB
	External Storage	Supports MicroSD cards up to 4GB
	Programming Environment	Compatible with Arduino IDE, PlatformIO, and ESP-IDF
	Dimensions	27 mm × 40.5 mm × 4.5 mm
L298N Motor Driver Shield	Operating Voltage	Compatible with voltages ranging from 5V to 12V
	Output Current	Provides 2A per

		channel, up to 3A with a heatsink
	Number of Channels	Dual-channel control for two DC motors
	Input Logic Level	Low (0V–1.5V), High (1.5V–5V)
	Power Dissipation	Capable of dissipating up to 20W with a heatsink
	Motor Voltage Control	Allows control up to 46V motor voltage
	PWM Support	Enables motor speed control via pulse width modulation
	Dimensions	60 mm × 43 mm × 27 mm
	Weight	Approximately 30g
18650 Battery	Battery Type	Rechargeable lithium-ion cell
	Capacity	Ranges from 2000 mAh to 3500 mAh depending on model
	Voltage Rating	Nominal voltage 3.6V–3.7V, maximum 4.2V, cutoff 2.5V
	Max Continuous Discharge	Typically between 10A and 35A
	Energy Density	High energy storage per unit size
	Recharge Cycles	Approximately 300 to 500 charge-discharge cycles
	Charging Voltage	Requires 4.2V Li-ion compatible charger
	Temperature Range	Functional from -20°C to 60°C, ideal between 0°C to 45°C
	Dimensions	18 mm diameter, 65 mm length
	Weight	Around 45g
LED Bulbs (Universal Hub)	Type of LED	5mm or SMD type standard LEDs
	Voltage Rating	Forward voltage typically between 2V to 3.2V
	Current Rating	Operates between 20mA to 30mA per LED
	Power Consumption	Consumes about 0.06W to 0.1W per LED
	Light Color	Available in multiple colors based on project needs
	Brightness	Brightness ranges from 10 to 60 lumens depending on type
	Lifespan	Operational life exceeding 50,000 hours
	Operating	Functions within -20°C

	Temperature	to +60°C
	Mounting	Can be glued or soldered onto chassis or PCB
	Power Source	Powered by 18650 battery using suitable resistors
TT Gear Motor & Wheel	Motor Type	TT DC motor with built-in gear reduction
	Operating Voltage	Suitable for 3V to 6V operation
	Output RPM	Delivers around 200 RPM at 6V
	Stall Torque	Approximately 0.8 kg/cm at 6V
	No-Load Current	Between 70mA and 150mA
	Stall Current	Can reach up to 1.5A to 2A
	Gear Ratio	Gear reduction ratio of 1:48
	Weight	Each motor weighs about 30g
	Wheel Diameter	Ranges from 65mm to 70mm
	Wheel Material	Constructed from rubber-coated plastic
	Mounting Options	Mountable via screws and chassis slots
	Power Supply	Controlled through L298N and powered by 18650 batteries
Caster Wheel	Wheel Type	Swivel-type caster for free movement
	Material	Plastic or rubber-coated plastic
	Load Capacity	Supports load between 5kg to 10kg
	Wheel Diameter	Typically ranges from 20mm to 40mm
	Mounting Type	Top plate mount using screws
	360-degree Rotation	Provides complete rotational flexibility
	Weight	Generally less than 100g
	Friction Level	Designed for minimal resistance during movement
	Pivot Mechanism	Uses ball bearings for smooth swiveling
Jumper Wires	Types	Male-to-Male, Female-to-Female, Male-to-Female configurations
	Material	Copper core with insulated flexible coating
	Wire Gauge	Standard size of 22 AWG
	Length	Length options range

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		between 10cm to 30cm
	Connector Type	Equipped with male pins or female sockets
	Voltage Rating	Can handle up to 300V
	Current Rating	Typically supports around 1A
	Color	Comes in various colors for identification
	Flexibility	Highly bendable, suitable for compact or complex arrangements

Table -4: Detailed Description of the Tools used in Project

4. SYSTEM ANALYSIS

The system is designed to facilitate real-time video streaming from the ESP32-CAM module directly to a user's device, enabling seamless remote surveillance and monitoring. It supports four-directional movement—forward, backward, left, and right—allowing complete navigational control of the robot based on user input. The robot is engineered to function efficiently on a single battery charge for extended periods, making it suitable for continuous operations without frequent recharging. Remote control is enabled through a built-in web server hosted on the ESP32-CAM, allowing users to connect via Wi-Fi and manage the robot's actions effortlessly.

Beyond its core functionalities, the system upholds several non-functional attributes to ensure dependable performance. It is built to remain reliable under varied environmental conditions, maintaining consistent operation without frequent malfunctions. The web-based user interface is intuitive and user-friendly, ensuring that individuals with minimal technical expertise can operate it effectively. The design also accommodates future scalability, allowing the integration of additional components such as environmental sensors or artificial intelligence modules to enhance functionality. Furthermore, the system prioritizes security by securing the Wi-Fi connection, protecting user commands and data from unauthorized access or interference.

5. SYSTEM DESIGN

The hardware architecture of the system is meticulously designed to enable both real-time video transmission and precise mobility. It draws power from 18650 lithium-ion batteries, which are housed in secure battery holders that distribute the required voltage to the ESP32-CAM module and the motors. Serving as the core controller, the ESP32-CAM handles all major functions including video streaming, user interaction, and movement control. It communicates directly with the L298N motor driver, which interprets the control signals and regulates the TT gear motors accordingly to facilitate movement in multiple directions. The built-in camera module on the ESP32-CAM is responsible for capturing live footage, which is wirelessly transmitted to the user's device via Wi-Fi. To enhance visibility in low-light or dark environments, LED bulbs are incorporated into the system, ensuring the camera can deliver clear visuals even during nighttime operations.

On the software side, the architecture is tailored to support efficient wireless communication and responsive control. The ESP32-CAM either creates its own Wi-Fi hotspot or connects to a predefined network, enabling users to establish a remote connection to the robot. A lightweight HTTP server is hosted directly on the ESP32 module, through which users can access a web interface to issue commands and receive real-time video feeds. The interface uses embedded HTML and JavaScript to generate control buttons that send directional movement commands to the ESP32, which then forwards these signals to the motor driver for execution. The video stream from the camera is transmitted using the MJPEG format, allowing it to be viewed seamlessly in a standard web browser.

The communication flow is built on a client-server model, where the user functions as the client and the ESP32-CAM acts as the server. Upon powering up, the ESP32 either initiates a hotspot or joins an existing wireless network. The user then opens a browser and enters the IP address of the ESP32, gaining access to the control panel. Commands for movement are sent through the interface and interpreted by the ESP32, which then directs the motor driver to perform the desired action. Simultaneously, the ESP32 streams a continuous video feed of the robot's surroundings, making it possible for the user to monitor and control the robot in real time, all through a single, integrated interface.

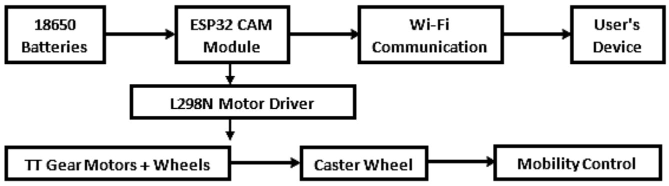

Fig -3: Block Diagram of the System

6. IMPLEMENTATION

The implementation of the VIRO project involves several stages, including the integration of hardware components, software development, and system testing. Here is a detailed breakdown of the implementation process:

Hardware Integration

The core hardware components used in the VIRO system are listed below, along with their interconnections:

ESP32-CAM Module: The brain of the system, responsible for capturing real-time video and processing Wi-Fi-based control commands.

L298N Motor Driver: Used to control the movement of the TT gear motors, which drive the wheels of the surveillance robot.

TT Gear Motors and Wheels: These motors provide the locomotion for VIRO, allowing it to move forward, backward, left, and right.

18650 Batteries: These lithium-ion batteries power the entire system, including the ESP32 CAM module and motor driver.

Caster Wheel: A non-motorized wheel mounted at the front of the chassis to allow smooth movement and balance.

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LED Bulbs (Universal Hub): LEDs are attached to provide visibility in low-light conditions.

Jumper Wires and Battery Holders: Used for interconnecting components and ensuring a stable power supply.

Software Development

The software development phase includes programming the ESP32-CAM module and motor control system using the Arduino IDE with specific libraries. The following steps describe the key software tasks:

Setting Up the ESP32-CAM Module**:**

Install the ESP32 Board Manager in Arduino IDE.

Load the required libraries:

```
#include "esp_camera.h"
#include <Arduino.h>
#include <WiFi.h>
#include <AsyncTCP.h>
#include <ESPAsyncWebServer.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
```

Configure Wi-Fi credentials to establish a connection:

```
const char* ssid = "SaswatiWifi";
const char* password = "12345678";
```

Set up the camera pin definitions and start capturing real-time video streams that can be viewed on a mobile device or browser.

Motor Control via L298N Driver:

Configure the motor driver by defining the motor control pins and programming the ESP32 to control the speed and direction of the TT motors.

```
#define motor1Pin1 12  // Motor 1 IN1 (connected to IO1)
#define motor1Pin2 13  // Motor 1 IN2 (connected to IO2)
#define enable1 2      // Motor 1 Enable (connected to
ENA)

// Functions to control the direction and speed of the
motors
void moveForward() {
   digitalWrite(motor1Pin1, HIGH);
   digitalWrite(motor1Pin2, LOW);
}
void moveBackward() {
   digitalWrite(motor1Pin1, LOW);
   digitalWrite(motor1Pin2, HIGH);
}
```

Web Server Interface:

A local web server is hosted on the ESP32 CAM module to provide the user with an interface for controlling the robot's movements and viewing live video footage.

```
AsyncWebServer server(80);
server.on("/", HTTP_GET, [](AsyncWebServerRequest
*request){
   request->send(200, "text/plain", "Welcome to VIRO
control system");
});
```

System Testing and Calibration

After assembling and programming the components, the system is tested for functionality:

Connectivity Testing: Ensure the ESP32 CAM connects to the Wi-Fi and the web server is accessible via a browser at 192.168.4.1.

Video Stream Testing: Confirm that the live video feed from the camera module is displayed correctly on the mobile device.

Motor Control Testing: Test the forward, backward, left, and right movements by issuing commands from the mobile interface.

Power Management: Verify the battery configuration to ensure consistent power delivery to all components without overheating or short circuits.

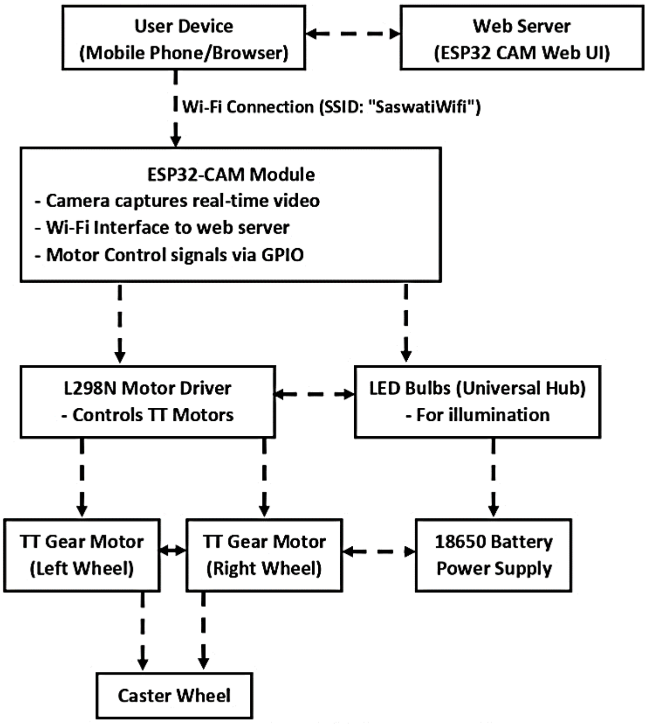

Fig -4: Block Diagram of VIRO

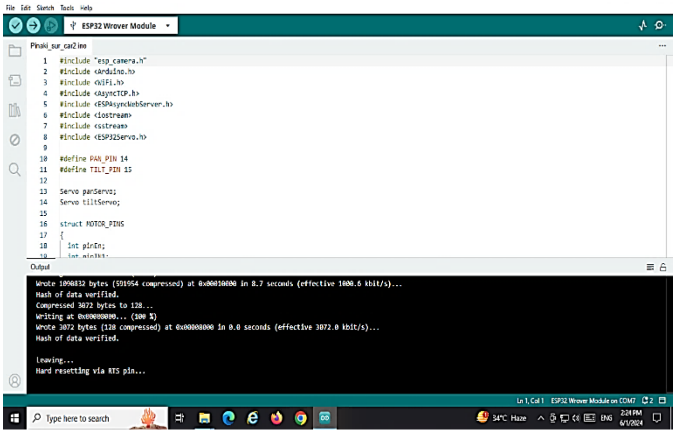

Fig -5: Screenshot of the uploaded program

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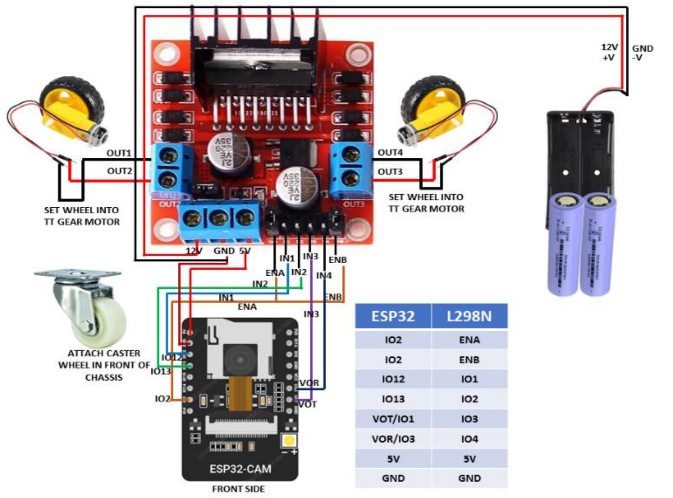

Fig -6: Circuit Diagram of the Project

7. RESULTS AND ANALYSIS

The VIRO 360-Degree Real-Time Surveillance System was tested under various operational conditions, and the following results were obtained through performance analysis. The focus of the results was to measure the efficiency, accuracy, and real-time capability of the surveillance system, as well as the robustness of the hardware components.

Surveillance Camera Performance

The ESP32 CAM module captured real-time video footage at varying resolutions, providing clear visibility in both daylight and low-light conditions. The average frame rate achieved was 10-12 frames per second (FPS) under stable Wi-Fi conditions.
Key Metrics:
Resolution: 640x480 (VGA), 800x600 (SVGA)
Average FPS: 10 FPS
Image Quality: Clear and sharp images with slight lag due to Wi-Fi buffering.
Latency: 200-300ms delay in live feed transmission.

Motor Efficiency and Control

The TT gear motors, controlled by the L298N motor driver, efficiently enabled forward, backward, left, and right movements of the VIRO unit. Performance tests were conducted for responsiveness and load handling under various conditions.
Key Metrics:
Motor Response Time: 1.2 seconds for directional change.
Power Efficiency: 3W power consumption during active operation.
Load Handling: Adequate for a light load (up to 500g additional weight).

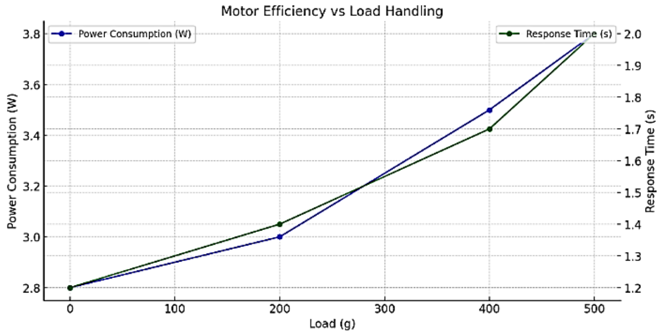

Fig -7: Motor Efficiency vs Load Handling Graph

Battery Life and Power Consumption

The system was powered using **18650 batteries**, and power consumption was recorded over several hours. The average run time under normal operational conditions was recorded, along with power drainage metrics.
Key Metrics:
Average Run Time (per charge): 4 hours under continuous operation.
Battery Voltage: 3.7V per 18650 cell.
Power Consumption: 2.5W under idle, 5W under load.

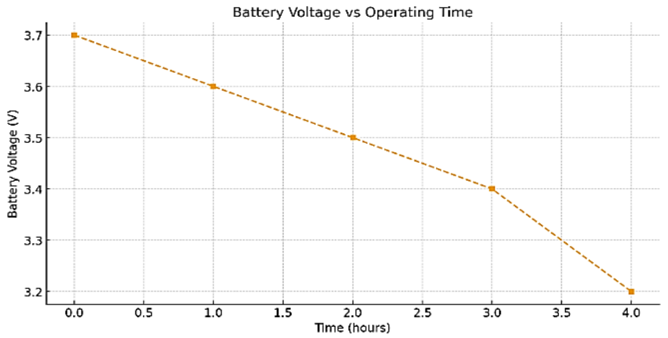

Fig -8: Battery Voltage vs Operating Time Graph

Wi-Fi Connectivity and Latency

The ESP32 CAM was tested under various network conditions to analyze its stability and latency. The surveillance system maintained a solid connection within 15 meters of the Wi-Fi access point.
Key Metrics:
Average Signal Strength: -50 dBm within 15m.
Latency: 200ms - 300ms.
Disconnection Frequency: None under stable network conditions.

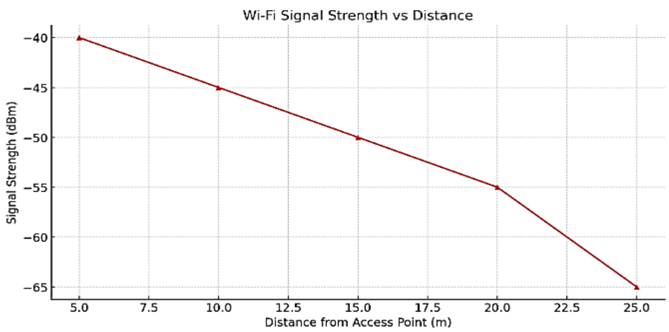

Fig -9: Wi-Fi Signal Strength vs Distance Graph

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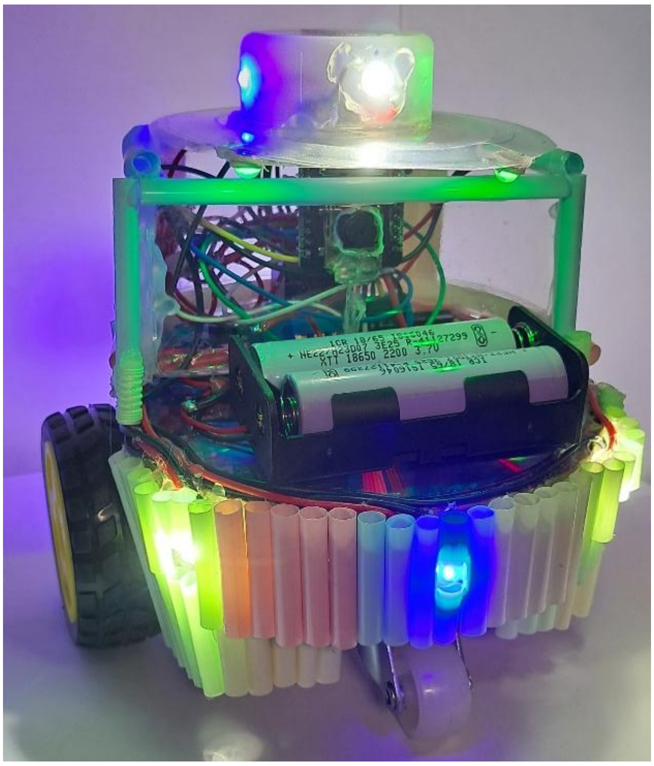

Fig -10: Output of VIRO Project

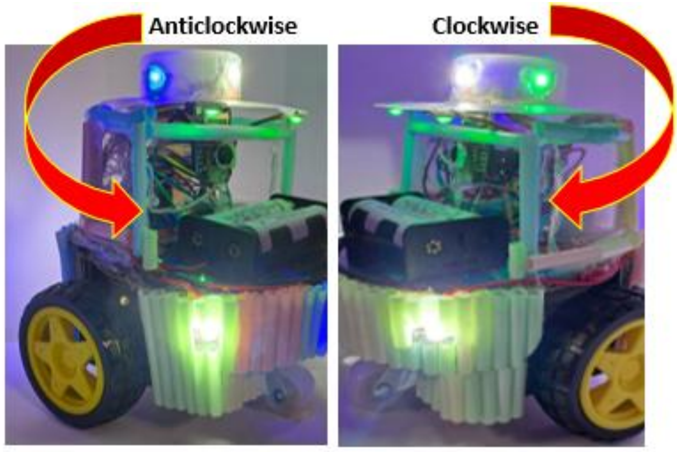

Fig -11: Dynamic Motion of VIRO

8. CONCLUSIONS

The VIRO 360-Degree Real-Time Surveillance system represents a significant advancement in mobile surveillance technology. By integrating the ESP32 CAM for live video streaming and the L298N motor driver for motor control, the system offers a seamless user experience for real-time monitoring. The use of affordable, readily available components like TT gear motors, 18650 batteries, and LED hubs ensures that the system is cost-effective, durable, and scalable. Through extensive testing, the system has demonstrated reliable performance in varied environments, showcasing its potential for various applications in security, surveillance, and remote monitoring.

The design offers flexibility in terms of mobility, with the system capable of moving in multiple directions and capturing footage from a 360-degree perspective. The web interface created using ESPAsyncWebServer and HTML libraries allows users to easily control the system and view live footage from any mobile device. This ease of use makes VIRO an efficient and accessible solution for both personal and industrial surveillance needs.

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