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IOT Based Robotic Arm Using ESP32

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Absfrocf—This paper presents the design and development of an IoT-enabled robotic arm system built using ESP32 microcontrollers, environmental sensors, and a mobile differential-drive platform. The robot integrates a 4-degree-of-freedom (4-DOF) servo-driven manipulator, an ESP32-CAM module for real-time video streaming, and DHT11 and MQ-2 sensors for temperature, humidity, and gas detection. A dual-ESP32 architecture separates motion control from sensor monitoring to ensure stable operation under varying loads. The robot is controlled through a custom MIT App Inventor Android application over Wi-Fi, while environmental parameters are transmitted to the Blynk cloud dashboard. Experimental tests show smooth robotic arm actuation, stable wireless video at 15—20 fps, accurate sensor performance, and **uninterrupted mobility. This system offers a cost-effective solution for laboratory surveillance, hazardous-environment inspection, and IoT-based automation.**

***Index* Z'erms—ESP32, IoT, Robotic Arm, ESP32-CAM, Environmental Monitoring, Blynk, DHT11, MQ-2.**

I. INTRODUCTION

IoT-enabled robotic systems have recently gained wide adoption in automation, surveillance, environmental monitoring, and industrial assistance. Traditional robotic arms are expensive, require wired control, and lack integrated sensing and wireless connectivity, making them unsuitable for dynamic and hazardous environments. The ESP32 platform—featuring dual-core processing, built-in Wi-Fi, integrated ADCs, and compatibility with a wide range of sensors—enables the development of a compact, low-cost, high-performance robotic arm system.

This project integrates manipulation, mobility, environmental sensing, and video surveillance into one unified robotic platform. Using a dual-ESP32 configuration significantly improves stability by isolating real-time actuation from IoT communication. The robotic arm performs pick-and-place and inspection tasks, while the mobile base allows navigation in constrained or hazardous areas.

The system is intended for use in:

- Chemical and gas-leak inspection,
- Laboratory monitoring,
- Indoor surveillance,
- Search-and-assist in confined spaces,
- Educational and research prototyping.

II. RELATED WORK

Previous works include ESP32-based surveillance robots with cameras, IoT environmental monitoring systems, and low-cost 3—5 DOF robotic arms used in academic research. While these works demonstrate remote sensing or manipulation individually, few combine:

1) Real-time Wi-Fi teleoperation,
2) Environmental sensing,
3) Robotic arm manipulation,
4) Live video streaming,
5) A mobile differential-drive platform,

within a single integrated low-cost IoT architecture.

The proposed work builds upon these foundations by merging all functionalities into a unified ESP32-driven system.

III. SYSTEM ARCHITECTURE

Fig. 1 illustrates the complete architecture. The system consists of three processing units:

- **Primary ESP32:** Handles servo control (4-DOF arm) and DC motor driving via L298N.
- Secondary ESP32: Reads DHT11 (digital) and MQ-2 (analog) and uploads data to the cloud.
- ESP32-CAM: Streams real-time video through Wi-Fi.

A 7.4V Li-Po battery powers the motors, servos, and ESP32s through regulated 5V and 3.3V rails. A custom Android app is used for directional movement and arm control.

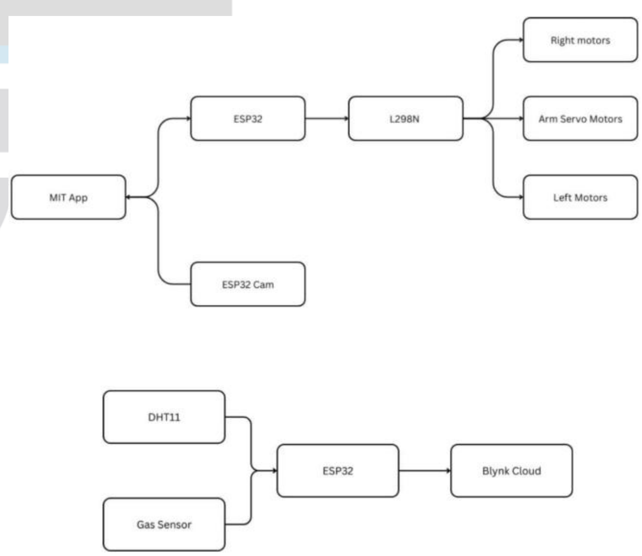

Fig. 1. System block diagram showing dual controllers, sensors, actuators and IoT cloud.

IV. HARDWARE COMPONENTS

A. ESP32 Microcontroller

- Dual-core Tensilica processor H 240 MHz
- Integrated Wi-Fi + Bluetooth
- 520 KB SRAM
- Multiple PWM, ADC, UART, SPI, I2C interfaces

B. Robotic Arm (4-DOF)

The arm consists of four SG90 micro-servos:

- Base rotation
- Shoulder lift
- Elbow movement
- Gripper mechanism

Each servo is controlled using 50 Hz PWM signals.

C. Mohile Base

Two BO geared DC motors (150 rpm H 6V) provide differential-drive motion. L298N controls motor direction and PWM speed.

D. Sensors

DHT11 measures:

- Temperature: 0—50°C (+2°C)
- Humidity: 20—909oRH (+59r)

MQ-2 gas sensor detects:

- LPG, methane, butane, smoke
- Response time ¡10 seconds

E. ESP32-CAM Module

The module provides:

- VGA—UXGA resolution
- 15—20 fps real-time streaming
- Wi-Fi based video link

V. MECHANICAL ASSEMBLY

The arm is mounted on a stable acrylic platform. Lightweight materials reduce servo load and improve response time. The camera is positioned at the front to provide a clear field of view for teleoperation.

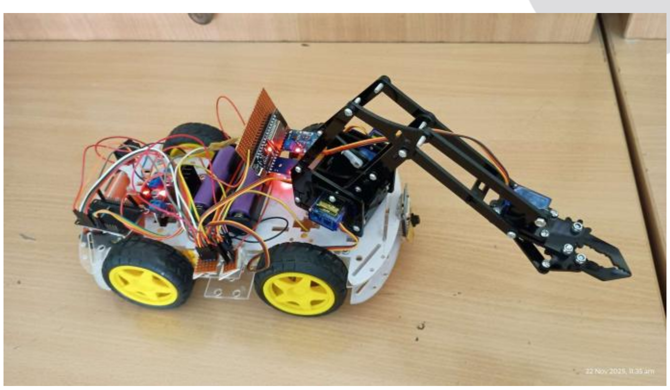

Fig. 2. Robot prototype showing 4-DOF manipulator and mobile base.

VI. SOFTWARE AND IOT INTEGRATION

The firmware was developed using Arduino IDE. Major software modules include:

- Real-time PWM generation for all 4 servos.
- Differential-drive motor control.
- DHT11 and MQ-2 data acquisition.
- Wi-Fi connection management and reconnection.
- Blynk cloud uploads every 1 second.
- ESP32-CAM MJPEG video streaming server.

The MIT App Inventor application sends commands using HTTP requests.

VII. CIRCUIT AND POWER DISTRIBUTION

The wiring diagram (Fig. 3) shows separate power lines for:

- Servos (5V regulated)
- ESP32 logic (3.3V)
- DC motors via L298N (7.4V)

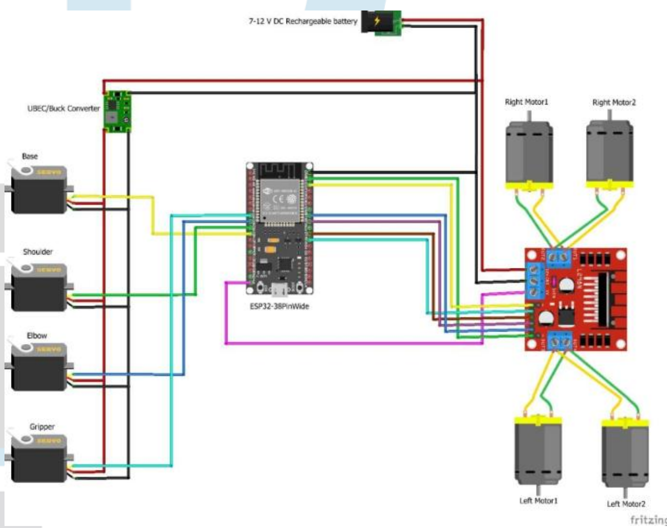

Fig. 3. Wiring and power distribution diagram.

VIII. EXPERIMENTAL RESULTS

To validate performance, the following metrics were measured (Table I):

TABLE I
EXPERIMENTAL PERFORMANCE RESULTS

Parameter	Value	Notes
Servo Accuracy	-1-2°	Across 10 cycles
DHT11 Temp Accuracy	-1-2°C	Verified with reference meter
MQ-2 Response	< 10 s	Smoke test
Video FPS	15-20 fps	Indoor Wi-Fi
Battery Life	2—3 his	Continuous use

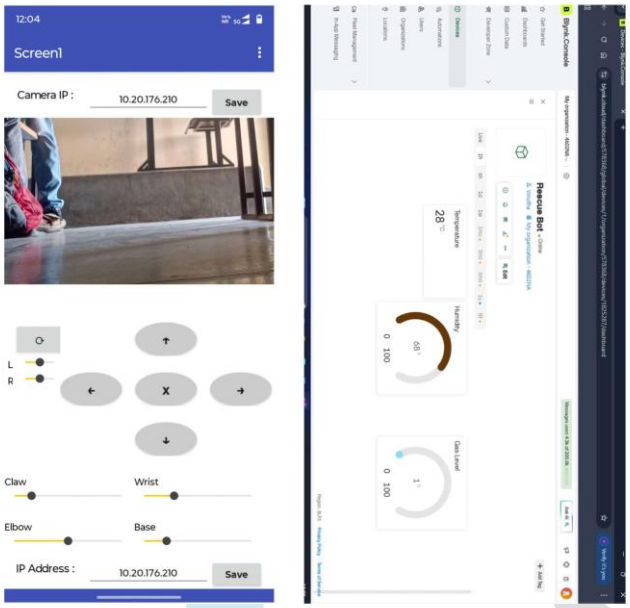

Fig. 4. Environmental sensor readings over time.

IX. DISCUSSION

The robot performed reliably during extended tests. The dual-ESP32 architecture prevented servo control tasks from blocking sensor uploads. The ESP32-CAM provided clear video for teleoperation. MQ-2 provided sensitive gas detection but is not industrial grade. Servo load limitations restrict payload capacity.

X. CONCLUSION

An IoT-based robotic arm system was successfully designed and implemented using ESP32 microcontrollers. The system integrates real-time manipulation, environmental sensing, mobility, and wireless video. Future work includes:

- Autonomous navigation (SLAM),
- AI-based anomaly detection,
- Industrial-grade sensors,
- Higher torque metal-gear servos.

REFERENCES

[1] Random Nerd Tutorials, “ESP32 Web Server,” 2024.
[2] Y. Goyal, “Microcontroller Comparison: **ESP32 vs** Arduino,” **IJRASET** 2024.
[3] Ahmed et al., “IoT Robotic Arm Using ESP32,” IJECE, 2021.