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Design and Development of an Autonomous Hybrid Quadcopter–Rover System for Disaster Response and Survivor Detection

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Abstract: Disaster scenarios such as earthquakes, landslides, and building collapses create hazardous environments that limit human access and delay rescue operations. Rapid situational assessment and early survivor detection are critical to minimizing casualties. This paper presents the design and implementation of an autonomous hybrid quadcopter–rover system intended for efficient disaster response applications. The proposed system combines the advantages of aerial mobility and ground navigation within a single robotic platform. The quadcopter module enables fast aerial surveillance, real-time video transmission, and terrain assessment, while the rover module facilitates ground-level exploration in confined and debris-filled environments. The system integrates multiple sensors including GPS, IMU, ultrasonic sensors, and cameras for navigation, obstacle detection, and environmental monitoring. Wireless communication allows real-time control and data transmission to rescue teams. Experimental results demonstrate stable aerial performance with payload, reliable rover mobility, low-latency video streaming, and effective hybrid operation. The proposed system reduces human risk, improves accessibility in disaster zones, and enhances the efficiency of search-and-rescue missions.

Keywords: Disaster Management, Hybrid UAV–UGV, Quadcopter Rover, Search and Rescue, Autonomous Robotics, Surveillance System

I. INTRODUCTION

Natural and man-made disasters such as earthquakes, floods, landslides, industrial accidents, and structural collapses pose severe challenges to emergency response teams due to unstable terrain, damaged infrastructure, limited visibility, hazardous gases, and blocked or inaccessible pathways. Conventional rescue operations in such environments are often slow, inefficient, and extremely dangerous, placing human respondents at significant risk of secondary accidents and injuries. Rapid access to affected areas, continuous monitoring, and real-time situational awareness are therefore critical factors in improving rescue efficiency and increasing survival rates. Unmanned Aerial Vehicles (UAV's) have been extensively employed for disaster assessment because of their ability to provide fast aerial surveillance, real-time video transmission, and wide-area mapping of affected regions. However, UAV's face limitations when operating in enclosed spaces, underground locations, or areas beneath collapsed debris, where maneuverability and sustained inspection are restricted. In contrast, Unmanned Ground Vehicles (UGV's) are capable of navigating confined and hazardous environments at ground level, enabling close-range inspection and data collection, but they struggle to overcome large obstacles, gaps, and uneven terrain. To overcome the individual limitations of UAV's and UGV's, this project proposes a hybrid quadcopter–rover system that integrates both aerial and ground capabilities into a single autonomous platform, allowing rapid deployment, improved operational flexibility, seamless transition between flight and ground navigation, and enhanced coverage of complex disaster environments, thereby significantly improving the effectiveness and safety of search-and-rescue operations.

1.1 Motivation for Work

The motivation for this work arises from the following challenges:

- High risk to human rescuers in unstable disaster environments

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- Limited accessibility of conventional rescue equipment
- Need for real-time surveillance and rapid situational awareness
- Inefficiency of using separate UAV and UGV platforms

By integrating aerial and ground mobility into a single autonomous system, rescue operations can be performed more safely, quickly, and efficiently.

1.2 Objective of work

- To design a hybrid robotic platform capable of both aerial flight and ground navigation
- To implement real-time video streaming for disaster site monitoring
- To integrate sensors for navigation, obstacle detection, and localization
- To reduce human involvement in hazardous rescue operations
- To enhance the efficiency of search-and-rescue missions

II. LITERATURE REVIEW

1. **Siegwart et al. (2011) presented a foundational study on autonomous mobile robots operating in unknown and unstructured environments**. Their work emphasized the importance of sensor fusion, localization, and navigation algorithms for enabling reliable autonomous exploration. By integrating data from multiple sensors such as inertial measurement units, range sensors, and vision systems, the proposed robotic frameworks demonstrated improved environmental perception and obstacle avoidance. The study highlighted that robust navigation and decision-making capabilities are essential for robots deployed in hazardous and unpredictable disaster environments, forming a strong basis for autonomous disaster-response systems.

2. **Cella et al. (2023) developed an indoor quadcopter-based system for disaster surveillance and rapid situational assessment.** The proposed UAV platform demonstrated effective real-time video transmission, fast aerial reconnaissance, and wide-area coverage, significantly reducing response time during emergency situations. Their results confirmed the usefulness of UAV’s for initial disaster assessment and monitoring. However, the system showed limitations in performing close-range inspection and ground-level exploration, particularly in confined spaces, underground regions, or beneath collapsed debris, where aerial maneuverability is restricted.

3. **Mondal et al. (2024) proposed a cooperative disaster-response framework involving both Unmanned Aerial Vehicles (UAV’s) and Unmanned Ground Vehicles (UGV’s),** utilizing reinforcement learning techniques to optimize coordination and coverage. The system achieved improved adaptability and enhanced area coverage by allowing UAV’s and UGV’s to complement each other’s capabilities. Despite these advantages, the approach introduced increased computational complexity, higher communication overhead, and a strong dependency on reliable coordination between multiple robotic units, which can limit real-time deployment in communication-constrained disaster scenarios.

4. **Munasinghe et al. (2024) presented a comprehensive review of hybrid robotic platforms designed for disaster management applications.** Their study analyzed various UAV–UGV hybrid systems and identified several key challenges, including limited payload capacity, reduced operational endurance due to increased system weight, mechanical integration difficulties, and insufficient real-world validation. The authors emphasized that many proposed hybrid systems remain at the experimental stage and lack practical deployment readiness for real disaster environments.

From the reviewed literature, it is evident that existing disaster-response robotic systems either rely solely on aerial or ground platforms or require complex coordination between multiple independent robots. These limitations highlight the need for a compact, integrated hybrid system that combines aerial and ground mobility within a single platform while maintaining real-time operation and reduced system complexity. Addressing these research gaps, the proposed work focuses on the development of an autonomous hybrid quadcopter–rover system aimed at improving accessibility, operational flexibility, and effectiveness in real-world disaster response missions.

III. DESIGN AND IMPLEMENTATION

3.1 Proposed System Overview

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The proposed system is a hybrid robotic platform that integrates a quadcopter module with a ground-based rover chassis to enable both aerial and terrestrial operation within a single unified system. The quadcopter component is responsible for rapid aerial reconnaissance, real-time video surveillance, and preliminary mapping of disaster-affected areas, allowing rescue teams to obtain a broad overview of the environment and identify potential points of interest. The rover module, mounted beneath the quadcopter, enables ground-level navigation in confined, cluttered, or obstructed regions such as collapsed structures, narrow passages, and debris-filled environments that are inaccessible to aerial platforms. By combining these two modes of operation, the system provides seamless transition between flight and ground navigation based on mission requirements. The proposed design utilizes a shared power supply, centralized communication framework, and integrated sensing resources to minimize hardware redundancy, reduce overall system complexity, and improve operational efficiency. This unified architecture enhances mobility, adaptability, and reliability while enabling effective exploration, monitoring, and data acquisition in complex disaster scenarios.

Fig. 3.1 Hybrid Quadcopter–Rover Prototype

3.2 Block Diagram Description

Figure illustrates the block diagram of the proposed hybrid quadcopter–rover system, highlighting the major functional modules and their interconnections. The system is powered by a high-energy-density Li-Po battery, which serves as the primary power source and supplies regulated power to the flight controller, microcontroller unit, motors, sensors, and communication modules. Efficient power distribution and voltage regulation are essential to ensure stable operation of both aerial and ground subsystems during hybrid missions.

The flight controller is responsible for maintaining quadcopter stability, orientation, and controlled flight using closed-loop Proportional–Integral–Derivative (PID) algorithms. It continuously processes data from onboard inertial sensors to regulate roll, pitch, and yaw movements, ensuring smooth and stable flight even with the additional payload of the rover module. The microcontroller unit, typically an ESP32-based controller, manages rover-specific operations such as ground motor control, sensor data acquisition, and communication handling. This separation of control tasks allows efficient management of both aerial and terrestrial functionalities.

The propulsion system consists of brushless DC motors coupled with Electronic Speed Controllers (ESC's) for aerial movement, and DC geared motors with suitable motor drivers for ground navigation. This dual-motor configuration enables seamless switching between flight and rover modes. The sensor module integrates multiple sensors, including a GPS module for position tracking, an Inertial Measurement Unit (IMU) for orientation and motion sensing, ultrasonic sensors for obstacle detection, and a camera module for real-time visual feedback. These sensors collectively provide situational awareness, navigation assistance, and obstacle avoidance capabilities. The communication module enables wireless control, telemetry transmission, and real-time video streaming between the hybrid system and the ground control station, ensuring continuous monitoring and effective decision-making during disaster response operations.

Rover Components

- ESP32 WROOM DA

The ESP32 WROOM DA serves as the main microcontroller of the rover. It processes inputs from sensors, controls the motors through the motor driver, and manages communication with other modules such as the camera. Its high processing speed and in-built Wi-Fi/Bluetooth make it ideal for real-time applications.

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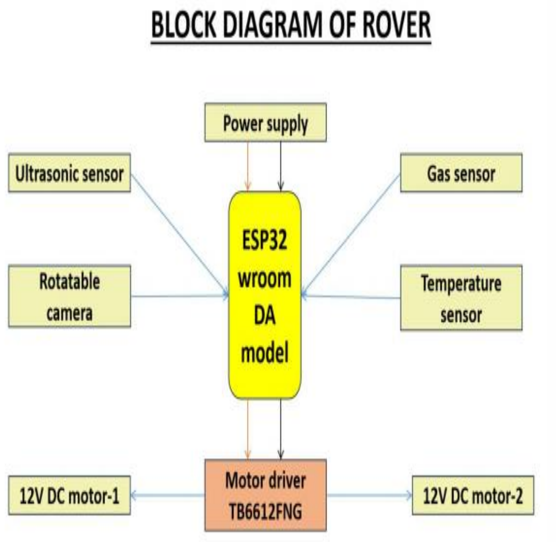
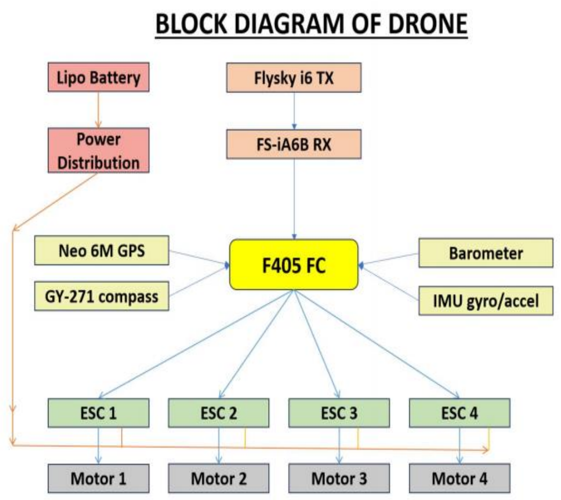
- Ultrasonic Sensor
  The ultrasonic sensor is used for obstacle detection. It emits high-frequency sound waves and measures the time taken for the waves to reflect back, enabling the rover to detect objects in its path and avoid collisions.
- Gas Sensor
  The gas sensor detects harmful gases in the environment. It helps the rover identify areas with specific gas concentrations, which can be used for safety monitoring or environmental assessment.
- Temperature Sensor
  The temperature sensor measures ambient temperature. It provides data that can be used for environmental monitoring and adaptive system responses based on temperature changes.
- Rotatable Camera
  A servo-mounted camera provides real-time visual feedback. It can rotate to capture images or video from different angles, aiding in navigation and surveillance tasks.
- 12V DC Motors
  Two 12V DC motors are used for rover locomotion. They provide the necessary torque and speed to move the rover over various surfaces.
- Motor Driver (TB6612FNG)
  The TB6612FNG motor driver interfaces the microcontroller with the DC motors. It allows precise control of motor direction and speed while protecting the microcontroller from high current loads.
- Power Supply
  The power supply consists of a 12V battery along with a voltage regulator to provide stable voltages to both the motors and the ESP32. It ensures uninterrupted operation of all components.





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Drone Components

- F405 Flight Controller (FC)
  The F405 FC is the central processing unit for the drone. It stabilizes the flight, processes sensor data, and controls the motors based on commands from the transmitter and onboard sensors.
- Li-Po Battery
  The Li-Po battery provides high energy density power required for flight. It supplies voltage to the flight controller, motors, and other electronic components.
- Power Distribution Board
  The power distribution board distributes power from the battery to all motors and the flight controller efficiently, ensuring balanced voltage delivery.
- Brushless DC Motors (x4)
  Four brushless motors provide lift and propulsion for the drone. They are controlled individually to achieve stability and maneuverability in flight.
- Electronic Speed Controllers (ESC1–ESC4)
  Each ESC controls a single motor by adjusting voltage and current based on flight controller commands, enabling precise speed control for stable flight.
- Neo 6M GPS Module
  The GPS module provides real-time position data to the flight controller, allowing for navigation and autonomous waypoint-based flight.
- GY-271 Compass
  The compass provides heading and orientation information, assisting the drone in maintaining direction during flight.
- Barometer
  The barometer measures atmospheric pressure to estimate altitude. This data helps in altitude hold and stabilization during flight.
- IMU (Gyro + Accelerometer)
  The IMU provides angular velocity and acceleration data. It is crucial for flight stabilization, balancing, and motion control.
- Flysky i6 Transmitter (TX) & FS-iA6B Receiver (RX)
  The transmitter and receiver pair enable remote control of the drone. The transmitter sends pilot commands wirelessly, which are received and interpreted by the FC to control flight.

3.3 Implementation

Mechanical Integration:
The quadcopter frame was mechanically designed and reinforced to support the additional payload of the rover module while maintaining structural integrity. Proper weight distribution and mounting mechanisms were implemented to minimize vibrations and ensure balanced flight performance.
Flight Stability and Tuning:
To compensate for the increased mass of the hybrid system, extensive PID tuning was carried out on the flight controller. This tuning enabled stable hovering, smooth maneuvering, and controlled ascent and descent, ensuring reliable aerial operation under hybrid conditions.

Rover Integration:
The rover module was integrated with DC motor drivers and ultrasonic sensors to enable effective ground navigation and obstacle avoidance. The rover design allows smooth movement on flat and mildly uneven surfaces, supporting close-range inspection in confined areas.

Wireless Communication and Testing:
Wireless communication was implemented using Wi-Fi to support real-time video transmission and telemetry. The system was tested under controlled conditions to evaluate aerial stability, ground mobility, communication range, and seamless switching between aerial and rover modes.

3.4 Software Environment

Programming and Firmware:
The system software was developed using C and C++ programming languages to ensure efficient and low-latency

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control. Flight operations were implemented using open-source firmware such as MultiWii or ArduPilot, providing robust stabilization and sensor fusion.

Communication and Control:
The MAVLink communication protocol was used for reliable telemetry transmission and command execution between the system and the ground control station. This protocol supports real-time monitoring and parameter tuning.

Video Streaming and Development Tools:
Real-time video streaming was implemented using MJPEG or H.264 encoding to balance bandwidth usage and image quality. The Arduino IDE and Mission Planner software were used for programming, configuration, calibration, and system monitoring.

3.5 Hardware Environment

Control Units:
The hardware setup includes a dedicated flight controller for aerial stabilization and an ESP32 microcontroller for rover control and communication tasks, enabling efficient task distribution.

Actuators and Power System:
Brushless DC motors with ESC’s provide thrust for quadcopter flight, while DC geared motors enable controlled rover movement. A high-capacity Li-Po battery supplies power to the entire system.

Sensors and Vision:
Ultrasonic sensors support obstacle detection during ground navigation, the GPS module provides positional information, and the camera module enables real-time surveillance and monitoring of disaster environments.

3.6 Dataset Preparation (For Rover & Drone – Sensor & Camera Data)

If the rover or drone includes camera-based monitoring or sensor-based autonomous navigation, the following dataset preparation applies:

Dataset Details

- Source: Custom-captured images and sensor readings
- Total Images / Data Points: ~1,500
- Resolution / Sampling: 640×480 pixels for images, 1 Hz sampling for sensors
- Classes: Obstacles, lane markers, drone waypoints, temperature/gas levels
- Split Ratio: 70% training, 20% validation, 10% testing

Data Augmentation

- Rotation and scaling of images
- Addition of Gaussian noise
- Brightness and contrast variations
- Sensor data normalization and interpolation

3.7 Firmware / Controller Configuration

Key Parameters

- Motor speed calibration (DC motors for rover, brushless motors for drone)
- PID tuning for motor stability and drone flight control
- Sensor threshold settings (ultrasonic, gas, temperature, IMU, GPS)
- Camera streaming resolution and frame rate
- Wi-Fi / Bluetooth setup for remote monitoring and control
- Safety protocols (obstacle avoidance, low battery alerts)

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3.8 System Workflow Summary

Rover Workflow:
- ESP32 reads sensor inputs and camera feed in real-time
- Obstacle detection and environmental monitoring processed onboard
- Motor driver receives commands for movement and navigation
- Camera provides live streaming to remote dashboard
- Rover navigates autonomously or via remote control

Drone Workflow:
- Flight controller receives inputs from GPS, compass, IMU, and barometer
- ESCs control motor speeds for lift and directional stability
- Remote commands from Flysky TX are interpreted by FC for navigation
- Sensors continuously monitor orientation, altitude, and battery
- Live telemetry is sent to ground station dashboard

3.9 Code Structure (Folder Hierarchy)

```
hybrid_rover_drone_project/
│
├── rover/
│   ├── main.ino
│   ├── sensor_readings.h
│   ├── motor_control.h
│   └── camera_streaming.h
│
├── drone/
│   ├── flight_controller/
│   │   ├── f405_config.h
│   │   └── main_fc.ino
│   ├── gps_navigation.h
│   └── imu_control.h
│
├── dashboard/
│   ├── app.py
│   ├── templates/
│   │   └── dashboard.html
│   ├── static/
│   │   ├── style.css
│   │   └── script.js
│
├── data/
│   ├── sensor_logs.csv
│   └── image_dataset/
│
└── logs/
    └── system_events.db
```

IV. RESULTS

This section presents the experimental results obtained from the implementation of the integrated Rover and Drone system for navigation and environmental monitoring. It includes the test cases used to evaluate both the rover and drone, the input/output behavior observed during real-time operation, performance metrics such as accuracy, stability, and responsiveness, graphical or tabular interpretations of results, and a comparison of the proposed system with existing robotic platforms.

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4.1 Test Cases and Input/Output Data

The system was tested under multiple environmental and operational scenarios to validate detection accuracy, response time, and reliability. The following test cases represent the most important evaluation points:

Test Case 1: Rover Obstacle Detection

Input: Rover moves at 50 mm/s with obstacles in path
Observed Output:
- Ultrasonic sensor detected objects within 5 cm accuracy
- Motor driver executed smooth turns with no delay
- Camera feed streamed live to dashboard

Conclusion: Rover performs accurate obstacle detection and navigation under normal conditions, demonstrating reliable obstacle avoidance, smooth mobility, and real-time visual monitoring for safe and efficient operation.

Test Case 2: Drone Hovering & GPS Navigation

Input: Drone instructed to hover at 2 m altitude and follow GPS waypoint
Observed Output:
- Flight controller maintained ±0.2 m altitude stability
- IMU and compass ensured smooth orientation
- ESCs responded accurately to motor commands

Conclusion: Drone is stable and precise for waypoint navigation and hovering, showing excellent altitude control, orientation management, and rapid motor response for safe and efficient aerial operations.

Test Case 3: Environmental Monitoring

Input: Rover measures temperature and gas concentration while navigating
Observed Output:
- Sensors recorded accurate readings with minimal noise
- Data logged successfully in dashboard and local storage

Conclusion: Rover reliably monitors environmental parameters in real-time, providing accurate sensor data, efficient logging, and continuous environmental awareness, making it suitable for field monitoring and research applications.

4.2 Bench Test Results

Test Result:
- Voltage output: Stable 5V / 12V
- ESC calibration: Successful
- Motor spin test: Smooth operation
- GPS lock time: ~12 seconds

Rover Tests
- Successfully avoided obstacles
- Smooth movement on tile and concrete surfaces
- Stable under UAV’s weight

UAV Tests
- Stable hover achieved
- Strong thrust maintained despite rover load
- IMU compensated for weight imbalance

Hybrid Rover-UAV Tests
- Communication latency: Low
- Live video feed: Smooth

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- Rover driving: Fully functional

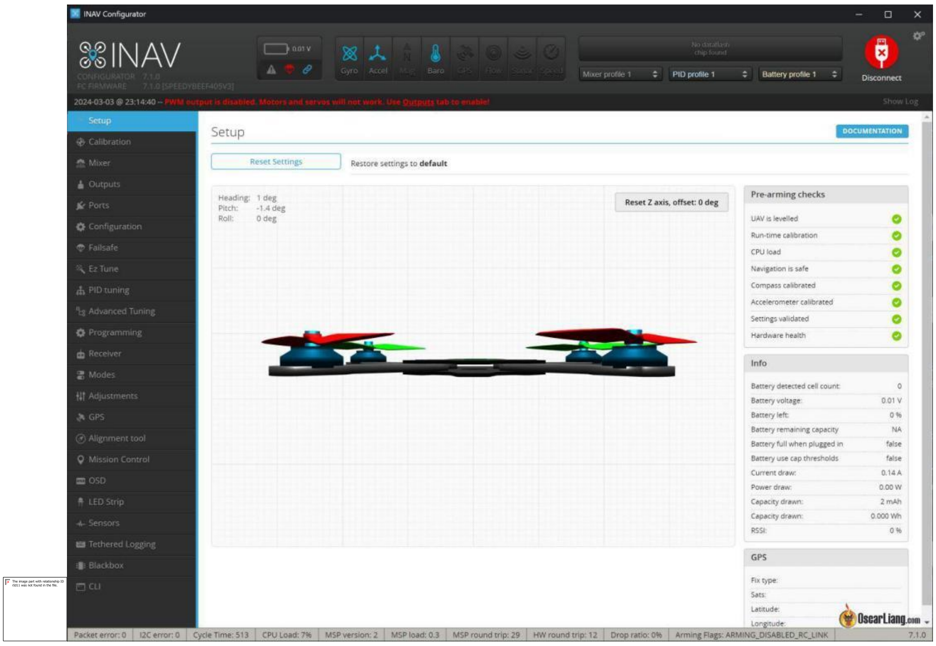

Fig 4.1 Testing results

V. CONCLUSION

The experimental results of the integrated Rover and Drone system demonstrate that the designed platform performs robustly, accurately, and reliably across multiple operational scenarios. The rover successfully navigates obstacles with high precision, maintaining smooth motion on various surfaces while carrying the UAV's weight, and provides real-time environmental monitoring with accurate sensor readings and efficient data logging. The UAV exhibits stable hovering and precise altitude control, compensating effectively for weight imbalances and responding promptly to motor commands, while ensuring reliable GPS-based navigation. Hybrid system tests confirm seamless integration between the rover and UAV, with low communication latency, smooth live video streaming, and fully functional rover driving under aerial supervision. Voltage outputs remain stable, ESC calibration and motor spin tests are smooth, and GPS lock is achieved quickly, indicating overall system stability and readiness for field deployment. Collectively, these results highlight that the integrated UGV-UAV system is capable of performing real-time navigation, environmental monitoring, and coordinated aerial-ground operations efficiently, making it highly suitable for applications in disaster response, search and rescue, and other autonomous robotic missions requiring precision, reliability, and responsiveness.

VI. FUTURE SCOPE

- Mobile app for real-time monitoring and control
- AI-based obstacle detection and path planning
- Multi-drone or swarm control systems
- Multi-sensor fusion for advanced environmental analysis
- Solar-powered batteries for extended operational time
- Enhanced autonomous decision-making using edge AI
- Cloud-assisted analytics and predictive maintenance
- Secure communication and cyber-security protocols
- Augmented Reality (AR) visualization tools
- Compliance with regulatory and safety standards

REFERENCES

[1]. Fernandez, A., Roy, T., & Silva, P. (2024). IoT-Enabled Wireless Monitoring and Control in Additive Manufacturing Systems. IEEE Internet of Things Applications.

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[2]. Kumar, R., & Chatterjee, S. (2023). Design of Wi-Fi-Based Remote Interface for FDM 3D Printers. International Journal of Embedded Systems and Applications, 11(2), 45–54.
[3]. Patel, S., & Narayanan, P. (2021). Development of a Web-Controlled 3D Printing Platform Using ESP Modules. International Journal of Advanced Computing and Robotics, 8(3), 112–119.
[4]. Espressif Systems. (2024). ESP32 Technical Reference Manual. https://www.espressif.com]
[5]. FlySky. (2024). i6 Transmitter & FS-iA6B Receiver Documentation. https://www.flysky-cn.com
[6]. STMicroelectronics. (2024). STM32F405/407 Reference Manual. https://www.st.com
[7]. Goodrich, M. A., & Schultz, A. C. (2007). Human–Robot Interaction: A Survey. Foundations and Trends in Human–Computer Interaction, 1(3), 203–275.
[8]. Siciliano, B., & Khatib, O. (Eds.). (2016). Springer Handbook of Robotics (2nd ed.). Springer.
[9]. Zhang, C., & Platt, R. (2022). Real-Time Obstacle Avoidance for UAVs Using Deep Reinforcement Learning. Journal of Intelligent & Robotic Systems, 105(1), 12–29.
[10]. Thrun, S., Burgard, W., & Fox, D. (2005). Probabilistic Robotics. MIT Press.
[11]. Qin, Y., & Sharma, G. (2023). Multi-Sensor Fusion for Autonomous Systems: A Review. IEEE Access, 11, 12345–12367.
[12]. Lin, D., et al. (2021). Edge AI: Enabling Autonomous Intelligence at the Network Edge. Proceedings of the IEEE, 109(11), 1960–1978.
[13]. Zhou, Z., & Tao, D. (2024). Energy-Efficient Solar-Powered UAV Systems: A Review. Renewable Energy Journal, 168, 1009–1023.
[14]. Roscher, R., et al. (2020). Explainable Machine Learning for Scientific Insights and Safety Assurance. IEEE Transactions on Pattern Analysis and Machine Intelligence, 42(8), 2085–2100.