IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, January 2026
Impact Factor: 7.67

Smart Object Detection and Identification System

Abhishek S P[1], Sandeep M[2], Shayan R[3], Yashas K S[4], Dr. Hadimani Shivakumar[5]
Student, Department of Electronics and Communication Engineering[1-4]
Professor, Department of Electronics and Communication Engineering[5]
Kalpataru Institute of Technology, Tiptur, India

Abstract: *In the era of automation and intelligent systems, the ability to recognize and classify physical objects in real-time has become increasingly vital across various domains, including smart homes, retail, inventory management, and educational technology. This project presents a low-cost, efficient, and real-time Smart Object Identification System using the ESP-CAM microcontroller integrated with a machine learning model. The ESP32- CAM captures images of objects and transmits them over Wi-Fi to a Python-based Flask server running a per- trained image classification model developed using Google's Teachable Machine. The server processes the images and returns the predicted object class, which can be displayed or used for further automated actions. By leveraging edge computing and lightweight machine learning techniques, this system demonstrates how embedded devices can be used for intelligent visual recognition tasks without relying heavily on cloud-based infrastructure. The solution is scalable, customization, and suitable for use in low-resource environments where affordability and portability are key.*

Keywords: ESP-32 Cam Module, Digital Image Processing , Open-CV in python, Control in web-server

I. INTRODUCTION

The advancement of embedded systems and artificial intelligence has enabled the development of intelligent, cost-effective solutions for real-world problems. Object identification, a subfield of computer vision, plays a crucial role in applications ranging from automation and security to retail and education. Traditionally, such systems require powerful processors, high memory capacity, and continuous cloud access, making them unsuitable for low-power, standalone devices.

The ESP32-CAM, a microcontroller with an integrated camera and Wi-Fi capabilities, provides an ideal platform for deploying lightweight vision-based systems. Coupled with machine learning models trained to recognize specific objects, it becomes possible to design a smart object identification system that is both efficient and portable. In this project, the ESP32-CAM captures images and sends them to a local server running a trained machine learning model.

II. PROBLEM STATEMENT

Traditional object identification systems often rely on high-performance computing re- sources and cloud- based services, making them expensive and unsuitable for deployment in resource-constrained environments. These systems may suffer from latency issues due to network dependencies and are not ideal for real-time applications in areas with limited connectivity. There is a need for a low-cost, efficient, and real-time object identification system that can operate independently without relying heavily on external infrastructure.

III. METHODOLOGY

1. Object Dataset Collection:

Capture multiple images of different target objects (e.g., bottle, phone, cup) from various angles and lighting conditions.

2. Model Training:

Use Google Teachable Machine or Tensor Flow to train a simple image classifier and ex- port it as a .h5 Keras model.

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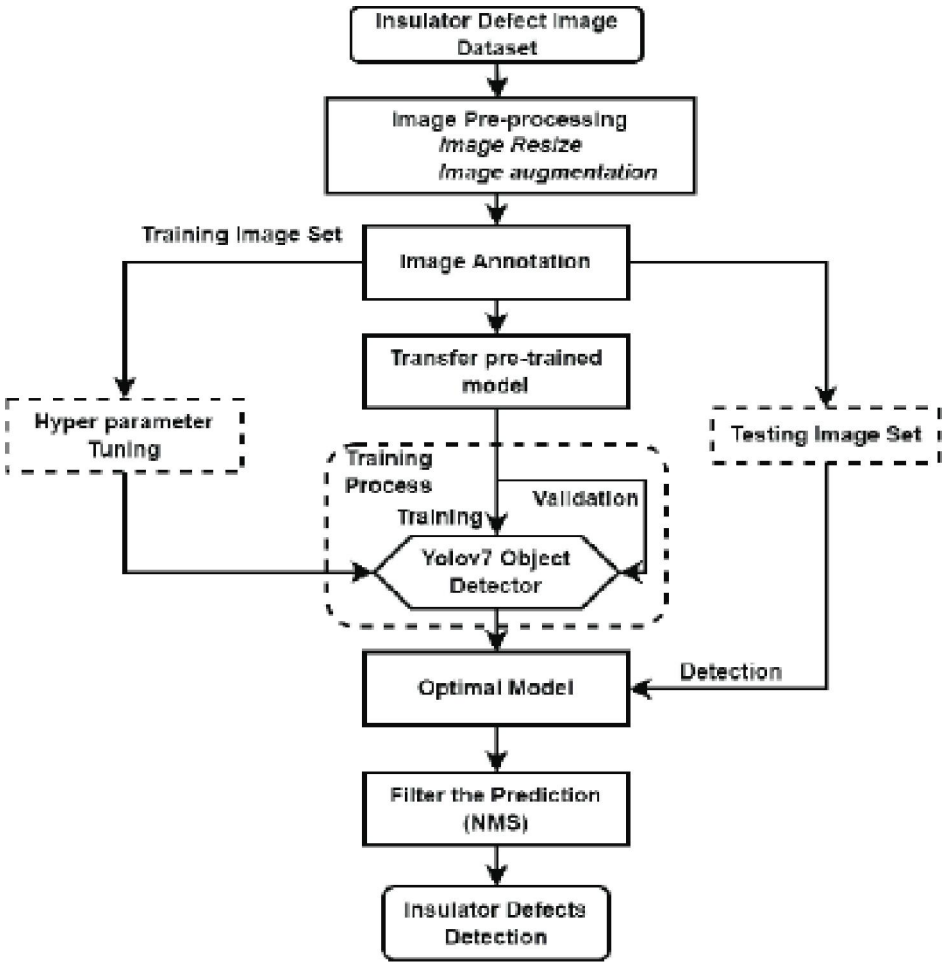

3. Server Development:

A lightweight Flask server is developed in Python to load the model, accept image data, perform classification, and return the identified object name and confidence score.

4. ESP32-CAM Integration:

The ESP32-CAM captures images and sends them to the server via HTTP POST re- quests. It then receives and displays the prediction result.

5. User Interface (Optional):

Display output on serial monitor, OLED screen, or log to Blynk/Firebase for remote monitoring.

IV. HARDWARE COMPONENTS

A. ESP-32 Cam Module:

The ESP32-CAM is a compact, low-cost development board that combines the powerful ESP32-S microcontroller with an OV2640 camera module. It is widely used in Internet of Things (IoT) applications requiring image capture, processing, and wireless communication. The ESP32-CAM can be programmed using the Arduino IDE or Espressif's IDF. Due to the absence of a built-in USB interface, programming requires an

FTDI programmer or an ESP32-CAM-MB adapter. The module supports various development environments and has a rich set of libraries and community support.

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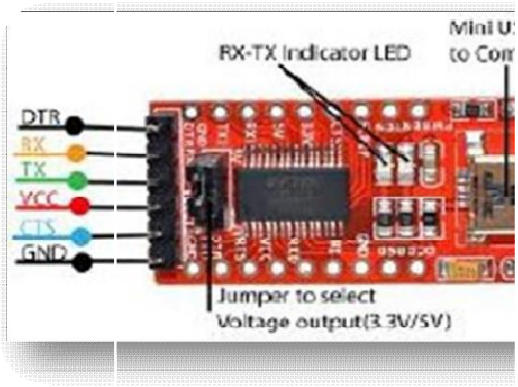
B. FTDI (Future Technology Devices International):

The FTDI (Future Technology Devices International) chip is a widely used USB-to-serial converter that facilitates communication between a computer's USB port and serial de- vices like microcontrollers. In the context of programming an ESP32-CAM module, which lacks a native USB interface, an FTDI adapter is essential for uploading code and establishing serial communication. To program the ESP32-CAM module, an FTDI programmer is essential as it facilitates serial communication between your computer and the ESP32- CAM, which lacks a native USB interface.



V. CIRCUIT DIAGRAM

This circuit diagram shows the basic wiring connection between the ESP32-CAM module and a USB-to-Serial (FTDI) programmer required for uploading code and powering the device.

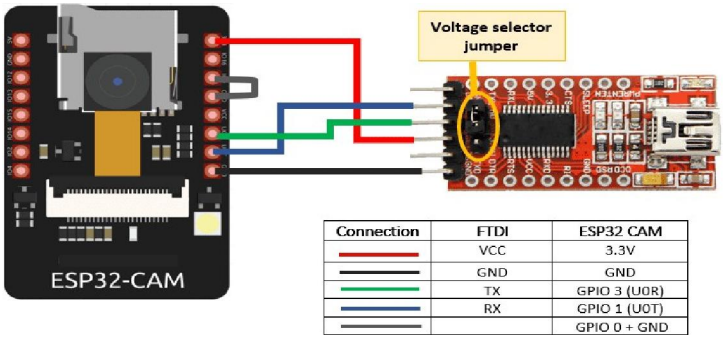


Fig. Circuit Diagram

DOI: 10.48175/IJARSCT-31066

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VI. RESULTS AND DISCUSSION

A. Results

The Smart Object Detection and Identification System using ESP32-CAM was successfully implemented and tested, demonstrating effective real-time video streaming and object recognition capabilities.

The ESP32-CAM module was able to connect reliably to the Wi-Fi network and provide a stable live camera feed through the web interface. The system accurately detected and identified objects within its field of view under proper lighting conditions, and the output was displayed with bounding boxes and labels. The performance remained smooth at lower resolutions (such as QVGA and VGA), and the optimized configuration ensured minimal latency during streaming.

The project achieved its primary objective of creating a low-cost, compact, and functional embedded vision system capable of performing basic object detection. The results clearly show that the ESP32-CAM can serve as an efficient platform for small-scale AI and IoT based surveillance applications.

B. Discussion

The Smart Object Detection and Identification System using ESP32-CAM is an innovative embedded vision project that integrates hardware, software, and AI techniques to perform real-time image processing and object recognition. The system uses the ESP32-CAM module, a low-cost microcontroller with a built-in camera and Wi-Fi connectivity, which makes it highly suitable for edge-based AI applications. The camera captures live video frames, which are either processed on the device using lightweight Tiny ML models or streamed to a connected server for YOLO-based object detection. This design demonstrates how advanced AI capabilities can be achieved on compact, resource-constrained hardware.

During the implementation, the system was successfully configured to connect to a Wi-Fi network and transmit live camera footage through a web server, which can be accessed from any device on the same network. The object detection performance was found to be efficient for basic recognition tasks under adequate lighting conditions. The use of a JPEG- based streaming format ensures faster frame transfer and reduced data load. The ESP32-CAM's onboard PSRAM further enhances image buffering and processing efficiency.

VI. CONCLUSION

The Smart Object Detection and Identification System using ESP32-CAM successfully demonstrates how embedded technology and artificial intelligence can be combined to develop a compact, intelligent, and cost-effective vision-based system. The project achieves real-time video streaming and object detection using the ESP32-CAM module, which integrates a camera and Wi-Fi connectivity into a single low-power device.

Through proper configuration and optimization, the system efficiently detects and identifies objects in its surroundings, proving useful for security, automation, and IoT based monitoring applications.

Despite hardware limitations such as limited RAM and processing power, the ESP32-CAM provides reliable performance for small-scale applications and show- cases the potential of edge-based AI systems.

This project not only highlights the power of embedded computer vision but also lays the groundwork for future innovations in smart surveillance and automation systems.

VII. ACKNOWLEDGMENT

I would like to express my sincere gratitude to all those who have supported me throughout the preparation of this paper. I am deeply thankful to my mentors and faculty for their invaluable guidance, encouragement, and constructive feedback, which have been instrumental in shaping this research. I also extend my appreciation to the researchers and institutions whose work on artificial intelligence, remote sensing, and smart agriculture provided essential insights and inspiration for this study. Finally, I am grateful to my family and peers for their continuous support and motivation, which enabled me to complete this work successfully.

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