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OBJECT RECOGNITION SYSTEM USING ESP32-CAM AND EDGE IMPULSE

Abstract

This project presents the design and implementation of a real-time object recognition system using the ESP32-CAM microcontroller and the Edge Impulse platform. The system captures images through an onboard camera and performs on-device machine learning inference to identify objects. The proposed solution demonstrates how embedded vision and TinyML can be implemented on low-cost hardware.

1. Introduction

With the rapid growth of Artificial Intelligence and embedded systems, object recognition has become an essential component in smart applications such as surveillance, automation, and monitoring. Traditional object recognition systems require powerful hardware and cloud computing. This project focuses on deploying a lightweight machine learning model directly on an embedded device, making the system efficient, low-cost, and independent of internet connectivity.

2. Problem Statement

Object recognition is an important requirement in many smart and embedded applications. However, implementing object recognition on low-cost embedded devices is challenging due to limited processing power and memory. There is a need for an efficient and lightweight system that can capture images and recognize objects in real time using embedded hardware.

3. Objectives

- To design a standalone object recognition system using ESP32-CAM
- To train and deploy a machine learning model using Edge Impulse
- To perform real-time object detection
- To analyze the performance of embedded machine learning models

4. Project Scope

The scope of this project focuses on the design and implementation of a real-time object recognition system using embedded hardware. The system performs image capture and object classification directly on the ESP32-CAM module using a lightweight machine learning model. The project covers dataset collection, model training, deployment, and on-device inference. The solution is intended for small-scale embedded vision applications such as monitoring, identification, and smart automation where low cost, low power consumption, and real-time performance are required.

5. System Architecture

The system architecture consists of an ESP32-CAM module responsible for image acquisition and inference. Images are captured by the camera sensor, processed by the embedded machine learning model generated using Edge Impulse, and results are displayed via serial monitor and web interface.

6. Hardware Description

The hardware components used in this project include:
- ESP32-CAM module with OV2640 camera
- USB to TTL converter for programming
- Jumper wires for connections
- External power supply (5V)

The ESP32-CAM was selected due to its low cost, built-in camera, and sufficient processing capability for TinyML applications.

7. Software Description

The software tools used in this project include:
- Arduino IDE for programming the ESP32-CAM
- Edge Impulse Studio for dataset preparation and model training
- ESP32 board support packages

8. Methodology

The methodology followed in this project includes:
1. Image data collection using ESP32-CAM
2. Dataset labeling and preprocessing in Edge Impulse
3. Training and validation of the machine learning model
4. Conversion of the model to a lightweight embedded format
5. Deployment of the model on ESP32-CAM
6. Real-time object recognition and result visualization

9. Results and Discussion

The implemented system successfully recognizes trained objects in real time. The model achieves satisfactory accuracy under controlled lighting conditions.

Performance evaluation shows that on-device inference reduces latency and eliminates dependency on internet connectivity.

10. Conclusion

This project demonstrates the feasibility of deploying machine learning models on low-cost embedded devices. By using ESP32-CAM and Edge Impulse, an efficient and standalone object recognition system was developed. The project highlights the potential of TinyML in real-world embedded applications.

11. Future Work

- Improving accuracy using larger and diverse datasets
- Integrating additional sensors
- Expanding the system for multiple object classes
- Optional cloud integration for logging and analytics