CSE341: Microprocessors

Project Report

Object Detection & Robotic Interaction
with
Raspberry Pi

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Group Information

Enhanced Object Detection with Raspberry Pi: Targeted Recognition, Random Detection, and Robotic Interaction.*

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***Abstract*—This versatile object detection system employs a Raspberry Pi camera and robotic arm for precise identification and targeting. Integrating computer vision in Industry 4.0 redefines manufacturing practices. Modern solutions optimize cost-effective computing, transferring video processing from cameras to embedded systems, streamlining operations and enhancing efficiency.**

I. Introduction

This object detection system showcases versatility by identifying three object types and enabling manual targeting. The model integrates a robotic arm for physical movement and synchronized light displays for visual feedback. In Industry 4.0, computer vision transforms manufacturing, revolutionizing automation and quality control. It redefines tasks like object identification, selection, and measurement. Unlike in the past, where specialized cameras were common, modern solutions leverage cost-effective computing for real-time responsiveness. This shift seamlessly transfers video processing from cameras to embedded systems or computers, streamlining operations.

This dynamic shift from dedicated hardware to versatile computing infrastructure is epitomized by the paradigm presented in this report. By leveraging a modestly-priced Rev 1.3 Raspberry pi camera, in tandem with the Raspberry Pi 4B embedded system boasting a 1.4 GHz 64-bit processor, 8GB RAM, and an array of essential features, the traditional boundaries of computer vision are challenged. At the heart of crafting the artificial vision system to achieve real-time object classification is the utilization of Python3 programming language, synergized with the OpenCV computer vision library, and the operating system framework of Raspberry OS. This configuration underscores a commitment to employing open-source software tools, thereby facilitating the establishment of a classifier with the capability to differentiate hexagonal nuts within an immersive setting, irrespective of their dimensions or orientations.

This achievement is meticulously balanced with the computational requisites, ensuring a judicious equilibrium between predictive accuracy and computational efficiency.

II. Literature review

The human capacity to swiftly identify and pinpoint objects within images is a remarkable ability. This innate skill enables complex tasks such as the recognition of multiple objects with remarkable efficiency and precision. Importantly, this process occurs rapidly and with a high level of accuracy. Presently, machines can be trained effectively due to the availability of extensive datasets, enhanced GPU processing speeds, and refined algorithms.

In the study by SERRANO-RAMÍREZ et al. [1], the image dataset classification process involves three phases. Firstly, the image database is collected, followed by training a Haar Cascade predictive algorithm using the dataset. A real-time detection test is then conducted, assessing classification accuracy and addressing Haar Cascade's limitations. An evaluation algorithm is introduced to process novel grayscale images resembling the training set conditions. This algorithm employs the Adaboost algorithm, utilizing weak classifiers to analyze test image subregions. Positive and negative outcomes assign weights, with positively classified areas undergoing cascaded analysis. The proposed algorithm achieves 0.825 accuracy and 0.175 error rate.

Konaite et al.'s study introduces a system using combined blind techniques to aid navigation and object awareness for the visually impaired. Real-time image processing enables detection of objects and road signs via models like TensorFlow Lite API, SSD, and OpenCV. Operating on a Raspberry Pi 4 with a camera and speaker, TensorFlow Lite 2 performs object detection on captured frames. Audible feedback informs users about detected objects and estimated distances. Pixel analysis in 320x320 images determines distances with object size-based constants. The system employs SSD-MobileNet v2, prioritizing speed while maintaining accuracy by filtering low-confidence results, and enhancing spatial awareness for improved independent navigation.

Priya et al. [3] developed a Real-Time Text Detection and Shopping Assistance system for the visually impaired, utilizing a camera and optical character recognition to audibly convey product information. However, it's confined to shop-based products and lacks mobility. Another proposed wearable system integrates deep learning, machine vision, and ROS. Equipped with ultrasonic sensors on smart glasses, it detects objects and triggers directional vibrations via a Raspberry Pi, accompanied by emergency GSM calls. Despite benefits, the absence of a camera results in imprecise object identification. This study highlights innovations in aiding the visually impaired but acknowledges challenges like recognition accuracy and mobility.

III. Methodology

The central operational principle involves a shift in object detection dynamics, transitioning from GPU-intensive tasks to an Internet of Things (IoT) platform like Raspberry Pi. The project employs the OpenCV module alongside AngularServo obtained.

OpenCV: OpenCV, or Open Source Computer Vision Library, is a cornerstone in the realm of computer vision and image processing. It equips researchers with a powerful toolkit to unravel complex visual data, enabling the extraction of meaningful insights from images and videos. Covering a broad spectrum of functions, from basic image manipulation to intricate tasks like object recognition and deep learning integration, OpenCV is a crucial asset in various domains such as robotics, medical imaging, and augmented reality [4]. Its open-source nature fosters collaboration, supporting multiple programming languages like Python and C++. As a dynamic and evolving framework, OpenCV continues to drive advancements in computer vision research, offering researchers a versatile platform to delve into visual data and propel the field forward.

AngularServo: Angular servos play a crucial role in robotics and automation by enabling precise control of rotational angles, unlike continuous rotation servos. With a limited range usually between -90 to +90 degrees, they closely resemble the movement of mechanical systems' rotational joints. Angular servos find utility in tasks requiring precise positioning, such as controlling robotic arm angles or camera orientations. They operate by receiving electrical signals through input pins, which guide them to specific angles. Feedback mechanisms, often internal potentiometers, enhance precision by providing position information. The gpiozero library's AngularServo class is significant in this context. It serves as a vital interface for interacting with angular servos via Raspberry Pi's GPIO pins. Researchers and developers can effortlessly create angular servo instances, controlling their angles in degrees. This functionality holds potential for various applications, from automated mechanisms to interactive devices. The user-friendly AngularServo class contributes to advancing angular servo utilization, shaping robotics and automation research and implementation. The AngularServo class facilitates robotic arm movement by precisely controlling the angles of angular servos through Raspberry Pi's GPIO pins. Researchers and developers can easily instantiate AngularServo instances, setting desired angles in degrees. As a result, when these servos are integrated into a robotic arm, the class allows the arm's joints to move with accuracy and control. This seamless interaction simplifies the process of programming and controlling the arm's movements, enabling the robot to perform specific tasks requiring precise positional adjustments.

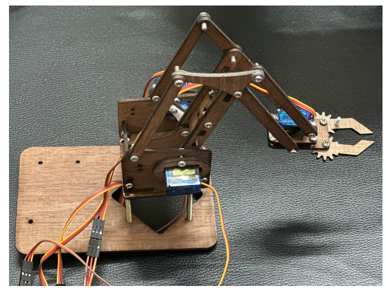

Fig. 1. Robo-Arm

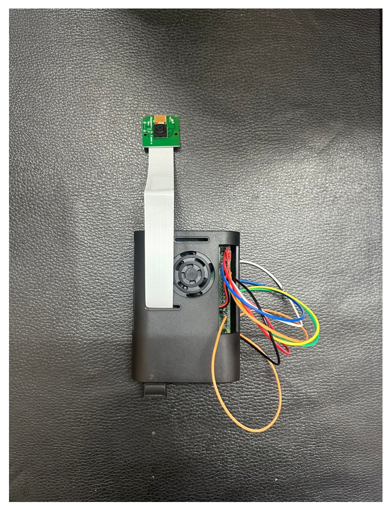

Fig. 2. Raspberry-pi with Camera

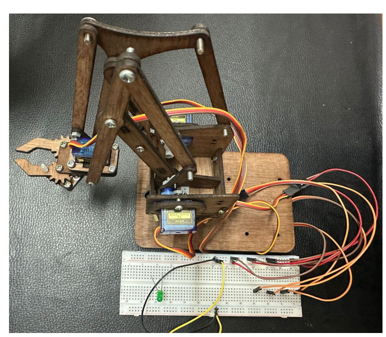

Fig. 3. Robo-arm with Circuit

IV. Workflow

The workflow of the object detection system is illustrated in Figure 4 & 5.

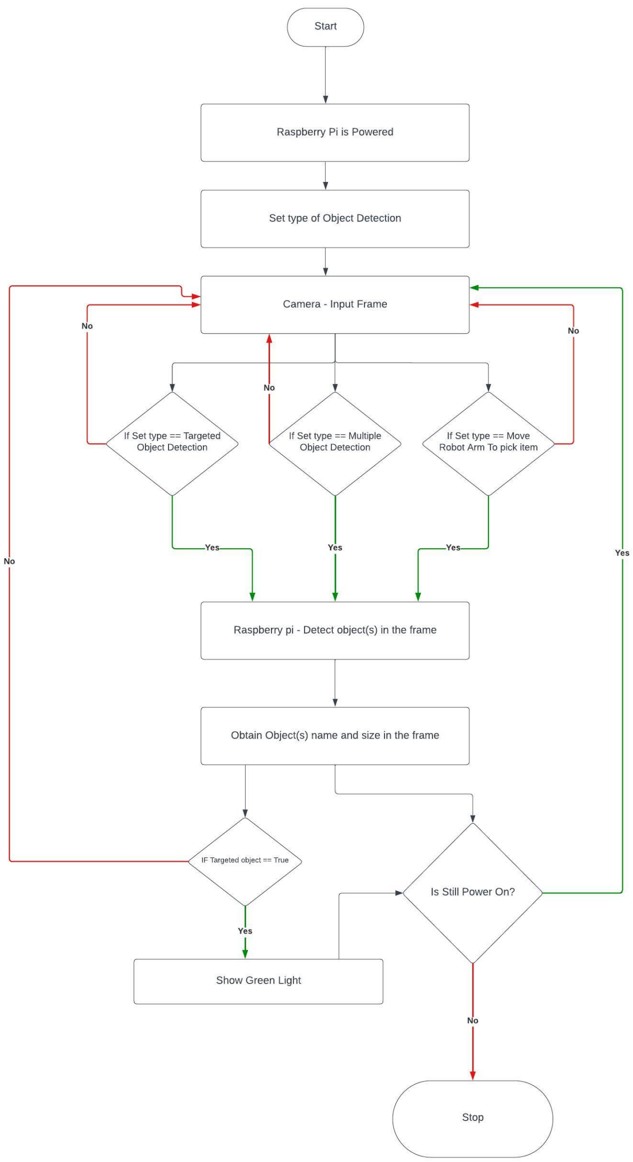

Fig. 4. Object Detection Workflow

Fig. 5. Object Detection Demo

V. Result & Analysis

The Raspberry Pi camera successfully identifies various everyday objects, including plastic, humans, and cell phones. During live feed analysis, it accurately detects a person with 61% certainty, plastic with 70% certainty, and a cell phone with 67% certainty. This showcases its effectiveness in object recognition. The system's ability to discern objects highlights its potential for diverse applications in security, waste management, and smart environments.

VI. Conclusion

In conclusion, the presented object detection system underscores the transformative potential of computer vision in Industry 4.0. By seamlessly integrating a Raspberry Pi camera and robotic arm, the system showcases adaptability and precision in identifying and targeting objects. This paradigm shift towards cost-effective computing reshapes manufacturing practices, enhancing automation and quality control. The utilization of open-source tools further emphasizes the commitment to innovation. As we embrace this dynamic evolution, the boundaries of traditional manufacturing continue to expand, redefining efficiency and reimagining possibilities.

References

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