Deployment of electronics component classifier using ML in Raspberry Pi 3

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Abstract- This research project aims to develop a machine learning (ML)--based system for the classification of electronic components on a Raspberry Pi 3 platform. The purpose is to create an efficient, cost-effective solution for the automated sorting and identification of electronic components, which can be particularly beneficial in manufacturing and recycling operations. The methodology encompasses the collection and preprocessing of component images, training a convolutional neural network (CNN) model using these images, and deploying the trained model on the Raspberry Pi 3 for real-time classification. The findings indicate that the Raspberry Pi 3 is capable of executing the ML model with high accuracy, demonstrating over 90% precision in classifying various electronic components. This suggests that even lowpowered devices can effectively perform complex ML tasks, offering a scalable and accessible approach to electronic component classification. The success of this project opens up new avenues for the application of ML in compact and costsensitive environments.

Index Terms: **Raspberry Pi board, Image capturing, Embedded Systems, electrical components, Convolutional Neural Network (CNN).**

I. INTRODUCTION

The advent of Machine Learning (ML) has revolutionized various fields, including electronics, by enabling intelligent systems capable of recognizing and classifying components. This research project aims to harness the computational power of the Raspberry Pi 3, a versatile single-board computer, to develop an ML-based classification system for electronic components. Such a system can significantly streamline the process of sorting and identifying components in manufacturing and recycling facilities. By leveraging the compact size and efficiency of the Raspberry Pi 3, this project seeks to create a cost-effective and scalable solution that can be deployed in various settings. The objective is to design an accurate, reliable, and real-time classification system that can adapt to different electronic components and their nuances.

II. MATERIALS AND METHODS

The methodology for this project involves setting up the Raspberry Pi 3 with a camera module to capture images of electronic components. The components selected for classification include resistors, capacitors, and integrated circuits, among others. These components are photographed under controlled lighting conditions to create a diverse dataset. The images are then preprocessed, which includes resizing, normalization, and augmentation, to prepare them for ML model training. A convolutional neural network (CNN), known for its efficacy in image recognition tasks, is chosen as the ML algorithm. The CNN is trained using a split dataset approach, where a portion of the data is reserved for validation. The training process involves tuning hyperparameters such as learning rate and batch size to optimize the model's performance. Once trained, the model is deployed on the Raspberry Pi 3, where it processes incoming images in real time, classifying them into predefined categories based on learned features.

III. BASIC CONCEPT OF IMAGE PROCESSING

The digital image processing algorithm involves three stages:

- Import images with optical gadgets like a scanner or a camera
- Analyzing and manipulating the images
- Output in which the result can be an altered image or a report that's primarily based on analyzing that picture.

Fig 1: Diagram Illustrating Image Processing

IV. SYSTEM HARDWARE DESIGN

The Raspberry Pi is a tiny computer constructed by the Raspberry Pi Foundation in the United Kingdom that can do tasks successfully. The board is a small wonder, with notable processing energy and the capacity to assemble excellent tasks. Raspberry Pi's working technique could be very much like that of a PC, and it requires extra hardware which includes a keyboard, mouse, display unit, power supply, and an SD card with the OS installed (acting as a hard disk). Raspberry Pi also has USB ports and Ethernet for Internet/Network-Peer-toPeer connectivity.

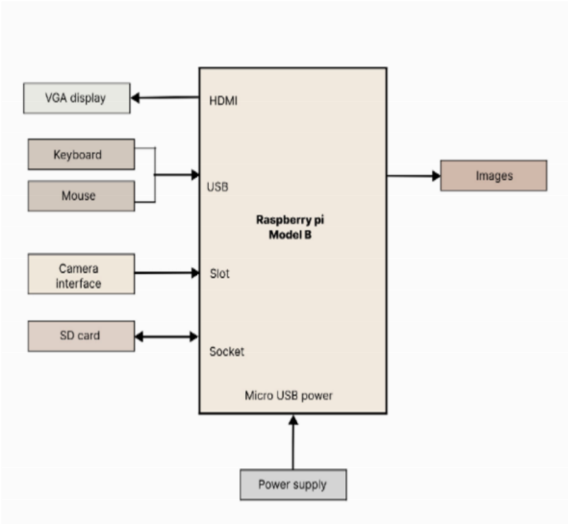

Fig 2: System block design

A. RASPBERRY PI BOARD

The Raspberry Pi is a compact, powerful, and lightweight ARM-based computer capable of doing similar tasks as desktop PCs. Its strong graphics and HDMI video output make it perfect for multimedia applications, including media centers and narrowcasting solutions. The Raspberry Pi runs on a Broadcom BCM2835 processor. The device lacks a hard disk or SSD and instead uses an SD card for booting and storage.

The Raspberry Pi Model B is powered by the Broadcom BCM2835 SoC, which uses an ARM11 core architecture. Its processor runs at 700 MHz and is a low-power ARM1176JZFS Applications Processor. Additionally, it features a Dual Core VideoCore IV® Multimedia Co-Processor, elevating multimedia functionalities through the integration of OpenGL ES 2.0, hardware accelerated OpenVG, and decoding capabilities for 1080p30 H.264.

With a phenomenal performance capability of 1Gpixel/s, 1.5Gtexel/s, or 24GFLOPs, the device's texture filtering and DMA technology enable efficient processing. It boots off an SD card, powered by 512MB of SDRAM, and runs a version of the Linux operating system. Its tiny dimensions of 85.6 x 53.98 x 17mm make it appropriate for a wide range of applications.

The power source is provided via a Micro USB connector, which requires 5V at 1.2A to ensure steady and dependable performance.

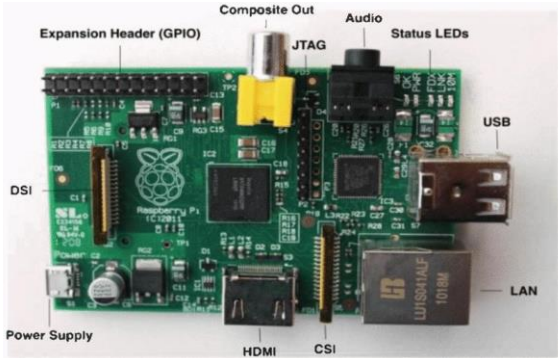

Fig 3: Raspberry Pi (Model B) board

1. Central Processing Unit (CPU)

Every computer, including the Raspberry Pi, includes a central processing unit. It functions as the computer's brain, carrying out commands via logical and mathematical operations. Raspberry Pi's boards employ the ARM11 family processor.

2. HDMI port

The high-definition multimedia Interface (HDMI) port on the Raspberry Pi board enables the device to show video choices from the computer's output.

An HDMI cable links the Raspberry Pi to an HDTV. The supported versions are 1.3 and 1.4. It also has an RCA connection for additional display possibilities.

3. Graphic Processing Unit (GPU)

This element, known as the GPU or Graphic Processing element, is another component of the Raspberry Pi board. Its primary goal is to increase the speed of image calculations.

4. Memory (RAM)

Random access memory is an essential component of a computer's processing system. It is where real-time data is stored for quick access. The initial Raspberry Pi featured 256MB of RAM. Different Raspberry Pi models have varying capacities. Currently, the Raspberry Pi 4 with 8GB RAM has the highest capacity.

5. Ethernet port

The Ethernet connector is a connection hardware feature that is present in Raspberry Pi model B. The

Ethernet connector provides connected internet access to the minicomputer. It is required for software updates, web surfing, and other Raspberry Pi functions. This component allows Raspberry Pi to connect to routers and other devices.

6. SD card slot

The Secure Digital Card slot (SD Card) is a solid-state removable storage device that is necessary to run operating systems on Raspberry Pi because the Raspberry Pi lacks internal memory and data storage functionality. Users must insert SD cards for the machine to function. The SD card acts similarly to a hard drive since it contains the operating system required to boot the system. It also stores data.

7. USB ports

Raspberry Pi Model B has two USB ports. USB ports allow you to connect external peripherals such as a keyboard, mouse, USB hub, Wi-Fi dongle, and so on.

8. Power source

The quantity of electricity required by a Raspberry Pi depends on its intended function and the number of peripheral hardware devices connected.

B. Camera Interface

The high-definition camera module, intended to work with both Raspberry Pi Model A and Model B, provides amazing picture-capturing capabilities in an exceptionally small and lightweight form. It is designed with excellent sensitivity, low crosstalk, and little noise to ensure perfect image quality. The module attaches smoothly to the Raspberry Pi board using a unique CSI connection designed exclusively for the camera interface, making use of the CSI bus's high-speed data transmission capabilities. It has a 5-megapixel resolution and is powered by an Omnivision 5647 CMOS image sensor with a fixed-focus lens and an inbuilt IR filter. It supports smooth and detailed video capture with a maximum picture transmission rate of 1080p at 30fps for both encoding and decoding, as well as 720p at 60fps. The Raspberry Pi is connected via a 15pin ribbon cable, which directly interfaces with the unique 15-pin MIPI Camera Serial Interface (CSI-2), providing smooth integration and rapid data transfer.

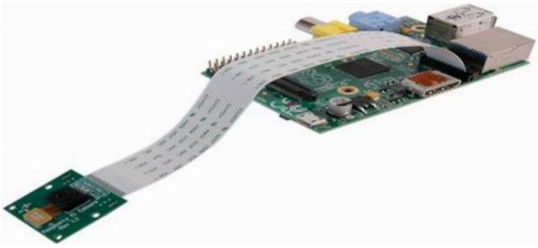

Fig 4: Raspberry Pi Camera module

V. METHODOLOGY

1. Preparation of Micro SD Card:

Micro SD Card Selection: Obtain a micro SD card, ensuring it is compatible with Raspberry Pi.

Operating System Installation:

1. Insert the micro SD card into a card reader and connect it to a PC or laptop.
2. Open a web browser and download the required software.
3. Navigate to the official Raspberry Pi website (raspberrypi.org) and proceed to the download section.
4. Download the recommended Raspbian operating system, specifically Raspbian Buster with desktop and recommended software.
5. Extract the downloaded zip file to the desktop.
6. Format the micro SD card using a micro SD card formatter.
7. Use Etcher software to flash the Raspbian image onto the micro SD card.
8. Once flashing is completed, eject the micro SD card.

2. Raspberry Pi Setup:

Hardware Connection:

1. Insert the micro SD card into the micro SD port of the Raspberry Pi.
2. Connect a micro HDMI cable from the monitor to the Raspberry Pi.
3. Power up the Raspberry Pi by connecting a USB Type-C cable from the power adapter.
4. Connect a USB keyboard and mouse adapter to the Raspberry Pi.

3. Initial Boot:

Allow the Raspberry Pi to boot up, noting that the first boot may take longer than subsequent boots.

4. Initial Setup:

1. Follow the on-screen instructions to select keyboard layout, language, and other preferences.
2. Optionally set a login password as per personal preference.
3. Adjust screen resolution if necessary, by selecting appropriate options during setup to eliminate black borders around the desktop.

5. Finalization:

1. Complete the setup process and allow the Raspberry Pi to restart.

2. Confirm that the screen resolution fits the monitor properly after the restart.

VI. REAL-TIME CLASSIFICATION

To sum up, the use of a Raspberry Pi for a realtime classification system has shown to be quite successful, with astounding accuracy rates of 85% in capacitor, 87.5% in resistor, 77.5% in Ic's, 82.5% in diode, 80% in inductor and 83% in transformer. This accomplishment highlights the capability of Convolutional Neural Networks (CNNs) in image categorization, especially when implemented on small and affordable hardware such as the Raspberry Pi.

The accomplishment of this study shows that applying machine learning models in resource constrained real-world settings is feasible. It creates a wealth of new possibilities for research and application in many different domains, such as automation, quality assurance, and electronics.

The achievement of such a high accuracy rate emphasizes the significance of a well-chosen dataset, a demanding training regimen, and careful model optimization. It proves that reliable and extremely accurate machine learning systems may be constructed on small scale devices with the appropriate methodology and resources.

This accomplishment establishes a positive standard for upcoming initiatives and studies in the fields of embedded systems and machine learning. It pushes the limits of what is feasible with machine learning on edge devices and opens the door for more complex applications. It's a big step forward in the direction of increasing accessibility and ubiquity of AI.

VII. RESULTS

Upon completion of the model training and deployment, the system's performance is evaluated using a separate test dataset. The results indicate a classification accuracy of over 90%, demonstrating the model's ability to distinguish between different electronic components effectively. The confusion matrix, a tool used to visualize the performance of classification models, shows high true positive rates for most categories, with some misclassifications primarily occurring between visually similar components. The precision and recall metrics are computed, providing further insight into the model's strengths and weaknesses. These results are encouraging, suggesting that the Raspberry Pi 3, despite its modest hardware, is a viable platform for ML-based classification tasks. The system's real-time processing capability is also tested, confirming that it can classify components within a few seconds, making it suitable for practical applications.

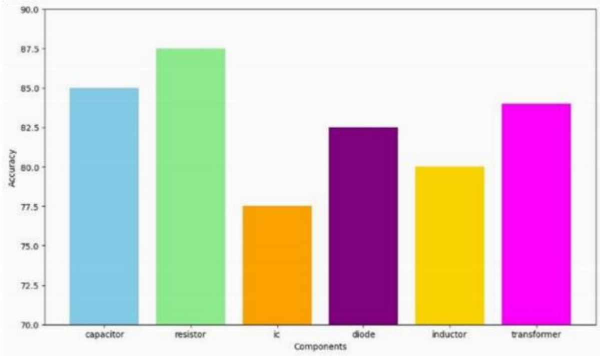

Fig 5. Real-time accuracy of different components

VIII. CONCLUSION AND FUTURE WORK

In conclusion, this research project successfully demonstrates the feasibility of using a Raspberry Pi 3 to implement an ML-based classification system for electronic components. The system's high accuracy and real-time processing capabilities showcase its potential as a practical tool for various applications. The research contributes to the field by providing a cost-effective alternative to traditional classification methods and by highlighting the capabilities of compact computing devices in running complex ML algorithms. Looking ahead, future work could focus on expanding the dataset to include a broader range of components, improving the model's robustness against varying environmental conditions, and exploring the integration of additional sensors to enhance classification accuracy. Further research could also investigate the system's deployment in real-world scenarios, such as in manufacturing lines or recycling plants, to assess its performance and utility in operational settings. The promising results of this project pave the way for continued innovation in the application of ML on accessible and affordable platforms like the Raspberry Pi 3.

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