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DEVELOPMENT OF ROBOTIC SYSTEM FOR SEGREGATION OF METALLIC COMPONENTS

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Abstract

The task of segregation of components is simple yet time-consuming. Automating such a task frees up time and resources to invest in other sectors. Pick and place operations performed by a robot reduce the workforce required and assure a degree of precision. In this paper, the different factors that come into play in designing a portable robotic system for pick and place operations were considered. The design focus was performing pick-and-place operations of components with ferromagnetic properties using object classification with a compact and portable nature. The developed robotic system included a microcontroller for controlling the robotic arm and a Raspberry Pi 4 for performing object classification. The portable system was built for performing the segregation of objects in a mobile manner. The robotic arm and other components were designed and selected for efficient performance.

Keywords: Robotic Arm, Raspberry Pi, Pico, TFLite

Introduction

As technology has progressed, robots have started performing significant roles in vari ous sectors of different industries. Soon robots will be an irreplaceable part of society. One of the common use of robots is to perform pick and place operations. Robotic 2 arms are primarily engineered for industrial applications; however, there exists a grow ing demand for their utilization in residential and commercial settings as well. [1]. The main factors that are to be focused on when designing such a robot are the compactness, mobile nature of the device, the safety of the people around the device, the easy use of the robot, and aesthetics. Robotic systems are designed to meet specific requirements, primarily aimed at assisting and automating various tasks. The HSV colour detection algorithm was employed to effectively segregate coloured balls [2]. For object manipulation, the grain boundary function was employed to accurately determine the centroid of the ball, thus enabling the precise location estimation for pick and place operations. Waste segregation processes can be effectively automated through the implementation of robotic arms. Sensors were employed to identify the nature of waste materials for effective segregation [3]. Specifically, a moisture sensor and a metal sensor were utilized to discern wet and metallic wastes, respectively. In an alternative method of waste segregation, convolutional neural network (CNN)-based classifiers were employed to determine the biodegradability of waste items [4]. The development of a robotic arm system dedicated to the segregation of common objects plays a significant role in minimizing the need for human labour in trivial tasks. The segregation task may seem trivial but it usually requires a person to perform it. Thus, by incorporating a robot to assist with the task, an additional workforce is freed up for other requirements. This paper presents the development of a robotic system specifically designed for the segregation of ferromagnetic components. The system employs a TFLite model for object identification, while a solenoid is utilized for object picking and segregation. The object identification model is deployed on a Raspberry Pi, while the design of the robotic arm prioritizes portability as a key consideration.

Implementation

As the objective of keeping the robotic system portable with minimal calibration, the components of the system must be compact and have minimal setup while having the resources for performing fast and precise actions. The selection of components required for the system was based on their optimal characteristics and suitability for the intended purpose.

Raspberry Pi 4

The Raspberry Pi 4 can run resource-intensive applications and multitask effectively. It is powered by a quad-core ARM Cortex-A72 processor with 8 GB RAM. For per forming object classification, significant processing power is required for efficient and accurate classification. For modification of the classification set, the Pi 4 is accessible and easy to work with.

Raspberry Pi Pico

Selecting the appropriate microcontroller is a critical aspect as it is the core of the system. The main requirements of the microcontrollers are to efficiently perform the required tasks without taking up too much physical space. By selecting the best micro controller, the development process is streamlined, resulting in a more effective and fruitful system. Raspberry Pi Pico is a compact and inexpensive microcontroller. Pico has 264 kB of RAM and 2 MB of flash memory and is powered by a dual-core Arm Cortex-M0+ processor that operates up to 133 MHz [5]. The compact nature of the Pico and its high performance are the main highlights.

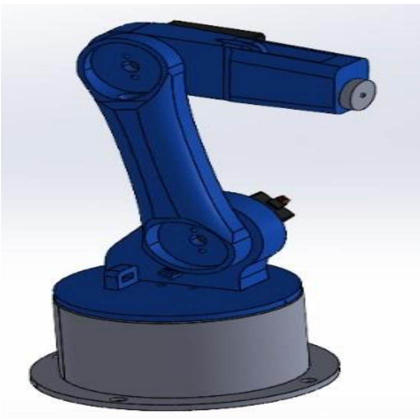

Figure 1: Robotic arm design.

Robotic Arm

Selecting the right robotic arm is of paramount importance in pick-and-place opera tions. The choice of the robotic arm is determined by the arm's workspace and design. The robotic arm should ensure high repeatability and reliability. For the specific requirements of the robotic system, a robotic arm is 3D printed as shown in Figure 1 using the Anycubic Mega Pro. The robotic arm is modified such that the end effector has a slot for attaching the solenoid so that it acts as an electromagnet end effector.

Ultrasonic Sensor

The ultrasonic sensor utilizes sound waves to measure distances and detect objects in its vicinity. It emits high-frequency sound pulses and calculates the time it takes for the sound waves to bounce back after hitting an object. This data enables the sensor to determine the distance between itself and the object. The sensor sends a signal for the Pico to determine if an object is close enough for picking application.

Pi Camera Module

The camera module is an add-on designed for Raspberry Pi single-board computers. This compact camera module enables users to capture images and record videos directly from their Raspberry Pi. The camera module is compact in nature and the object classification is performed from the images captured from the camera module.

TensorFlow Lite

TFLite is a lightweight machine-learning framework designed specifically for edge models and mobile platforms. TFlite allows real-time inference and efficient memory utilization. The compact nature of the machine learning framework makes it easier to train and deploy on an edge device such as the Raspberry Pi 4.

Solenoid Electromagnet

The KK-P20 solenoid electromagnet shown in Figure 2 attracts magnetic substances using the induced magnetism produced by electric current. The solenoid can lift up to 3 Kg, thereby making it optimal for everyday objects like scissors and screws.

Figure 2: KK-P20 solenoid.

Working Principle

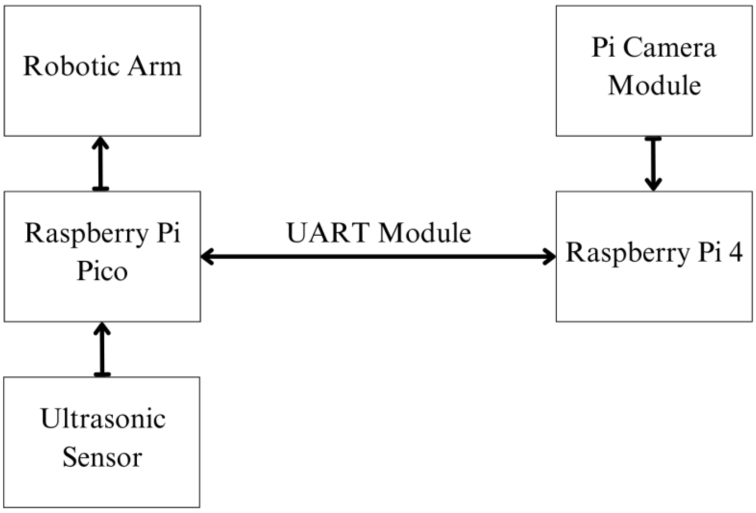

Figure 3: Block diagram.

The working principle of the robotic system developed for the segregation of com ponents is presented in Figure 3. The main objective of the robotic system is to perform object segregation based on object type. To perform the tasks within the set param eters and while keeping the object portable the model is built in a compact design. The robotic arm is designed to be small yet able to carry the required loads. Object classification is performed on a Raspberry Pi 4 and Raspberry Pi Pico is used as the microcontroller for controlling the robotic arm. The functionality of the model is designed such that when an object is detected by the ultrasonic sensor, the Pico sends a signal to the Raspberry Pi to activate the camera module which captures an image of the object to be segregated. Data transfer between the Pico and Pi is performed using a UART module as shown in Figure 3. Both modules are set to receive and transmit data based on the requirements. A TfLite model is deployed in the Pi for the classification of the object. The identification of an object is performed by training the system using the data collected through the Pi Camera module. The object ID number is passed back to the Pico. Based on the object ID number, the Pico sends a command to the robotic arm to pick the object and segregate the object in a specified location which is calculated based on the number of objects to be segregated. The microcontroller is designed such that the robotic arm picks the object when the object ID is received. The solenoid is magnetized and the object is picked up and placed at the required location.

Microcontroller

The Raspberry Pi Pico acts as the central control unit for the robotic arm system. This microcontroller assumes responsibility for governing various modules within the system, including the robotic arm, ultrasonic sensor data acquisition, and activation of the electromagnet end effector as shown in Figure 4. Synchronization and control of all these distinct modules are achieved through the utilization of a micropython script. 6 To ascertain the proximity of an object to the robotic arm, a predefined threshold is established for the ultrasonic sensor. Upon receiving distance data from the ultrasonic sensor, if the measured distance falls below this threshold, the presence of an object is detected. Subsequently, a UART protocol is employed to transmit a signal to the Raspberry Pi 4, triggering the magnetization of the Solenoid through the utilization of a relay.

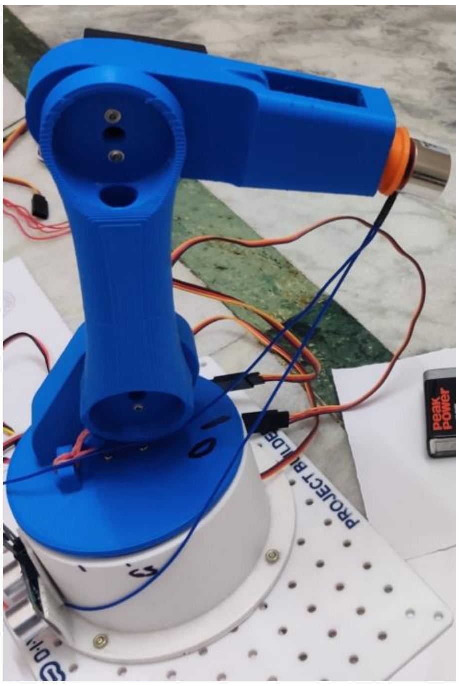

Figure 4: Robotic arm prototype.

Robotic Arm

The robotic arm comprises three servos and is equipped with an electromagnet end effector (Figure 5). The robotic arm is programmed for performing pick and place operations and performing object segregation based on the type of object detected. On startup, the robotic arm moves to its home position. When an object is detected by the ultrasonic sensor a signal is sent to the Pi 4 for object classification. The drop locations for each object are calculated on startup based on the number of objects to be segregated. The object is picked up by the electromagnet and dropped at the designated location based on the identified object class. After successfully dropping, the robotic arm is moved back to its home position and is set on standby till another object is detected.

Object Classification

Machine learning is crucial in the efficient detection and separation of different components. For the present system, there are a few criteria to be met. Timely and precise identification and separation of components are the main necessity. The trained model must be deployed on edge devices. In the present system, a TFLite model is deployed for object classification. TFLite is a collection of tools to convert and optimize TensorFlow models to run on mobile and edge devices [6]. A custom model is trained based on the required object to be segregated. The object classification model is deployed on the Raspberry Pi 4 and the Pi Camera module is used for acquiring images. When an object is detected by the ultrasonic sensor, the Pico sends a signal to the Pi 4 to perform object classification. The camera module is activated and the object is identified as shown in Figure 6. After successful classification, the object ID is passed back to the Pico through the UART protocol for object segregation.

Figure 5: Object classification.

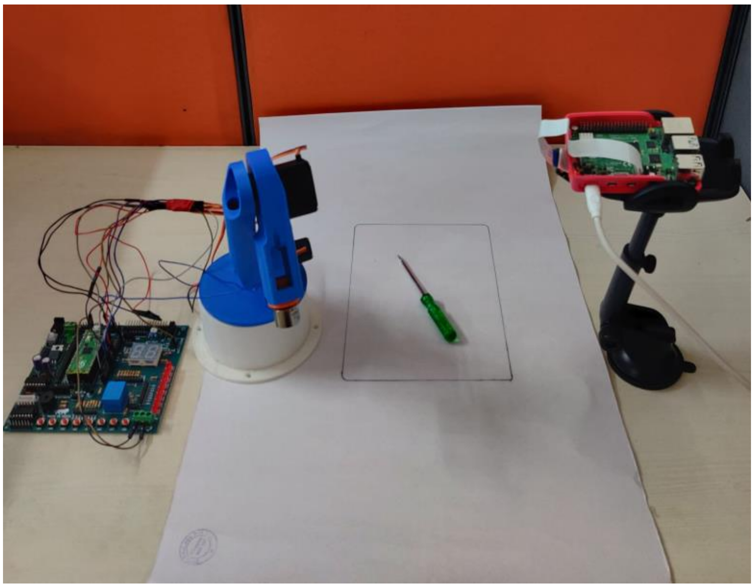

Figure 6: Project setup.

Results

The developed robotic system is displayed in Figure 7. The system has been tested for three objects; screwdriver, scissor, and battery (Figure 8). The Raspberry Pi 4 is externally powered and the Raspberry Pi Pico is powered by the Pi. On startup, the robotic arm is moved to a home position. When the ultrasonic sensor detects an object, a signal is sent to the Raspberry Pi 4 for performing object classification. The classification ID is sent to the Pico and the robotic arm picks and places the object in a precalculated position.

Conclusion

A robotic system for the segregation of the components was developed using a robotic arc, a microcontroller, an ultrasonic sensor, and a camera. It was trained to identify three components and the system was tested to segregate the components. It was found that the robotic system performed well for the purpose for which it was developed.

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