"Implementation of Edge Impulse Algorithm for Automatic Waste Sorting Machine".

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Abstract- *The amount of waste we generate globally is growing rapidly and we must find efficient ways to manage it. Automatic waste sorting machines have emerged as a promising solution to streamline the waste sorting process and promote recycling. In this project, we propose the implementation of an automatic waste sorting machine using Edge Impulse, a platform for developing machine learning models for edge devices. The proposed waste sorting machine classifies different types of waste materials, such as paper, plastic, metal, and glass, by using images. We collect and preprocess a diverse dataset of waste samples, leveraging the capabilities of Edge Impulse, to ensure the representation of real-world scenarios. With Edge Impulse's intuitive interface and tools, we optimize the trained model for deployment on edge devices like microcontrollers or development boards. Integrating this model with the waste sorting machine hardware enables real-time classification of waste materials, facilitating efficient sorting and recycling processes.*

Keywords: Edge Impulse, Edge Devices, Microcontrollers, Development boards

I. Introduction

A. Edge Impulse: Edge Impulse is a comprehensive platform that makes it easy for developers to create and deploy machine learning models on edge devices, even when resources are limited. The platform simplifies the entire process of building, training, and deploying machine learning models without requiring extensive knowledge in machine learning or deep learning.

The platform provides tools to collect and preprocess data from various sources, including sensors, cameras, and other environmental inputs. It allows developers to gather datasets relevant to their specific use cases and prepares them for model training. Edge Impulse supports the training of machine learning models using collected data. Developers can choose from a range of model architectures to train their models. Once the model is trained, Edge Impulse facilitates seamless deployment to edge devices such as microcontrollers and development boards like Arduino Nano, or custom hardware. It provides libraries and integrations for popular development platforms, making it easy to integrate the deployed models with existing hardware and software systems**.**

B. Sorting Machine: A waste sorting machine is a technological solution that automates the process of categorizing and separating various types of waste materials. The primary objective of waste sorting machines is to streamline waste management, reduce manual labor, and promote recycling to minimize the environmental impact of waste disposal.

- Using waste sorting machines offers a range of benefits, including increased efficiency and speed compared to manual sorting methods.
- This approach also reduces landfill waste and environmental pollution, leading to better sustainability.
- Additionally, using waste sorting machines can result in cost savings and improved profitability for waste management facilities.

Hardware: The waste sorting machine has several components, including the ESP32 Camera, Arduino Nano, conveyor belt, and DC motors.

ESP32 camera: The ESP32 Camera is a module that combines the ESP32 microcontroller with a camera sensor. It captures images of the waste items moving along the conveyor belt. These images are processed using machine learning algorithms or image processing techniques to identify and classify the materials. The ESP32's processing power and Wi-Fi capabilities make it suitable for capturing and transmitting image data wirelessly to a central processing unit for analysis.

Arduino Nano: The Arduino Nano serves as the brain of the waste sorting machine. It controls various aspects of the machine's operation, such as receiving data from sensors, controlling motors, and making decisions based on programmed logic or machine learning algorithms. The Arduino Nano interfaces with sensors, such as the ESP32 Camera, to collect data and trigger actions, such as activating the conveyor belt or controlling sorting mechanisms based on the detected waste types.

Conveyor belt: The conveyor belt is a mechanical system used to transport waste items through the sorting machine. It ensures a continuous flow of waste materials, allowing for efficient processing and sorting. The conveyor belt is driven by one or more DC motors, which move the belt at a controlled speed. The waste items are placed on the conveyor belt at one end and are carried along its length, passing under the ESP32 Camera for classification and sorting.

DC Motors: DC motors provide the necessary torque and speed control to move the conveyor belt smoothly and precisely. The Arduino Nano controls the DC motors using motor driver circuits or motor control modules, adjusting their speed and direction as needed to maintain the desired flow of waste materials through the system. Additionally, DC motors may be used to actuate sorting mechanisms such as mechanical shafts to divert waste items into different collection bins based on their classification.

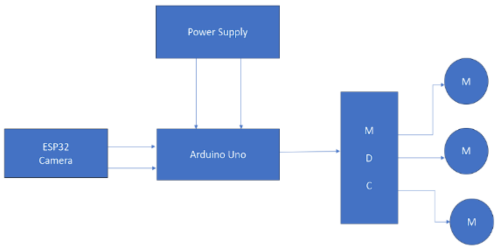
Software:

Arduino IDE**:** The Arduino IDE, also known as Integrated Development Environment, is a software tool used to write computer code and upload it to the physical board. Its simplicity is one of the main reasons for the popularity of the Arduino board. Nowadays, being compatible with the Arduino IDE is a primary requirement for a new microcontroller board. The Arduino IDE has improved over the years, adding many useful features. You can now manage third-party libraries and boards from the IDE while still enjoying the ease of programming the board.

II. Literature Survey

The proposed system in paper [1] monitors the solid waste collection process and management of the overall collection process. The inlet section is provided with an open and close mechanism to regular the flow of waste onto the conveyor. The proposed AWS system in paper [2] is designed to automate the waste segregation process by accurately classifying different types of waste based on images captured by a camera. The system begins by capturing images of the incoming waste using a camera installed at a designated sorting point. The proposed system in paper [3] is to make waste management easier and more efficient, an automatic sorter machine has been developed. The machine can sort out different types of waste materials and categorize them accordingly, such as metal, paper, plastics, and glass. The waste segregator is designed in paper [4] to provide ease in the disposal of waste that is collected. The system consists of three bins, each one for wet, metal, and dry waste. The conveyor belt system detects the incoming waste and classifies it as metal, dry, or wet using different sensors connected to the system and deflects it into the respective bin. The proposed strategy in paper [5] is simple and cost-effective. The separation of dry waste is proposed to categorize the trash into metallic waste and plastic waste. Since it is dry waste segregation, the technique uses a moisture sensing module to detect wet waste and if sensed thus stops working. The purpose of the proposed model in paper [6] is to identify, segregate, monitor, and develop a sorting system that sorts non-biodegradable waste automatically into three categories namely metal waste, plastic waste, and paper waste. The system mainly consists of Arduino Uno, an Inductive proximity sensor, an ultrasonic sensor, a capacitive sensor, an IR sensor, and Servo motors when the waste is dumped into the waste segregator through the conveyor belt the waste is pushed to the platform where the inductive sensor is attached which detects the metal things. In this article [7] a system is proposed for the automatic recognition and extraction of materials from unsorted waste, through the use of Computer Vision and Machine Learning techniques. This system can classify the materials of incoming objects, grasp them, and place them into appropriate bins. For the material classification phase, the system analyzes the information captured by a Near-Infrared (NIR) camera and an RGB camera. Experimental tests conducted on real-world datasets have shown highly promising accuracy values.

III. Proposed Methodology



Initialization: The garbage detection and sorting process involves the use of hardware components such as the ESP32 camera, Arduino Nano, and servo motors, which are set up and configured to work together. The trained machine learning model is then loaded onto the ESP32, which is responsible for classifying waste items based on the images captured by the camera.

Detection and Classification: The ESP32 camera captures an image of a waste item on the sorting conveyor belt. If necessary, the captured image is pre-processed by resizing or normalizing pixel values to prepare it for classification. The pre-processed image is then passed through the trained machine-learning model on the ESP32 for inference. The model analyses the image and predicts the type of waste item present, for example, a plastic bottle, a metal can, or an orange.

Decision Making: Based on the classification result obtained from the model, the system determines the appropriate action to take. For instance, if the waste item is a plastic bottle, the system activates a servo motor to sort it into the plastic bottle bin. Similarly, for a metal can or an orange, the system triggers the corresponding servo motor to sort the item accordingly.

Servo Motor Control: The Arduino Nano receives signals indicating which servo motor to activate and in which direction to move it. Using these signals, the Arduino controls the servo motors to move the sorting mechanism, directing the waste item to the correct bin.

Feedback: The system provides feedback to the user or system administrator to keep them informed about the classification results and sorting actions. This feedback can be displayed on a screen or sent to a remote server for monitoring and analysis purposes.

Repeat: The entire process is repeated continuously to handle incoming waste items on the conveyor belt. As new items are detected, classified, and sorted, the system loops back to the detection step to process the next item.

This methodology outlines the sequential flow of operations involved in the garbage detection and sorting process using the ESP32 camera, Edge Impulse model, and Arduino Nano. It demonstrates how the integration of hardware components, machine learning inference, decision-making, and feedback mechanisms enables automated waste sorting in real time.

IV. Implementation & Result

Module 1. Implementation of Camera Module:

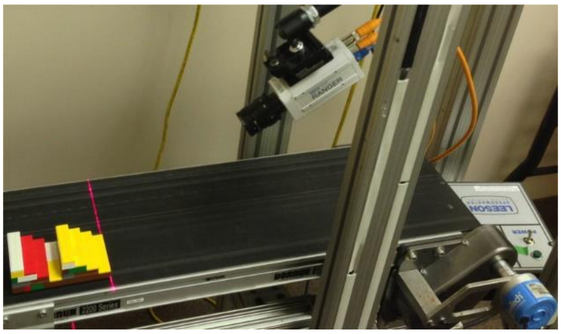
To implement the camera module (ESP32CAM) in the automatic waste sorting machine, you need to capture images of waste items on the conveyor belt for classification. Here's how to integrate the camera module and the expected results:

Hardware Setup:

Connect the ESP32CAM module to the Arduino Nano using appropriate communication interfaces (e.g., UART or SPI). Ensure that the camera module is securely mounted and positioned to capture clear images of waste items on the conveyor belt. Write Arduino code to initialize the ESP32CAM module and configure camera settings such as resolution, frame rate, and exposure. Set up communication protocols between Arduino Nano and ESP32CAM for image acquisition. Implement a routine in Arduino code to trigger the camera module to capture images at regular intervals or when prompted. Ensure that captured images are stored in a suitable format and location for processing.

Integration with Edge Impulse:

Modify the Arduino code to preprocess captured images (resize, convert to grayscale if needed) before feeding them into the Edge Impulse model for classification. Incorporate Edge Impulse's model inference code into the Arduino sketch to perform classification on captured images. Test the system with various waste items placed on the conveyor belt. Monitor the image capture process to ensure that images are captured correctly and promptly. Evaluate the accuracy of waste classification based on image data using Edge Impulse's trained model. Verify that the system can handle different lighting conditions and variations in waste item appearances for robust performance.



Results:

The camera module should successfully capture clear and identifiable images of waste items moving on the conveyor belt. The integration with Edge Impulse should enable accurate classification of waste items based on captured images. Monitor the system's performance metrics such as image capture speed, processing time, and classification accuracy. Upon successful implementation and testing, you should achieve a functioning automatic waste sorting machine that effectively uses the camera module (ESP32CAM) to capture images for waste classification, resulting in accurate sorting based on the trained model.

Module 2. Implementation of Mechanical Shafts:

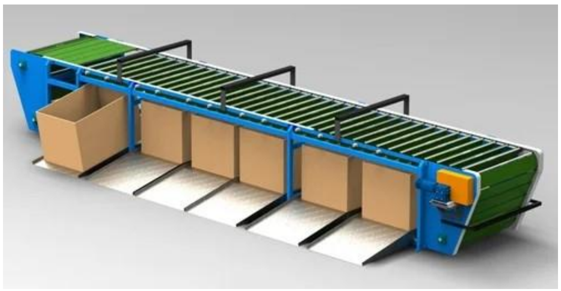
To implement mechanical shaft movement in the automatic waste sorting machine project, we need to integrate mechanical components that control the movement of the conveyor belt and the sorting mechanism based on the classification results. Here is a step-by-step process:

Mechanical Shaft Setup:

Design and build mechanical shafts that can pivot or move to divert waste items to the appropriate sorting bins. Connect the mechanical shafts to servo motors for precise control of movement. Modify the Arduino code to include motor control logic for the mechanical shafts. Define the movement patterns or angles for the mechanical shafts based on waste item classification results.

Integration with Edge Impulse and Classification:

Integrate the mechanical shaft control logic with the existing code for image capture, preprocessing, and classification using Edge Impulse. Upon receiving classification results (e.g., plastic waste), trigger the corresponding movement of the mechanical shafts to divert the waste item to the designated bin. Ensure seamless integration between the mechanical shafts and the conveyor belt system. Coordinate the movement of the conveyor belt with the movement of the mechanical shafts to ensure synchronized waste sorting.



Results:

The mechanical shafts should accurately divert waste items to the designated sorting bins based on Edge Impulse's classification results. Verify that the movement of the conveyor belt and the mechanical shafts is synchronized and coordinated for efficient waste sorting. Test the system with various waste items to ensure consistent and reliable sorting performance. Upon successful implementation and testing, you should have a fully functional automatic waste sorting machine that incorporates mechanical shafts for precise waste item diversion, contributing to efficient and accurate waste sorting processes.

Module 3. Implementation of Sorting Waste Items (Plastic, Metal):

To include plastic waste sorting in the automatic waste sorting machine project, it is necessary to use precise image processing and classification techniques to recognize and sort plastic waste items. This process requires collecting a dataset of images comprising different types of plastic waste items such as bottles, containers, and wrappers, and labelling them accordingly. This dataset is then used to train the Edge Impulse model specifically designed for plastic waste classification.

To carry out the Edge Impulse model training, you need to create a new project in Edge Impulse dedicated to plastic waste sorting and uploading the collected dataset of plastic waste images, labelling them, and training a machine learning model using Edge Impulse's image classification tools. It is essential to ensure a balanced and representative dataset and optimize the model parameters for accuracy and efficiency in classifying plastic waste items. Furthermore, you need to modify the Arduino code to capture images from the ESP32CAM module as waste items move on the conveyor belt and preprocess the captured images (resize, convert to grayscale if needed) to prepare them for classification. Load the trained Edge Impulse model specifically designed for plastic waste sorting onto the Arduino Nano. To classify plastic waste items, implement the Edge Impulse model inference code in the Arduino sketch to perform real-time classification of captured images. Define classification thresholds or confidence levels to accurately distinguish plastic waste items from other materials. Based on the classification results, control the DC motors to divert plastic waste items to the designated bin or sorting area. Implement logic to handle scenarios where the classification confidence is below a certain threshold to avoid misclassifications. Finally, test the system with a variety of plastic waste items to validate the accuracy of plastic waste sorting. Fine-tune parameters such as image capture frequency, model inference speed, and motor control thresholds for optimal performance. Evaluate the system's ability to handle different sizes, shapes, and colors of plastic waste items effectively.

Results:

The results are that the system accurately identifies and sorts plastic waste items (bottles, containers, wrappers, etc.) from other materials. Plastic waste items should be consistently diverted to the correct bin or sorting area based on classification results. Measure the system's accuracy, speed, and robustness in handling plastic waste sorting tasks in a real-world environment. Document any challenges encountered during implementation and potential improvements for future iterations of the system. Upon successful implementation and testing, you should have a functional automatic waste sorting machine capable of accurately sorting plastic waste items, contributing to efficient waste management practices.

The implementation for sorting metal and biodegradable waste items will be the same.

V. Conclusion

The implementation of an automatic waste sorting machine can streamline the waste management process. The machine uses components such as the ESP32 camera, Arduino Nano, and servo motors, and machine learning techniques facilitated by Edge Impulse. This solution can contribute to enhanced efficiency, reduced manual labor, and increased recycling rates by detecting, classifying, and sorting waste materials in real time. To establish a robust foundation for waste classification, we initialize the system and load a trained machine-learning model onto the ESP32. The ESP32 camera and Edge Impulse model accurately identify various types of waste items during the detection and classification process. This enables informed decision-making regarding their sorting and disposal. Based on the classification results, servo motors controlled by the Arduino Nano execute precise sorting actions, directing waste items to their appropriate destinations, whether recycling bins or designated waste collection points.

The automatic waste sorting machine project has a lot of potential for further improvement in several areas that can enhance its functionality and efficiency. To achieve this, one possible approach could be to refine the machine learning models used for waste classification, making them more precise and robust across different waste types and environmental conditions. Additionally, integrating additional sensors or technologies, such as infrared sensors or depth cameras, could provide complementary data streams for more comprehensive waste characterization. Another area of focus could be exploring methods for automated maintenance and calibration of the system, as well as implementing predictive maintenance algorithms. This would help ensure that the system operates continuously and with high reliability. Finally, by scaling the project for deployment in larger waste management facilities and integrating with broader smart city initiatives, we could extend its impact and contribute to more sustainable waste management practices on a community-wide scale.

VI. References

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