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ML-BIN: A Smart Dustbin to Control Waste Management via Automated Lid Control

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Abstract— *Waste is discarded in various forms worldwide, including plastic, glass and hazardous waste. People typically seek out designated containers, such as dustbins, for waste disposal. However, precisely gauging the volume of waste in a community can be a complex task, and dustbins have limited capacity. The IOT based Smart Dustbin project represents a promising step towards an intelligent Waste Management System. In our innovative Smart Dustbin project, we've designed a IOT equipped prototype with a unique feature. The dustbin's lid automatically opens when it detects presence of waste. After that the particular section of the dustbin's lid get's opened and then gets close by a period of time. This project incorporates key components like Microcontroller, Servo Motor, and Camera Module. There are traditional management systems like periodic and routine clearing by various civic bodies like the municipal corporation. But even though these routine maintenance are carried out low efficiently.*

Keywords— IoT, Ultrasonic, Camera module, Microcontroller, Object Detection, Servo Motor.

I. INTRODUCTION

Globally, people dispose of waste in various forms, such as plastics, wet waste, and dry waste. They typically look for a designated receptacle, commonly known as a dustbin, to properly discard their waste. Dustbins, typically made of plastic, serve as essential containers for waste disposal and act as storage units. In our innovative Smart Dustbin project, we've created a IOT prototype with a unique feature. This prototype has a lid that opens automatically upon detecting the presence of waste. After classifying the type of waste the specific lid is opened and automatically the lid get closed after some interval of time. Key components used in this prototype encompass Microcontroller, Servo Motor and Camera module. The key aspect of this approach is to foster a clean environment and support the 'Swachh Bharat' mission. It makes waste collection authorities job easier by not segregating huge amount of wastes and preventing them from coming in direct contact with garbage. This method Identifies and reduce the sources of waste generation and to improve the accuracy of waste sorting and recycling.

II. LITERATURE REVIEW

A. Primary Goal

This project aims to automate garbage bin operations by enabling them to open and close when motion is detected nearby. Additionally, it monitors garbage levels using ultrasonic sensors . [1].

In this project, the implementation of a smart dustbin with Arduino and IoT technology marks a significant advancement in cleanliness and sustainability. Equipped with an ultrasonic sensor, the bin opens automatically for users of all ages, reflecting a commitment to a cleaner, technologically-driven future. [4].

B. Identification

As our population skyrockets, so does our trash output, leading to a surge in environmental concerns. Dustbins, the unsung heroes of waste management, are meant to corral our garbage, whether recyclable or not, decomposable or not. But when they overflow, there's often no one around to clean up the mess, leaving trash strewn about and creating a breeding ground for pollution. [4].

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C. Integration of Components

The block diagram includes an ultrasonic sensor, Arduino Uno board, LCD display, power supply, crystal oscillator, reset logic, and a Wi-Fi module. The sensor detects trash levels, relayed to the ATmega328 microcontroller, which interfaces with all sensors and modules. The LCD shows trash levels, while the Wi-Fi module (ESP8266) sends data to the cloud via "ThingSpeak" for real-time monitoring and visualization [2].

D. Proposed Incorporation

Our project introduces a smart dustbin system tailored for hospitals, featuring three bins for plastic, hazardous, and glass waste. Using a camera module and Raspberry Pi, the system detects disposable items and triggers corresponding servo motors to open the appropriate bin. This innovative approach streamlines waste segregation, minimizing contamination risks and enhancing hygiene standards. With scalable Raspberry Pi integration and precise servo motor control, our system offers efficient and user-friendly waste management in healthcare settings.

III. WORKING OF ML-BIN

To handle waste disposal, as the person nears the dustbin, one can simply present the garbage in their hands in proximity to the Camera embedded on the bin. The camera identifies the presence of the waste and sends a signal to the microcontroller, which then send the signal to servo motor as per the decision made by ML model, prompting the lid to open automatically. Following the disposal of the garbage into the bin, the lid will automatically close after a specified time interval (in this case 10 seconds) . This efficient and user-friendly system ensures convenient waste disposal without direct human contact, enhancing hygiene and ease of use.

A Machine learning (ML) model is trained by exposing it to a diverse dataset, which includes multiple instances of objects that the system might encounter as waste. The purpose is to enable the model to recognize and categorize items as trash. Following the training phase, the ML model is seamlessly incorporated into the Microcontroller system, empowering it to generate real-time decisions by processing input data from the camera and comparing it to the learned patterns within the dataset.

This integration enables the Smartly-controlled smart dustbin to autonomously identify and classify objects as trash, thereby facilitating timely and responsive actions based on the environmental input received from the Camera. Upon successfully depositing the waste into the bin, the lid intelligently closes automatically after a predetermined time interval, typically set at 10 seconds. This thoughtful feature not only streamlines the waste disposal process but also promotes hygiene and convenience by minimizing direct human interaction with the bin.

The integration of machine learning adds a layer of adaptability to the system, enabling it to make real-time decisions based on various factors such as the type of waste or the bin's capacity. In essence, this user-friendly and efficient waste disposal solution leverages advanced technology to enhance cleanliness, ease of use, and overall environmental sustainability.

IV. BASIC PROTOTYPE.

The prototype features a single conventional dustbin with an ultrasonic sensor replacing a camera for waste detection. As Users approach, the ultrasonic sensor signals a microcontroller to activate a servo motor, opening the lid automatically. No machine learning is implemented; instead, the microcontroller follows a predefined algorithm for decision-making. After waste disposal, the lid remains open for 10 seconds before the microcontroller instructs the servo motor to close it.

This simple design ensures hands-free waste disposal without direct contact. The system is user-friendly and employs basic technology, making it practical for various environments. The minimalist yet efficient design of this waste disposal system, relying on an ultrasonic sensor and microcontroller, not only ensures hygienic and hands-free waste disposal but also presents a cost-effective and easily deployable solution for promoting cleanliness in diverse settings.

Fig. 1. Microcontroller

Fig. 2. Basic Prototype of ML-BIN

Fig. 3. One of the actual box of the prototype

V. MODULE IMPLEMENTED.

The module implemented operates based on the predefined libraries namely OpenCV, Sklearn, TensorFlow, utilizing convolutional neural networks (CNNs). Below is the algorithm used for implementation:

1. Initialization:
- Import the necessary libraries:
- OpenCV (`cv2`) for image processing.
- NumPy (`np`) for numerical operations.
-TensorFlow Keras (`tensorflow.keras.models.load_model`) for loading pre- trained CNN models.
- Operating System (`os`) for file system operations.
2. Loading Pre-trained Model:
- Load the pre-trained Convolutional Neural Network (CNN) model using TensorFlow Keras.
3. Defining Categories:
- Define the categories or fields and their corresponding indices to classify the images.
4. Image Classification:
- Define a function `classify_captured_image()` for classifying captured images:
- Preprocess the captured image by resizing it to the required dimensions and normalizing pixel values.
- Utilize the pre-trained CNN model to perform image classification.
- Map the predicted class index to the corresponding field/category.
5. User Interaction:
- Define a callback function `on_button_click()` to handle user interactions:
- Triggered upon left mouse button click.
- Classify the captured image and display the classification result.
- Prompt the user for feedback on the classification accuracy.
- Save the captured image in the appropriate folder based on the classification result.
6. Image Saving:
- Define a function `save_image()` to save captured images:
- Create a folder if it doesn't exist, based on the classification result.
- Generate a unique image name and save the image in the designated folder.
7. Image Capture:
- Initialize the webcam to capture images:
- Continuously read frames from the webcam and display them.
- Capture an image when the 'c' key is pressed.
- Display the captured image and wait for user interaction.
- Terminate the loop when the 'q' key is pressed.
8. Cleanup:
- Release the webcam and close all OpenCV windows gracefully.

VI. DATASET TRAINED.

We have used CNN to train the dataset, below is the algorithm used to train the dataset
1. Imports:
- Bring in the required libraries:
- {cv2}: Image processing OpenCV library.
- A library for numerical operations is called {numpy}.
- {os}: File handling operating system module.
- The function {train_test_split} from {sklearn.model_selection} divides data into sets for testing and training.
The {tensorflow.keras.models} layers include different types of layers and a sequential model.
2. Define Categories:
-Make a dictionary called {fields} that associates number labels with each category name.
3. Load Dataset:
- To load photos and labels from supplied dataset paths, define the function `load_dataset(dataset_paths)`.
- Repeat for every path in the dataset.
- For every category folder in the path of the dataset:

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- Load the images, resize them to 224 by 224 pixels, and add the images, together with the labels that go with them, to an images list.
4. Data Preprocessing:
- Divide the image pixel values by 255.0 to normalize them to the range [0, 1].
- Use `train_test_split()` to divide the dataset into training and testing sets. For reproducibility, select a random state and put aside 20% of the data for testing.
5.Encoding:
- Use the `np.eye()` function to transform categorical labels into one-hot encoded vectors. The labels are ready for multi-class categorization in this stage.
6. Define Model:
- Describe a model that is sequential:
- Include Conv2D layers for feature extraction, with a ReLU activation function in between each layer.
- Include layers of MaxPooling2D for down sampling in order to minimize spatial dimensions.
- To prepare for input to dense layers, flatten the output.
- Include dense layers with the proper activation functions for categorization.
7. Compile Model:
- Use the 'adam' optimizer and the 'categorical_crossentropy' loss function to compile the provided model. In this stage, the optimization algorithm and the loss function to be minimized are specified, setting up the model for training.
8. Train Model:
- Utilizing the training data, train the constructed model:
- Fit the model with a batch size of 32 over ten epochs using the training set of data.
- Verify the model's performance as it is being trained using the testing data.

9. Save Model:
- For later usage, save the trained model in the '.keras' format. This makes it possible to load and use the model without retraining.

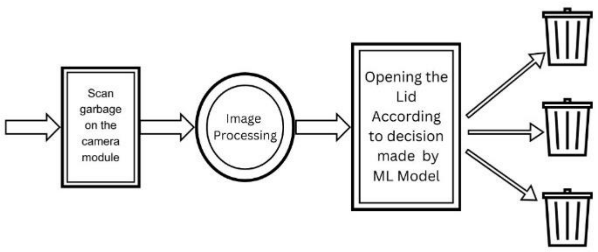

Fig. 4. Flow of process

KEY CHALLENGES

1. Selecting appropriate sensors for the dustbin.
2. Making proper connections between all the components.
3. Programming the microcontroller to work according to our needs.
4. Designing the dustbins unique, so that they can stand out from crowd.

VII. COMPONENTS.

A. Servo Motor

The servo motor operates by interpreting signals from sensors like infrared or ultrasonic sensors. These signals trigger the motor to open or close the lid in response to detected proximity or motion. The servo motor's precise control ensures automated, hands-free operation, optimizing the effectiveness of waste disposal.

B. Microcontroller

The microcontroller analysis sensor data, including signals from infrared or ultrasonic sensors, to decide on lid operations. Subsequently, it transmits instructions to the servo motor, facilitating automated and responsive control over the dustbin's functions. This system orchestrates seamless communication between components for efficient smart dustbin operation.

C. Ultrasonic Sensor

The ultrasonic sensor emits sound waves to measure the distance of objects in its range. By calculating this distance, the sensor empowers the microcontroller to make informed decisions, such as initiating lid opening, in response to the detected proximity of waste material or user interaction.

D. Jumper Wires

Jumper wires play a vital role in a smart dustbin by establishing electrical connections among components, including sensors, microcontrollers, and motors. Serving as conductive links, they enable smooth communication and coordination within the electronic circuit, ensuring the efficient operation of the smart dustbin system.

E. Camera Module

The camera module captures visual data to enable the system to identify and analyse waste. The microcontroller processes this information, enhancing the overall functionality of the dustbin and optimizing its efficiency in waste management.

RESULT

The expected results of the proposed projects hold significant promise for changing waste practices and promoting environmental protection. The proposed project exhibit considerable potential in revolutionizing waste management practices and fostering a heightened commitment to environmental protection. Projects in the healthcare sector demonstrate significant promise in revolutionizing waste management practices within hospital settings and concurrently promoting environmental protection. They have the potential to significantly improve public health by minimizing the risks associated with improper medical waste disposal.

CONCLUSION

This model is used in hospitals which has the feature of opening the lid given by ML model which helps the ragpickers prevent coming into contact with waste collected in the dustbin for a hygienic environment. The technology is also expected to have a significant impact on reducing waste. By detecting and controlling waste in a timely manner, it can reduce the adverse effects of waste in public hospitals. As it becomes an important part of waste management, it will contribute to the world's efforts to save resources, reduce waste and reduce the impact of waste on the environment.

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