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AUTOMATED WASTE SEGREGATION SYSTEMUSING IMAGE PROCESSING

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Abstract : Waste management and systematic sorting of them are considered to be a significant role in ecological development around the world. The procedure in which the garbage is segregated is by splitting the garbage into divergent components. This is regularly done by handpicking physically which sometimes causes hazardous and dreadful impact on human health if not appropriately done. Currently used waste sorting technologies have limitations on the composition of recyclable waste, which makes them specialized. Thus, the preliminary sorting of Municipal Solid Waste (MSW) is a necessary step, increasing the efficiency of using municipal solid waste as a resource.

Our project aims to create an automated waste segregation system using image processing techniques. The ultimate objective is to segregate the waste into two main categories- recyclable and non-recyclable. This would help in easy recovery of useful and recyclable items. The sorting unit performs detection and classification of waste components on a conveyor belt. Unpacked MSW is supplied to the conveyor belt as a sparse feed so that cases of objects overlapping are rare. Images are gathered from a camera and fed to a neural network input, which determines the position and type of detected objects. A L-Shaped structure is used as the sorting unit to move the MSW from the conveyor and classify them to the corresponding bin. The L-Shaped structure which can place the waste materials like cardboard, glass, metal, paper, plastic, and trash waste can be properly dumped in the corresponding recyclable and non-recyclable bin. The wastes are classified primarily into two levels such as recyclable and non-recyclable. These two main classes can be further classified into categories depending on their reusability. The hardware system is a conveyor, camera, L-shaped clamp and Arduino UNO for controlling conveyor, and the software is an image classification algorithm based on machine learning process. To train the neural network we use a database of municipal solid waste images.

IndexTerms **- Image Processing, Municipal Solid Waste (MSW), Machine learning, Waste Classification.**

I. INTRODUCTION

A major environmental issue that poses a critical challenge in almost all developed and developing countries is disposal of garbage. Proper handling of waste is the compelling requirement for ecological balance. Waste segregation can be defined as the process of identifying, classifying, dividing and sorting waste and waste products in an effort to reduce, reuse and recycle materials. In order to properly sort waste, it is important to correctly identify the type of waste that is generated. Waste segregation is critical because some types of waste can be hazardous and can contaminate the environment if not properly managed. (Some of these types of waste may also have the potential to cause disease (like medical waste) or enter water sources or contaminate soil with various types of leachate). When waste is not sorted, it can be contaminated with different types of waste that are stored together. Such waste cannot be handled or disposed of and usually ends up being dumped in local dumps or landfills. With waste segregation, it is possible to deal with different types of waste. This directly leads to a reduction in the amount of waste placed in landfills or landfills. Waste sorting is always the first step for all types of waste management solutions that can be implemented either at the individual level or at the community level. There is a need for a complete rethinking of "waste" - to analyze if waste is indeed waste. A rethinking that calls for

WASTE to become WEALTH
REFUSE to become RESOURCE
TRASH to become CASH

Our project focuses on identifying and classifying waste into three categories namely recyclable, non- recyclable

II. OBJECTIVE

The proper handling of waste is one of the biggest challenges of modern society. Municipal Solid Waste (MSW) requires categorization into a number of types, including bio, plastic, glass, metal, paper, etc. The problem of garbage disposal has increased many fold in recent years because of the massive production of disposable goods in almost every industry; ranging from potable drinking water packaged in plastic bottles to takeaway coffee cups, foam to medical waste, and lightbulbs to plastic bags, the list is endless. The primary motivation behind the proper handling of waste is the compelling requirement for ecological balance, which has already been disturbed by mankind, to a large extent, only in the past 200 years.

Our project aims to create an automated waste detection system using image processing technique. Municipal Solid Waste (MSW) is a collection of both hazardous and non-hazardous, disposable, and non-disposable items. MSW moves through a conveyor belt. The unpacked waste is supplied to the conveyor belt as sparse feed. Images are gathered from the camera with object recognition, detection, and prediction. An L shaped clamp is used as the sorting unit to move the MSW from the conveyer and classify them to the corresponding bin.

III. WASTE CLASSIFICATION USING IMAGE PROCESSING

3.1 Machine Learning

Machine learning is a branch of artificial intelligence (AI) and computer science. It focuses on utilizing data and algorithms to mimic human learning and improve accuracy over time. This field is closely related to data science and plays a vital role in extracting valuable insights from data mining projects. By training algorithms with statistical methods, machine learning enables the generation of classifications and predictions that can influence decision-making processes in applications and businesses. The demand for data scientists is expected to rise as big data continues to expand, as they will be instrumental in identifying crucial business questions and finding the relevant data to address them.

Machine learning is still considered critical for the advancement of AI, despite its shortcomings. However, ensuring its success entails adopting a different approach that overcomes its weaknesses, such as the "black box" problem in unsupervised learning. One such alternative is symbolic artificial intelligence, which relies on a rule-based methodology for processing data. In this approach, a knowledge graph is used to define concepts and semantic relationships, providing transparency and interpretability. By combining machine learning with symbolic AI, a hybrid AI approach emerges, enabling AI systems to understand language, not just raw data. This powerful approach revolutionizes data utilization across various industries by offering deeper insights into what has been learned and why. For instance, in waste management, our model follows deep learning algorithms to train the machine using specific waste image features like shape and size. Once learned, the machine can identify various classes of waste by recognizing objects resembling them in the images.

3.2 Image Processing

Image processing is a crucial process that involves converting an image into digital form and applying various operations to extract useful information from it. This field treats images as 2D signals and employs specific signal processing methods to analyze them. It aims to enhance images or extract relevant information, such as characteristics or properties associated with the image. Over time, image processing has emerged as a rapidly developing technology, occupying a significant research area within engineering and computer science disciplines.

Image processing can be broken down into three fundamental steps. Firstly, the process begins with the import of the image using specialized image acquisition tools. Secondly, the image undergoes analysis and manipulation to extract relevant information or enhance its visual quality. Lastly, the output of the image processing can take the form of an altered image or a comprehensive report based on the analysis conducted.

Image processing utilizes two primary methods: analog and digital image processing. Analog image processing is employed for hard copies like prints and photographs. Image analysts employ various visual techniques and interpretations in this context. On the other hand, digital image processing techniques leverage computer systems to manipulate digital images. When utilizing digital technology, all types of data typically undergo three general stages: pre-processing, which involves preparing the data for further analysis; enhancement and display, where techniques are applied to improve the visual quality of the image; and information extraction, which involves extracting relevant information or features from the processed image.

3.3 Convolutional Neural Network

Deep learning utilizes convolutional neural networks (CNNs or ConvNets), which are a type of artificial neural network (ANN) primarily used for analyzing visual imagery. CNNs are also referred to as Shift Invariant or Space Invariant Artificial Neural Networks (SIANNs) due to their shared-weight architecture of convolution kernels or filters. These kernels slide along input features, generating translation-equivariant responses called feature maps. CNNs find wide applications in various domains such as

image and video recognition, recommender systems, image classification, image segmentation, medical image analysis, natural image processing, brain-computer interfaces, and analyzing financial time series data**.**

Convolutional neural networks (CNNs) are specialized for processing grid-like data like images. They automatically learn hierarchical representations using convolutional, pooling, and fully connected layers. CNNs excel at tasks such as image classification, object detection, and medical image analysis. Their ability to learn features from raw data has led to breakthroughs in computer vision and other fields.

3.4 Waste Classification

For waste classification using deep learning, a sequential model with five convolutional layers was implemented. Max pooling with a stride of 2 and activation functions like ReLU and sigmoid were utilized. The number of kernels increased progressively (16, 32, 48, 64) to extract more features from the images. The model was built using the simplicity of the sequential model in Keras. After convolution and pooling, the output was flattened to a single vector, preserving spatial structure. The ReLU activation function ensured linearity, and pooling reduced complexity without sacrificing performance. The fully connected layer had hidden and output layers, with a softmax layer added for multi-class classification. The softmax function helped identify the class of a given waste image in litter classification tasks. Then the model was compiled using adam optimizer which is a stochastic gradient algorithm and the loss was given as categorical cross entropy since the problem comprised more than 2 categories. The performance metric was assigned with accuracy. Then the convolutional neural network model was fitted to the dataset for it to fit to the training test image datasets. The model was trained using 50 epochs and it achieved an accuracy of 97.01% and the testing was conducted and the test accuracy was found to be 91%.

IV. TOOLS AND FRAMEWORK

4.1 Software

4.1.1 Python 3.8

Python is an interpreted, high-level, general-purpose programming language. The python language is one of the most common languages in various machine learning and deep learning projects due to its simple structure and ease of use. There are various versions of python available and among them python 3.8 was used in the project.

4.1.2 Jupyter Notebook

The Jupyter Notebook is the original web application for creating and sharing computational documents. It offers a simple, streamlined, document-centric experience. If the network availability is ensured, it is a very good platform for creating and deploying the models as well as the training and testing. It unburdens the task of installations and provides a simple platform for exploring the deep learning projects for image classification and so on.

4.1.3 OpenCV

OpenCV is commonly employed for analyzing diverse images and videos, including tasks such as facial recognition, object detection, image editing, advanced robotic vision, optical character identification, and much more. The OpenCV library plays a vital role in image processing and is particularly geared towards real-time computer vision. In this model, Python scripts utilizing the OpenCV library will be developed to test the recently trained waste detection classifier on webcam feeds, images, or videos.

4.1.4 Tensorflow

TensorFlow is a software library that is freely available and open-source, enabling dataflow and differentiable programming across a wide range of functionalities. It serves as a symbolic computation library and finds extensive usage in machine learning applications, particularly for building neural networks. TensorFlow provides a robust platform for creating various models in the domains of machine learning and deep learning.

4.1.5 Keras

Keras serves as an application programming interface (API) that functions as a library. It allows for the importation of images and is primarily implemented in Python. Keras provides different models, such as the sequential model, among others. It is designed to operate seamlessly on top of frameworks like TensorFlow or Theano. The primary goal behind Keras' development is to facilitate rapid experimentation with various machine learning and deep learning tasks.

4.1.6 ImageDataGenerator

The Keras ImageDataGenerator is utilized to obtain input from the original data. Additionally, it applies random transformations to this data and outputs only the newly transformed data, without adding any additional data. The Keras ImageDataGenerator class is also instrumental in performing data augmentation, which aims to enhance the overall generalization of the model.

4.2 Hardware

Fig 4.2.1 Hardware Prototype

4.2.1 Conveyor

To transport waste objects in a controlled manner, a reliable conveyor belt system is employed. This system facilitates the smooth and regulated movement of waste items, enabling them to pass through cameras and the waste classification mechanism for efficient sorting and disposal. The conveyor belt is constructed using Rexin material, which is a blend of polyester and polyurethane. This combination of materials ensures that the belt is robust, durable, and long-lasting.

4.2.2 DC Gear Motor

The DC gear motor plays a vital role in supplying the required torque and rotational power to drive the conveyor belt. With a rated speed of 150 RPM, this motor operates at a voltage of 12 volts. It incorporates a gearbox that consists of gears, which effectively reduce the high rotational speed of the motor to a lower speed suitable for driving the conveyor belt. The motor can be controlled to adjust the speed of the conveyor belt according to specific requirements.

4.2.3 DC Motor Clamp

It is typically a metal bracket or clamp that fits around the motor and attaches to the conveyor frame.It is used in the motor to secure the motor to the conveyor frame.

4.2.4 Arduino Uno

The Arduino Uno is a widely recognized microcontroller board within the Arduino family, commonly employed by hobbyists, students, and professionals across various projects. It is centered around the ATmega328P microcontroller, delivering a user-friendly platform for electronics prototyping and experimentation. Equipped with a range of digital and analog input/output pins, the Uno allows for seamless connection and control of diverse sensors, actuators, and components. Programming the Uno can be accomplished through the Arduino IDE, which offers a simplified language based on C/C++. The board can be powered via USB or an external power source, offering versatility and portability. Additionally, the Uno includes built-in LEDs and a reset button for convenient debugging and programming purposes. In summary, the Arduino Uno is an exceptional option suitable for both novices and seasoned users, providing a solid foundation for exploring the realms of electronics and programming.

4.2.5 Relay

A relay provide an reliable and efficient means for controlling the motor that drive the conveyor. By utilizing a relay, the automated waste detection system can effectively control various electrical components, providing a means to switch on/off the motor, lighting, and other devices based on the signals received from the microcontroller.

4.2.6 Webcam

A webcam is used for capturing images of the waste objects on the conveyor belt. Selected based on factors like resolution, frame rate, and compatibility with the system, the webcam is connected to the Raspberry Pi or the controlling device via a USB connection.

4.2.7 Wooden Pulley

It consist of a grooved wheel made from wood that rotates around an axle, with the belt running through the groove to transmit power.

4.2.8 Raspberry Pi

The Raspberry Pi's adaptability, computational strength, and GPIO (General Purpose Input/Output) capabilities make it an ideal selection for data control and processing. It is employed to receive signals from cameras, process images, and transmit control signals to the motor. By offering a compact and cost-effective solution, the Raspberry Pi enhances the efficiency and autonomy of the system, particularly for image processing and control tasks.

V. RESEARCH METHODOLOGY

In this project we are using image processing methods for detecting the waste objects. These objects are classified as recyclable and non-recyclable. The hardware system is a trash bin framework based on the core module Raspberry Pi and the software is an image classification algorithm based on image processing. First, datasets of different waste materials are created. Then using machine learning, the features are detected from the datasets using Feature Extraction algorithms. The detected features are stored and the model is trained. Once the training is completed, the output variable is stored for prediction. The webcam runs live waste detection and get the image of the waste. The waste class is predicted using extracted features by comparing with the stored output variable and the results are plotted. The hardware components include the L shaped clamp, raspberry pi, conveyor belt and a camera module. Waste materials are fed to the conveyor as sparse feed. The camera module will capture the image of the waste and detect it. We have created a hardware model for waste sorting. Hardware model consist of a conveyor which is controlled by a dc motor. A pulley will be helping the conveyor for rolling. The pulley is made of wood and other parts of the conveyor is made of metal. A servo motor is attached to control the L-shaped clamp which is used to move the object to the corresponding waste bin. Circuit diagram was implemented to control dc motor and servo motor. Circuit diagram include arduino uno, relay module, servo motor and dc motor. Relay module is used to stop the conveyor when a recyclable object is detected through the camera. Trained CNN models for waste classification can be deployed and executed on Raspberry Pi. Raspberry Pi can control the L-shaped clamp mechanism used for waste sorting. It can send commands to control the movement and positioning of the clamp based on the classification results obtained from the CNN model.

5.1 Block Diagram

The block diagram for the automated waste detection system using image processing for Municipal Solid Waste (MSW) typically includes the following components:

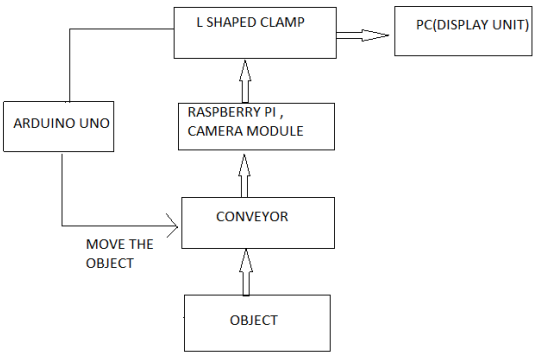

Fig 5.1: Block Diagram

5.1.1 Conveyor Belt

This component transports the waste items along a predefined path. It consists of a motorized belt that moves continuously, allowing the waste items to pass through the system.

5.1.2 Camera Module

It provides the visual input required for image processing and waste classification.

5.1.3 Control Unit

The control unit coordinates the operation of various components in the system. It receives data from the image processing module and waste classification model and sends commands to the waste sorting mechanism.

5.1.4 L-shaped clamp

Used for waste sorting. During operation, the L-shaped clamp receives instructions from the control unit based on the waste classification results.

5.1.5 Raspberry Pi

Raspberry Pi is typically connected to the camera system, image processing module, waste classification model, control unit, and user interface. It 24 receives input from the cameras, processes the captured images using the image processing algorithms, and sends the processed data to the waste classification model for waste item classification.

5.1.6 PC Display Unit

It allows operators to view the captured images of waste items, observe the waste classification results, and track the progress of waste sorting in real-time.

VI. RESULTS AND DISCUSSION

We have created a neural network and trained it using waste image dataset. Dataset consisting of recyclable and non-recyclable msw with 2060 images were collected. The model is trained via an open-source web platform, jupyter notebook. We have used tensorflow keras and ImageDataGenerator to build the neural network. All the data labeling is done with the help ImageDataGenerator. We have implemented Convolutional Neural Network (CNN) using a Python framework. Convolutional Neural Network (CNN) with maxpooling and dense layers is used for building up the model. We have used Matplotlib for visualizing data. The created model works on the test data. The experimental results show that the accuracy of classification is over 89% in the model. The model precisely classifies the type of waste materials into its corresponding recyclable and non-recyclable classes by detecting the type of objects shown in the webcam. The images of the testing data were utilized for testing the result of the created model.

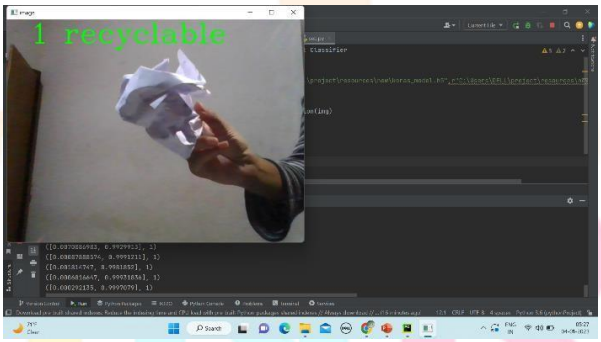

Fig 6.1: Recyclable Waste Detection (paper waste)

Fig 6.2: Non-recyclable Waste Detection (fruit waste)

We have created a hardware model for waste sorting. Hardware model consist of a conveyor which is controlled by a dc motor. The waste object will be moving through the conveyor as a sparse feed. A pulley will be helping the conveyor for rolling. The pulley

was made of wood. Other parts of the conveyor made of metal. A servo motor is attached to control the clamp which is used to move the object to the corresponding waste bin. Circuit diagram was implemented to control dc motor and servo motor.

6.1 Prediction Results

Image processing technique is employed to detect and classify different types of waste based on their visual characteristics. We have trained our model using Convolutional Neural Network. The model can take an input image, perform the necessary preprocessing steps, and output predictions regarding the presence of non-recyclable or recyclable waste objects in front of the webcam.

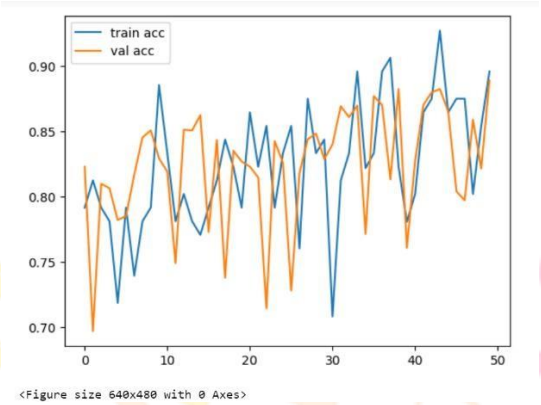

Fig 6.1.1 graph representing model accuracy

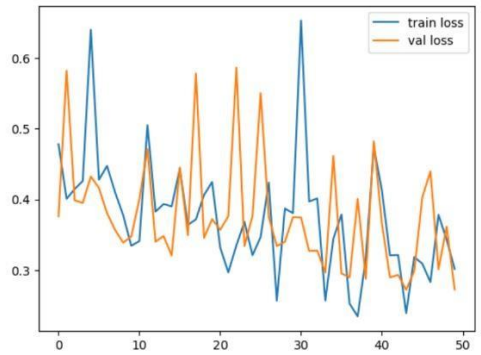

Fig 6.1.2 graph representing model loss

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