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Reverse Vending Machine for Plastic Bottle Recycling

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ABSTRACT

In this 21st century as the amount of waste generated is increasing but the landfill space for disposal is limited, recycling is an important approach to manage the waste effectively. The major contribution to the waste generated is plastic which are thrown away after their usage. We aim to build a Reverse Vending Machine for collecting plastic bottles with reward feature. The technology used for identifying plastic bottles is image processing. Once the number of bottles are identified depositor can claim the points by entering a unique ID and the accumulated points can be used to generate promo code for online shopping. The user and authority can keep track of their details by maintaining an account in the application software developed. Once the machine at a specified location is filled, this could be notified to the authority via messaging through the application.

Keywords :- (Reverse Vending Machine)RVM, (Field Programmable Gate Array)FPGA, (convolutional neural networks)CNN

I. INTRODUCTION

The amount of plastic produced daily and usage of such plastic materials is greatly harming the environment and is threat to the earth. Recycling means converting wastes to useful materials. It is fully implemented in western countries with the support of its government. However in our country, littering is a norm. Local authorities encourage recycling but only to get lukewarm responses. One of the program executed locally is by placing recycling bins at public places. For this reason, we can see that the inconvenience and ineffectiveness of the recycling process demotivates people from doing so. Another system implemented to boost recycling is by paying cash or shopping coupons to those who bring recyclable items to the shopping malls.

However, the program cannot be fully implemented in our country as it requires a full team to manage it. Hence, Reverse Vending Machine (RVM) is meant to encourage recycling habit by giving rewards to depositors for every recycled item in terms of reward points. Understanding the advantages of RVM, many countries have implemented these machines. Even though India initiates ways to reduce waste, RVM is not used because of its high implementation cost and maintenance.

The major motivation for this project is to enable the implementation of RVM in India by building a prototype which focuses on reduction in energy consumption. The amount of bottles used is too much and the recycling of such bottles is done in very less quantity. So to overcome such a huge problem by making the recycling procedure easy and profitable for a common man, we came up with this idea of smart machine for plastic bottle disposal.

The operation of such machine is as simple as that of an ATM machine. This is a machine provided with an inlet to accept bottles. The user could place the bottle in it. After the bottle is placed inside the inlet, image processing is used to decide whether to accept the bottle for recycling or not. If the bottle is accepted depositor can get the reward points by entering his/her unique pin number. If not accepted, the bottle is returned to the user. This project can be advantageous at various locations such as railway stations, bus stands or shopping malls. The huge amount of plastic bottle which are dumped on these public places can be collected easily if such machines are installed. Reverse Vending Machine (RVM) is just like any other vending machines available but the machine gives reward such as money or shopping coupons in exchange of certain materials identified when inserted into the machine. RVM is an innovative concept which has been introduced to help collect recyclable materials and hence, to boost recycling activities.

These machines have the ability to accept materials such as beverage cans, bottle glasses and plastics depending on the type of machine. Here the RVM generally automates plastic bottle recycling by accepting plastic bottles directly from the consumer, accounting for each bottle processed, and refunding the deposit to the user. The image processing is developed with a camera which takes pictures of the bottle as it is placed into the machine.

II. PREVIOUS WORK

In Maofic Farhan [1] suggested the design of a Smart Bottle Recycle Machine (SBRM) is presented. It is designed on a Field Programmable Gate Array using an ultrasonic range sensor. The detector was used to calculate the number of bottles and distinguish between them. Since hardware based implementation on a FPGA is usually much faster than the software based implementation on a microcontroller PGA was chosen.

Machine learning algorithm developed on with python platform was used to classify and collect the used bottles in the paper by Dhulekar [2]. The system consist raspberry-PI connected with camera and out of audio-visual interactive system. Reward is given through printed coupon generated using thermal receipt printer. The machine is designed in a way to accept plastic bottles and credits these as points, which then can be used to buy products. The proposed design of BRM provides identification of bottle and efficient recycling in low cost.

Dumpayan [3] proposed the operation of the machine which run on either commercial power or solar power showed

great accuracy in recognizing RFID accounts, differentiating between plastic and non- plastic bottles, storage or updating of points of each account, and distributing products. Along with providing a renewable source of energy, the addition of the solar panel and battery also serves as back-up power in the event of commercial power outage.

In the paper by Kokoulin [4], the authors describe their results in IoT and Convolutional Neural Networks application in reverse vending machine. This machine is implemented with IoT controllers and tiny single-board computers which have greater memory and computational restrictions. These controllers could recognize the different types of waste using cameras and provide sorting and preprocessing. This paper show CNN implementation on IoT for reverse vending machine.

Aditya gaur [5] suggested a Reverse Vending Machine that supports only plastic items as an input, coins as an output. The Reverse Vending machine (RVM) is implement using Xilinx in Verilog. This paper explains the duplication of Reverse Vending Machine for detecting fraud using Strain Gauge Weight Sensor, Capacitive Proximity Sensors and Infrared Photoelectric Sensor to detect.

In this paper by Andrey N. Kokulin [6] some approaches in computer vision and image processing and their application to the problem of automatic recognition of empty recyclable containers (bottles and cans) and detecting fraud were considered. The main function of RVM is the classification of image inside the machine by three feasible classes such as PET bottle, aluminum can or fraud (everything that doesn't match PET bottle or can), even if the cans or bottles are warped or jammed.

Edgar Scavino [7] proposed an experimental machine vision apparatus was used to identify and extract recyclable plastic bottles conveyor belt. Color images of the bottles were taken with a Webcamera, and the identification was performed by our homemade software, based on the shape and dimensions of object images.

III. METHODOLGY

Proposed design of machine accepts plastic bottles as input and reward the user with credit points that can be useful for online shopping. There are many types of bottles that are available nowadays and classifying them as plastic and non-plastic is a complex task. In the proposed system image processing is used for this classification. The proposed system is comprised of 3 modules that include Image processing, Reverse Vending Machine and Application software.

A. Image processing

Image processing includes importing the image for creating dataset with the help of LabelImg tool, analyzing and manipulating the image and outputting the result. Image processing is one of the computer vision technique which composed of Image recognition, object detection, Image super resolution and more.

Image recognition:

Image recognition in computer vision technique for recognizing objects in images or videos. Image recognition is a main output of deep learning and machine learning algorithms. When humans look at a photograph or watch a video, we are easily able to spot people, objects, scenes, and visual details.

The goal is to teach a computer to behave similar to humans: to gain a level of knowledge of what an image contains. Image recognition is the main technology behind driverless cars, enabling them to detect a stop sign or to distinguish a pedestrian from a lamppost. It is also useful in a great variety of applications such as disease identification in bio imaging, industrial inspection, and robotic vision.

Object detection:

Object detection refer the capability of computer and software systems to locate object in image and identify each object. Object detection has been widely used for applications such as face detection, vehicle detection, pedestrian counting, web images, security systems and driverless cars.

In early implementation of object detection mainly involved with the use of classical algorithms, like open CV. These classical algorithms could not achieve enough performance with certain conditions. Different ways of object detection can be used in different fields. In modern technology highly accurate object detection algorithms are implemented which are based on deep learning using machine learning algorithms.

Object Recognition Using Deep Learning & machine learning:

Deep learning techniques have become a popular and important method for doing object recognition. Deep learning models such as convolutional neural networks, or CNNs, are used to automatically learn an object's inherent features for identifying the object. For example, it can learn to find differences between cats and dogs by analyzing huge collection of training images and learning on the features that make cats and dogs different.

Highly accurate object detection algorithms and methods like R-CNN, Fast RCNN, Faster-RCNN, RetinaNet are there for implementation. Deep learning offers a high level of accuracy but at the same time requires a large amount of data for making accurate predictions. Machine learning techniques are used for object recognition and offer different approaches than those used in deep learning.

Object Detection in Google Colab with Custom dataset:

We propose a method to train a Tensorflow model for object detection in google Colab, based on custom datasets. There are mainly three steps performed. These include: Making dataset, Model training and inference. Here the dataset is created using LabelImg tool. The model is trained based on the dataset and corresponding inference must been generated.

1. Making dataset

It is a process of creating a dataset with appropriate number of photos (different kinds of bottles). LabelImg tool is used to create dataset. Object detection class will create a folder of image objects, extract each image, save each to the new folder created and return an extra array that contains the path to each of the image.

The image files are renamed in the format objectclass_id.jpg(i.e.bottle_001.jpg,bottle_002.jpg. Then in LabelImg, which defined the bounding box where the object is located, and saved annotations in Pascal Voc format.

2. Model training

- Install packages, repositories and environment variables used for object detection in Tensorflow.
- Extract dataset by download the file system dataset created and zip file has the structure.
- Empty png files used here to avoid error in creation of files.
- From the dataset it creates the TFRecord. Algorithm will train model in dataset.
- Edit the model config file by Set the fields of the config file.
- Different initial checkpoint models are update before training.
- Training model is performed training with data and configuration. Validation is performed.

3. Inference

Based on the trained model there are various steps performed to run inference are export trained model, upload image, run inference.

- Export trained model converts last trained model to the format to run inference.
- Upload image for inference which upload the test image file to run inference in the next step.
- It performs inference of the uploaded image in dataset and result are generated as per the rate of accuracy.

B. Reverse Vending Machine for Plastic Bottle Recycling

The Reverse Vending Machine is where user empty the plastic bottles for recycling. In this the user puts in bottle and gets credit points. The main functions of the machine include bottle acceptance, fill detection and alerting the authorities when the machine is fill. Proposed system uses a monitoring technique to monitors the machine. This can help the authorities to get real time information about the machine. The machine fill detection is based on an IR sensor placed on the machine which could be used to detect the filled level of the machine. For interfacing the sensor with the server we use a Bluetooth module that enables serial port communication. If the level is greater than threshold value, a message is sent to authorities through GSM module. The data of machine is also sent to the app, this information remains stored on the app.

C. Software application

Software module is an android based application that contains user login and authority login. By downloading the app and registering, each user will get a unique password that can be used while depositing the bottles in reverse vending machine. On login ,a user can view his/her credit details and based on the credit points he/she gets a promo code that can be used while shopping online. Through authority's login they can get notification when machine gets filled. Location of different machines are also included in the app. Proposed system uses a monitoring technique to monitors the machine. An IR sensor is added to notify the authorities when reverse vending machine is full so that they can locate the machine and collect the bottles.

Reverse Vending Machine for Plastic Bottle Recycling Architecture:

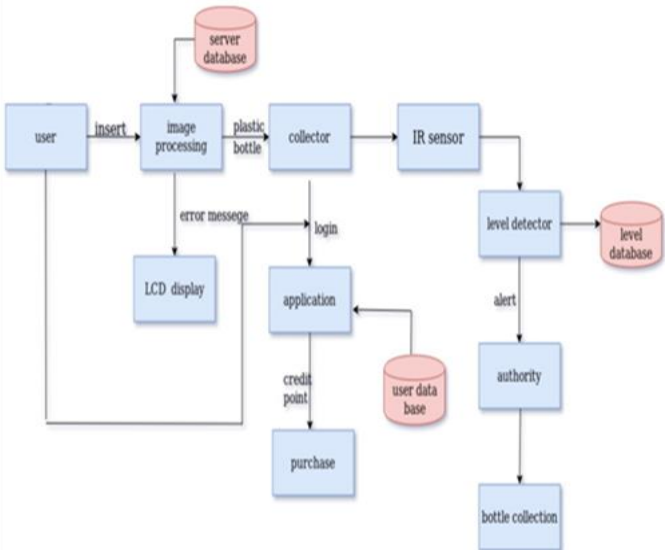


Fig. 1 Block Diagram of RVM

Fig. 1 shows the architecture of Reverse Vending Machine for recycling of Plastic Bottles. The working of machine begins with receiving the input, which is the bottle. Image processing is used to determine whether the inserted bottle is plastic or not. If the machine detects a plastic bottle, machine accepts it. The user can login to the machine through his/her unique password, credit point is calculated correspondingly and the value is stored in the database. If the machine detects a non- plastic bottle it rejects it and shows an error message in LCD display. User can view the credit points from the app and use the availed promo code for purchasing. When the machine gets filled with bottles an IR Sensor detects this and send notification to authorities through the app. This helps them to locate the reverse vending machine and collect the bottles.

Flow Chart of Reverse Vending Machine for Recycling Plastic Bottles:

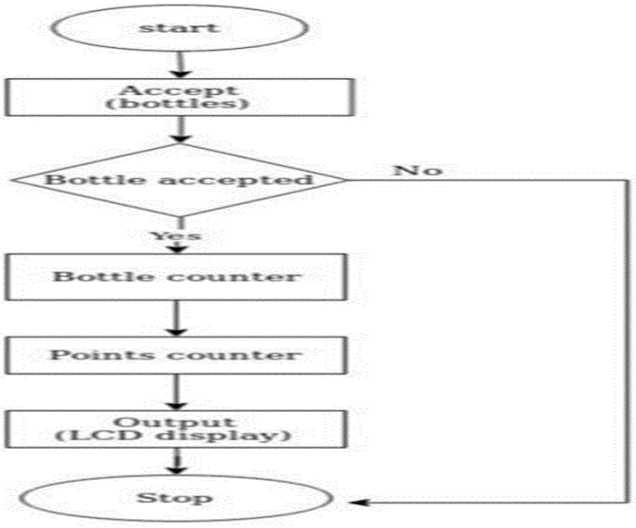


Fig.2 Flow chart of credit counting of RVM

IV. IMPLEMENTATION

The design of proposed reverse vending machine is constructed by the fulfillment of certain criteria:

1. Reliability

The machine must be able to work with minimum supervision. It must be able to work within 24 hours without any fail. All the components used in the design of machines should work properly according to the designated task.

2. Accuracy

The machine must be able to differentiate plastic bottles from other types of bottles and reject the non-plastic bottles. Image processing is used for this detection. The adding and subtraction of credit points for the insertion of plastic bottles must also be accurate. Credit points must be added to a user's account every time a deposited plastic bottle is accepted, and exact amount of credit points must be deducted from the user's account every time a purchase is made.

3. Response Time

The machine must be able to complete operation fast. Transaction time should be minimum for the user. The machine should show fast collection of data and execution of commands.

4. Efficiency

The machine must accept all types of plastic bottles irrespective of its size, shape and color. The machine should also reject all bottles that are not plastic.

5. Functionality

The machine must be able to function and complete process of operation without fail starting with the detection of plastic bottle up to using credit for purchasing.

Hardware Implementation:

A Prototype of the design was implemented to check the working of the simulation and synthesis. The prototype takes input from the user, records the type of input and displays the output in the LCD. The depositor presses push button for entering his unique password before inserting the bottles and then presses a "Done Button" at the end. The LCD output is updated with the number of inputs and reward points, every time a new depositor uses the machine.

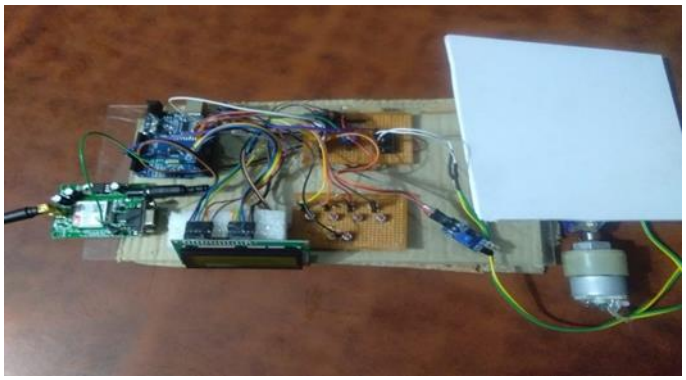


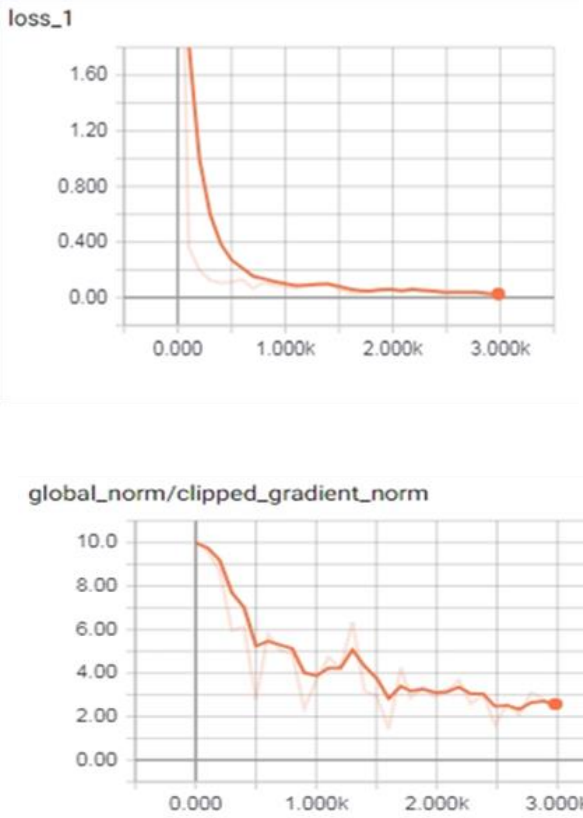
Fig 3 The prototype

Machine Construction:

The proposed design has push buttons for entering password of user. One push button "done button" is used when all the bottles from a user is placed into the machine. There is also a LCD placed on the design which displays the final credit points the user will receive. The bottles are placed at the hole on the top and if the machine detects it as plastic the trap door opens else it remains closed, indicating that it is not plastic and machine will not accept it.

V. RESULT

The system is trained using Tensorflow model. The model is used for plastic bottle detection (object detection) in Google Colab using custom dataset and it is found to be very efficient in plastic bottle detection. The dataset is created with LabelImg and is trained.



Graph 1 Tensorboard charts resulting from training process

The inlet of the reverse vending machine accepts the plastic bottles. All other bottles are rejected and an error message is displayed in LCD display. Depositor's name and credit points are displayed in the screen once the bottles are accepted by the machine

Type of input	Image processing Result	Credit points
Miranda bottle	Accepted	10
Coco-cola bottle	Accepted	10
Pepsi bottle	Accepted	10
Glass bottle	Rejected	0
Stainless steel bottle	Rejected	0
Aluminium bottle	Rejected	0
Copper bottle	Rejected	0

Table 1: acceptance of bottles by reverse vending machine

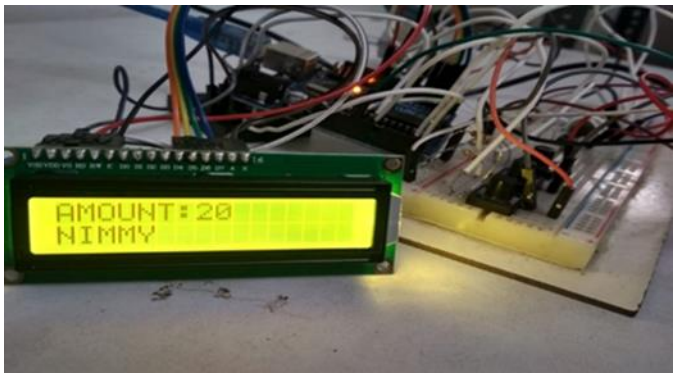


Fig 4 LCD display of user

The application of reverse vending machine has login for both user and authority. Users can view their credit points and use this points for online shopping whereas authorities will receive the notification from the machine when it is filled.

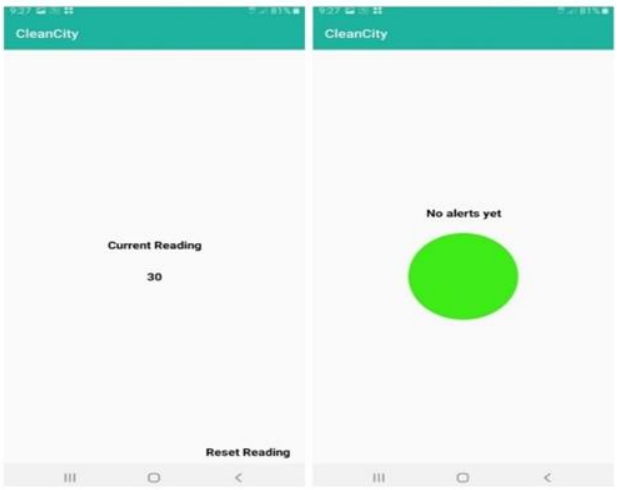


Fig 5 User credit points and authority alert

VI. CONCLUSION

In this paper a prototype of Reverse Vending Machine for Recycling Plastic Bottles is successfully generated and the depositor gets the credit according to the number of bottles deposited. Image processing was used for the detection of plastic bottles. Inlet of machine opens only when the machine detects plastic bottle else it remains closed. Once the depositor completes depositing the bottles he/she receives credit points accordingly. Depositor receives a promo code accordingly, that can be used for online shopping. When the machine is filled with plastic bottles alert message is send to the authorities through the app for collecting plastic bottles. Collected bottles are sent to the recycling center for recycling

VII. FUTURE WORK

There is large scope of research and improvement for Reverse Vending Machine. However in developing countries, Reverse Vending Machine (RVM) are not very common because of their high implementation and maintenance cost. They are not affordable and hence are not implemented in most of the countries. This project should work as a proof for a low cost RVM in such cases. The remaining problems and scopes of this work are:

1. Improved detection accuracy
2. Simpler user identification method
3. Can accept glass bottles
4. Can implement ticket vending in return of plastic bottles
5. Can interlink online bank accounts for funds transfer
6. Can issue Cards (like debit cards)
7. Solar energy can be used for power supply
8. Can be used by large number of people

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