Smart bin for easy waste sorting

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Figure 1: The prototype of the smart bin, using a laptop webcam

INTRODUCTION

The Smart Bin is a garbage bin with multiple compartments, each for a different kind of waste. It is important to properly sort waste, in order to maximize the recycling of it. If waste is not sorted properly, it can end up in a landfill instead of being recycled. Unfortunately, this is often still the case. At least 75% of American household waste could be recycled, but in 2017 only 35% was recycled with the rest of the waste going to landfills [1]. Improper sorting results in more waste, and in some cases can even be dangerous.

The Smart Bin is aimed to maximize the waste sorting, by using machine learning to detect the waste and allow the user to sort it properly. By scanning the waste, it can detect what material it is, and open the right compartment for the user to dispose it in. Furthermore, it allows for tracking what kind of waste is produced in the household, this information can help the household to use more recyclable packaging.

It is aimed to be used in any household where people struggle with their waste-sorting. Furthermore, it can also be used in office environments, with an ability to send an alert when a compartment is full. Anyone who finds it difficult to properly sort waste, can benefit from using this product.

PRODUCT DESCRIPTION

The product can be considered an intelligent, interactive product. It’s a physical product using Machine Learning to achieve something which can’t “simply” be programmed. Furthermore, it supports the user in an intuitive way.

Intelligence

The sensor used is a camera. The machine learning classifier uses the HSV color format, so the Hue (color), Saturation and Value (brightness) are all separate inputs for this model. Realistically, a final product could use a range of different sensors to detect the material, or use a deep-learning model with the camera for continuous learning. But for now, the learning problem can be defined like this:

$$g(x) = Y$$

$$x = \begin{bmatrix} Color \\ Saturation \\ Brightness \end{bmatrix}$$

$Y = \text{Cardboard/Plastic/Drinkcarton/Chemical/Nothing}$

$g(x) = \text{the classifier}$

The model was trained by showing the four different kinds of waste to the camera in multiple different locations, with different lighting conditions and environments. By collecting the data in different environments, the model would place more emphasis om the properties of the item being shown, rather than the surroundings.

Therefor, the skill the product learned from the data, is predicting the material shown to the camera based on its visual properties. Realistically, if humans can recognize a material only by looking at it, a machine learning model should be able to do this as well. This is not programmable, because there are too many visual properties specific for each material to manually create rules to classify them. Even if someone were to try, some small properties will almost certainly be missed or overlooked.

Tangibility

The product looks like a trash bin with multiple compartments. How this trash bin looks, is up to the visual design of it. It can be round or squared, tall or short, curvy or straight. The lid can be multiple separate lids each opening separately, or a rotational opening rotating to the right compartment. However the trash bin may look, it will be used the same way: The user will show / scan the waste item, wait a short time for the scanning and processing to be completed, and dispose the item in the compartment which opens. Optionally, they might check if the compartment is correct, and try again if the item is wrongly classified.

Interactivity

The product consist of 2 parts: The bin itself, and the scanning feedback (Figure 1). The user first interacts with the scanning screen, which shows the view from the camera, the instant scanning result and the result after processing. By looking at the camera view, the user can make sure their item is fully in the frame of the camera and the instant result shown might already tell them if it's going well. After a few seconds, the final result changes, after which the bin opens up.

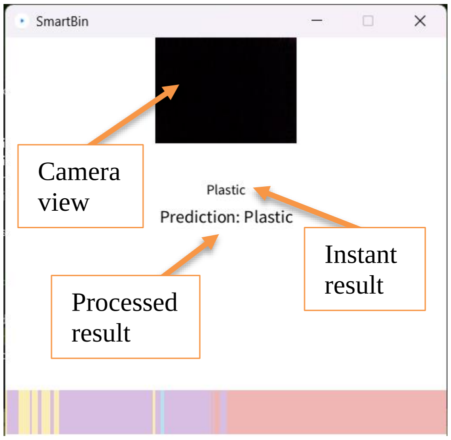

Figure 2: Screen with scanning information

While the screen already gives the immediate feedback, the most important feedback is given by the garbage bin itself: The right compartment will open up. This tells the user that something happened because of them showing their waste item to the product.

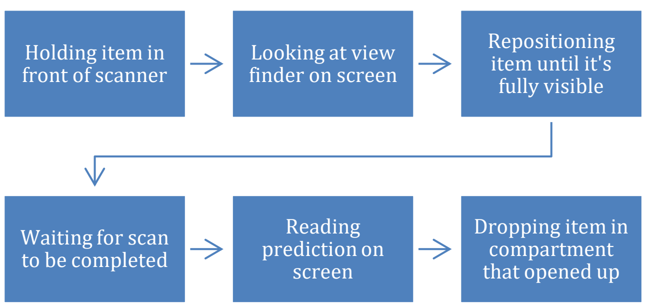

Figure 3: Interaction flow

PRODUCT REALIZATION / PROTOTYPING

Hardware

The prototype of the product is made from a recycled shoe box, of which a circle has been cut out from the lid. In this circle, another cutout was made as the opening of the bin. A mount was made for a servomotor, positioning its axile in the center of the box at the right height. The circular cutout was mounted on the servomotor, allowing it to spin. A Teensy 3.2 microcontroller was placed in the box to drive the motor.

To make sure the motor spins to the right location, the prediction is sent as a string through the Serial port to the Teensy. When the Teensy receives something from the Serial port, it will read it as a string and compare it to the strings it knows. If it matches, it will send a rotation command to the servomotor, the amount of degrees are also stored on the Teensy. After 7 seconds, it moves back to default position.

Data acquisition

For this prototype, the sensor is not located in the "smart bin" itself, instead the webcam of a laptop was used and directly opened in Processing. This webcam image is processed in HSV format using OpenCV, which means it reads the Hue, Saturation and Value channels separately. After this, the prediction is sent to the Teensy board as a string. This string is read on the Teensy board, making the servomotor move to the right location.

The model was trained by showing each item of waste to the camera, while also recording a "nothing" state (with nothing being shown). During the recording, the items were moved around, moved closer and further away from the camera. Also, the materials were changed in shape, by folding or squeezing it (if that's is possible with the material).

Learning algorithm

The prototype uses a Linear Support Vector Classification algorithm, which is trained using training data collected. In order to improve the results, the data was collected multiple times, in multiple different locations with different environmental conditions (lighting, background, etc). This was done to limit the sensitivity to noise as much as possible. In the end, the training data set contains more than 1000 data entries.

Evaluation

In some situations, the system still works quite poorly. This is mostly in challenging lighting conditions, like artificial lighting shining into the camera. This could be because the model wasn't trained with difficult lighting, but also because when light reflects in the camera it might see more of a certain color. In regular daylight conditions however, it works pretty well.

Too much time was spent on collecting as good training data as possible, resulting in not enough time to collect a dataset with test data and testing the model with it. However, if the reliability would not be good enough, it would not work as well in real life. Therefor, it can be stated that, if the lighting conditions are okay, the classifier performs pretty well.

LIMITATIONS / FUTURE WORK

One obvious limitation of this prototype in specific is that it is only trained with these four items of waste, and nothing else. These specific items were used because they all have a different color, to make the recognition easier. While this wouldn't recognize the material of any different item it wasn't trained with, that does not mean it wouldn't work if it would be trained with a very large sample of waste items. Therefor, in order to make a properly working machine learning model, the training data should be much more. Furthermore, using deep learning would be a good idea, because it can keep learning from any new materials shown to it. Additionally, if using a camera only is not enough to predict the material properly, it could be possible to use different kind of sensors to detect the material, although that might be (more) programmable.

REFERENCES

1. Greentumble. 2018. Why Is Waste Sorting Important When Recycling? *Greentumble*. Retrieved June 5, 2023 from https://greentumble.com/why-is-sorting-important-when-recycling.

Figure 4: Bin with lid removed, all waste materials inside, motor and electronics visible.