Smart Compost Bin

Automatic Measurement of Household Food Waste

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Abstract

Food waste continues to strain the global food supply even as millions suffer with food insecurity. A lack of effective food waste measurement solutions obstructs domain experts from guiding policy towards sustainable food resource management. We propose a system for measuring household food waste using an AI-enabled compost bin. Food waste identification can be framed as a computer vision task, however no public datasets of labeled post-consumer food items have been released to date. To power the development of computer vision models for food waste identification, we design a compost bin equipped with imaging sensors capable of capturing 2D, 3D, and thermal information about discarded food. This device encourages sustainable composting practices while building a novel dataset of commingled food waste images annotated with descriptive labels and segmentation masks. We design a volunteer-driven study to deploy fifty of these devices in households across the state of Oregon.

Introduction



Figure 1. Smart Compost Bin

Global food insecurity threatens vulnerable communities around the world. It is estimated that 828 million people suffered from chronic hunger in 2021. In the same year, 14% of edible food worldwide was wasted, with wealthy countries contributing disproportionately to the misuse [5]. To effectively manage this misappropriation of food resources, researchers and policymakers need high-quality information about food waste. Currently, there is no effective, scalable method for identifying and measuring food waste. Prior work has focused on asking residential and commercial consumers to manually track their food purchases and disposals, which is expensive, tedious, and prone to error [1]. Limited work on computer vision models for automatic food object recognition has produced methods for identifying edible consumer food. However, to date, there is no high-quality publicly available image dataset on post-consumer food refuse, preventing researchers from applying these computer vision methods to the task of food waste measurement.

We target three key outcomes towards automatic household food waste measurement:

1. We design and manufacture the Smart Compost Bin, a low-cost AI-enabled device which automatically collects image and sensor data for each disposed food item.
2. To produce the first annotated, public image dataset of post-consumer food, we will conduct a pilot study with fifty households to annotate images of food waste using our companion app.
3. We will use our dataset to train a computer vision model to automatically measure household food waste by segmenting disposed items from images of commingled food refuse.

We are recruiting participants for this study. If you are interested in volunteering to collect data on household food waste using the Smart Compost Bin or would like more information, please scan this QR code to fill out our interest survey.

Hardware Design

Our aim with the Smart Compost Bin is to produce a device equipped with a powerful array of sensors, enabling a rich multimodal dataset on post-consumer food, while remaining relatively inexpensive to produce. Towards this objective, we design our compost bin around a popular consumer-off-the-shelf microcontroller, the Raspberry Pi 5. To accelerate our deep learning models for image and audio recognition, we augment our microcontroller with a Google Coral TPU.



(a) Raspberry Pi 5 (b) Intel RealSense Camera (c) BME688 Gas Sensor (d) Load Cell Amplifier

(e) Google Coral TPU (f) Thermal Camera (g) USB DAC and Mic (h) C2 Load Cell

Figure 2. Microcontrollers and sensors used in the Smart Compost Bin

The structure of this device begins with the base scale, which houses the load cell measuring the mass of each food item. The compost bin's main body consists of an outer shell - which contains the microcontroller, and the inner shell - a polycarbonate dishwasher-safe trash receptacle used for easy compost disposal and cleanup. This then interfaces with the lid, which contains all of the imaging and environmental sensors protected behind a polycarbonate sheet. A combination of a rubber gasket seal and a carbon filtration system built into the lid help mitigate foul odors.

Detection Model

For automatic identification of food waste from 2D images, we use YOLOv8-seg - a deep convolutional neural network pretrained on the COCO dataset [2]. YOLO semantic segmentation models achieve real-time performance in mobile and embedded environments by processing the image in a single forward pass. We train YOLOv8 on three small, annotated food image datasets, to produce a pretrained model to later be fine-tuned on our post-consumer food waste dataset.

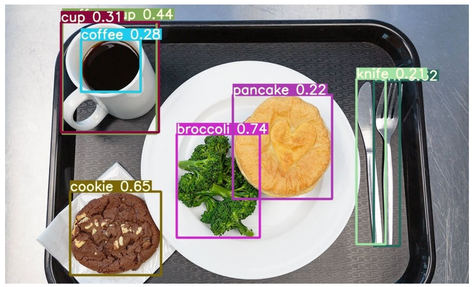


Figure 3. A demonstration of food object recognition, using a fine-tuned YOLOv8 image recognition model

Data Collection

We use an Intel RealSense camera to capture 2D stereoscopic image pairs and render a point cloud, providing spatial information to augment our object recognition model. An infrared camera enables thermal imaging; we hypothesize that the relative temperature difference of recently disposed waste may assist automatic segmentation. Additional sensors measure the total volatile organic compound emissions and weight of the waste, as well as ambient humidity and temperature.

Each time a user closes the lid of their compost bin, our device captures an image of the disposal and reads from auxiliary sensors. Using the Piper speech-to-text system, we prompt the user to verbally describe the waste item [3]. We automatically transcribe this audio description into an image label using a quantized implementation of Whisper optimized for edge inference [4]. The annotated image is then uploaded to our MongoDB instance running on OSU's Digital Research Infrastructure cluster. Once a study participant's device has uploaded a new waste entry, we push a request to the user's smartphone from our companion mobile app to request the user provide an image segmentation annotation. Our custom annotation platform allows users to draw a boundary around the labeled item in the image, which we convert to a segmentation map for model training.

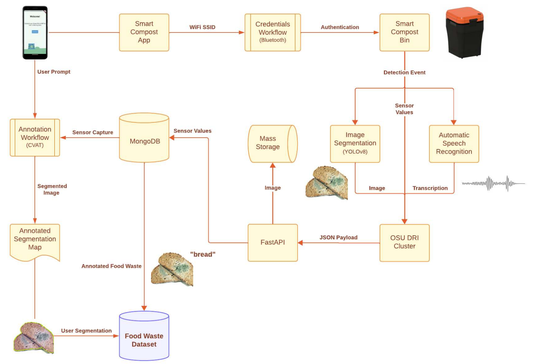


Figure 4. System architecture of our data processing pipeline

Discussion

Without effective data at every stage of the food distribution network, sustainable food resource management continues to be challenging. We present an end-to-end framework for measuring household food waste. Using a high-quality multimodal dataset of post-consumer food, annotated with descriptive labels and segmentation masks, we will develop an efficient semantic segmentation model for automatic food waste measurement. Such a model can be extended to track wasted food for commercial kitchens, healthcare and educational institutions, and food distributors.

Acknowledgements & References

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