Smart Compost Bin for Food Waste Measurement

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Introduction

Food waste constitutes an environmental and humanitarian crisis, threatening food security worldwide. An estimated 783 million people went hungry in 2022, while 19% of edible food - over 1.5 billion tons - of food was wasted, generating over $1 trillion in economic losses [1]. 60% of this waste is generated in the home, and yet there is no effective, scalable method for quantifying household food waste. Prior studies require users to maintain food waste journals, manually tracking each scrap of food. This process is tedious, expensive, and prone to user error. Meanwhile, a lack of high-quality food waste image datasets impedes the development of computer vision models to automate the task of food waste measurement.



Figure 1. The smart compost bin, a household food waste measurement device

We target three goals 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 of disposed food.
2. To produce the first annotated, public dataset of post-consumer food images, we will conduct a pilot study with fifty households to annotate images of food waste using our smartphone app annotation platform.
3. We will use our dataset to train a computer vision model to automatically measure household food waste.

We are recruiting participants for this study. If you are interested in volunteering to use the Smart Compost Bin, please scan this QR code to fill out our interest survey.

Hardware Design



(a) Raspberry Pi 5 (b) Stereo Camera (c) Gas Sensor (d) Amplifier

(e) PCB (f) Thermal Camera (g) Audio & Mic (h) C2 Load Cell

Figure 3. Sensors and microcontrollers used in the smart compost bin

Our goal is to design a low-cost data collection device to enable the production of a rich multimodal dataset on post-consumer food. We design our device around popular commercial-off-the-shelf sensors and 3D-printed structures to reduce cost and streamline production. The base of the device contains a load cell, used for weighing waste items, with cameras and sensors embedded in the lid. The waste receptacle contains a removable, dishwasher-safe polycarbonate bin for easy, sanitary disposal. The lid features a carbon filtration system to mitigate odors.

Data Collection

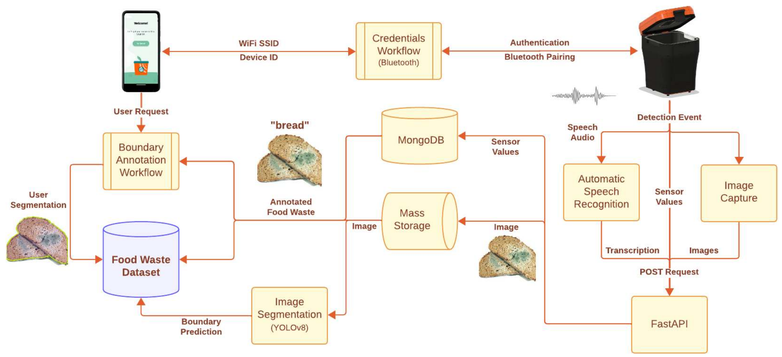


Figure 4. Data collection and annotation pipeline for images from compost bin

Each time a user disposes of a food item, the bin will first record an image of the inside of the compost bin, along with a 3D depth map, thermal imaging, and tVOC measurements. The bin will audibly prompt the user to describe the disposed item. An onboard microphone records the user's speech, and this annotation is transcribed to an image label using Whisper, an automatic speech recognition model.

Detailed image annotations are collected through our companion mobile app. Our mobile app connects to a MongoDB database server to retrieve the user's latest disposal images. Users are tasked to provide a drawn outline and categorical label of each food item in the image. This combination of coarse-grained open-vocabulary labels and detailed image segmentation annotations will enable multi-stage fine-tuning of multimodal vision-language models for food waste recognition.

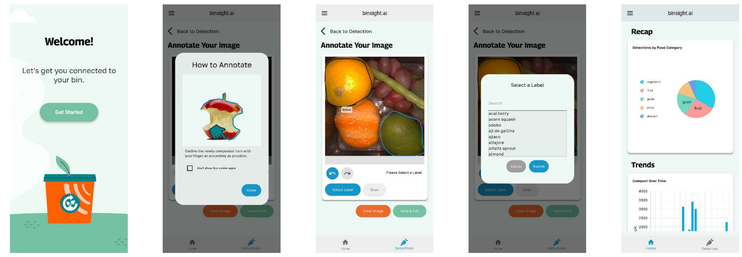


Figure 5. Companion mobile app for data annotation and device management

Food Waste Recognition

Recent advancements in multimodal language models (MLLMs) have enabled open-vocabulary image classification. As there are a broad range of descriptors for food items with significant cultural variance, we aim to develop a MLLM for open-vocabulary classification of food compost images. We use InternV2.5 [2], a vision-language model using a vision transformer (ViT) for image encoding. Preliminary experiments find this model achieves a zero-shot top-5 accuracy score of 0.533 on FoodX-251, a dataset of pre-consumer food images.

Image	VLM Description
	`The image shows a few food items, including: 1. **Onions**: There are several onion halves, which appear to be red onions. 2. **Bell Pepper**: There is a piece of red bell pepper, visible among the onions. 3. **Broccoli**: A piece of broccoli is also in the image.`
	`The image shows a variety of vegetables. There are two whole **onions** with their roots still attached. Additionally, there are **green onions** or scallions with their white parts and green stalks. There are also some **leafy greens** visible in the background.`
	`The image shows a few food items, including:1. **Green Beans**: Long, green beans are prominently visible. 2. **Squash**: There appears to be a type of squash, possibly acorn squash, with its characteristic shape and texture. 3. **Potatoes**: Some round, brownish items that look like potatoes.`

Table 1. Descriptions of compost images, generated from `InternV2.5` vision-language model

Discussion

We present a framework for household food waste measurement focused on ease of use and scalability. Using this device, our forthcoming human annotation study aims to produce the first public dataset of labeled food waste images, enabling future computer vision models for automatic food waste measurement. More information is available in our CoFI 2024 publication [3].

References

[1] United Nations Environment Programme. *Food Waste Index Report 2024. Think Eat Save: Tracking Progress to Halve Global Food Waste*. March 2024.

[2] Zhe Chen and et. al. Expanding performance boundaries of open-source multimodal models with model, data, and test-time scaling, 2025.

[3] Aidan J. Beery et al. Smart compost bin for measurement of consumer food waste. In *Companion Proceedings of the 26th International Conference on Multimodal Interaction*, ICMI Companion '24, page 100–107. Association for Computing Machinery, November 2024.