

Real-Time Waste Classification and Interactive Feedback on Embedded Edge Devices

Team 13: Yuan Jiang (yj2848), Lingxi Zhang (lz2991), Hongrui Huang (hh3084)





Motivation & Background

Global Issue

30% recyclables mis-sorted to landfill

Public Confusion

Unclear waste categories for consumers

Solution Need

Hands-free, accessible guidance at disposal



Problem Statement

Goal

Real-time on-device
recognition of 10 waste types

GPT API

label → prompt → answer

Eco Tips

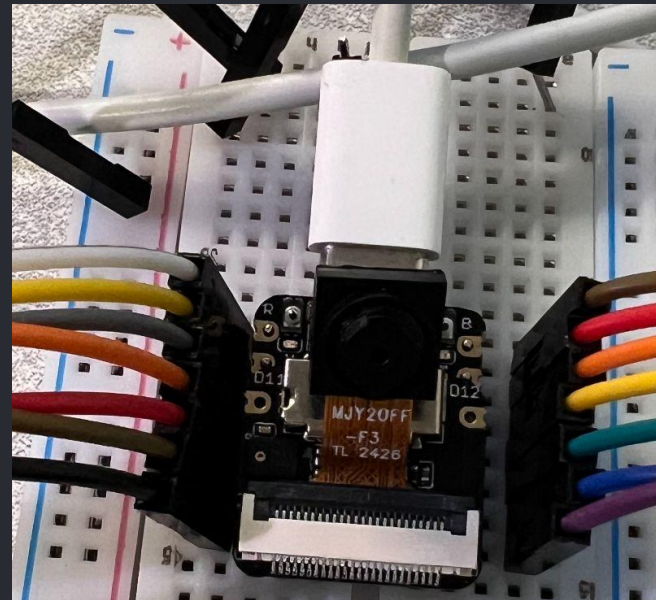
Immediate, actionable
environmental advice

Hardware & Software Stack

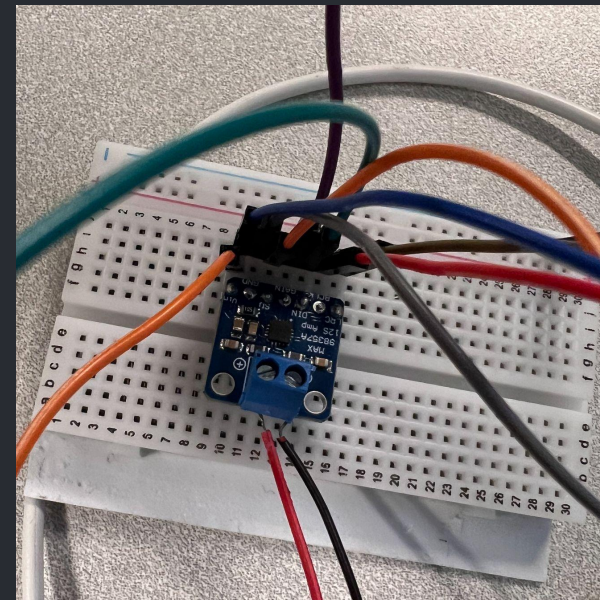
Hardware



Seed Studio Round
Display for XIAO



XIAO ESP32-S3 MCU
with Camera



I2S Amplifer



4Ω 3W mini speaker

Software

Arduino

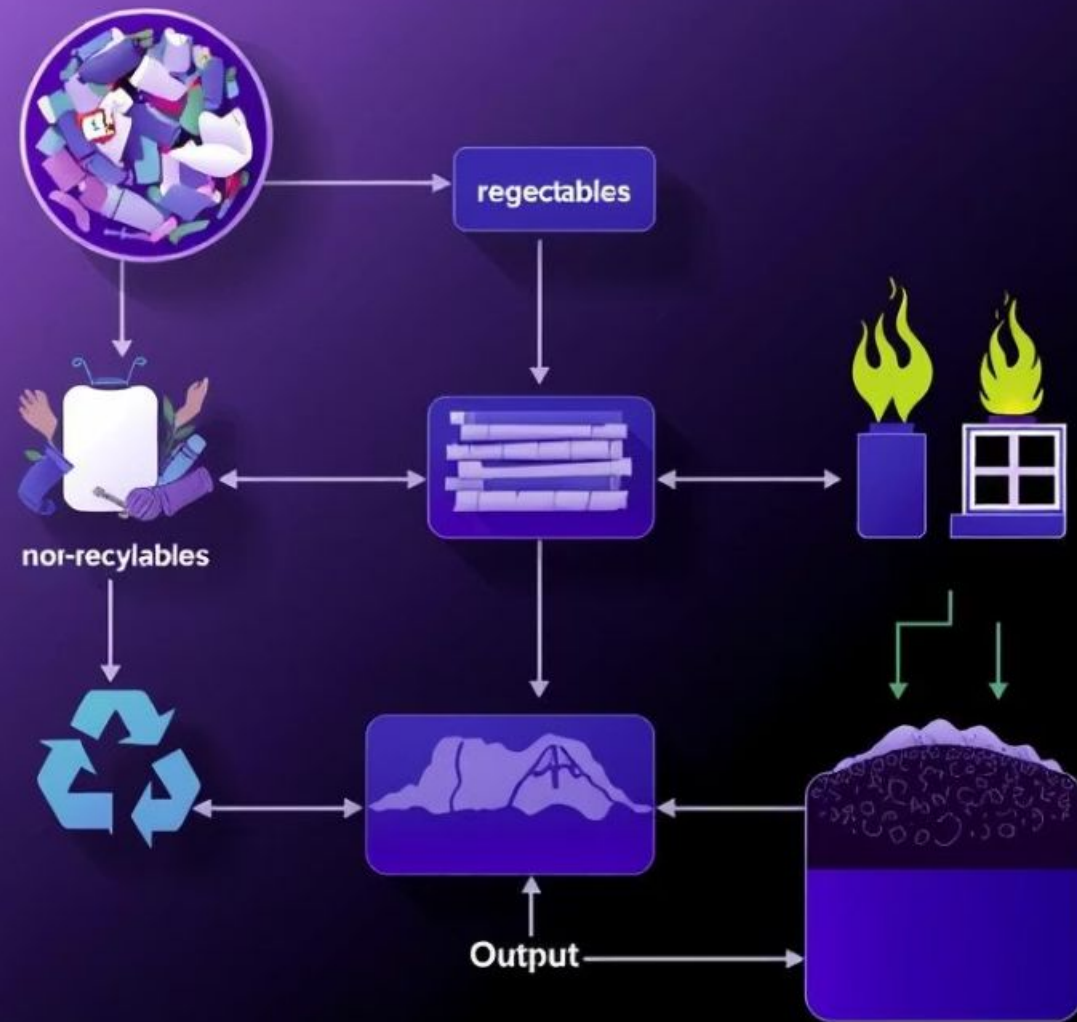


Edge Impulse



GPT3.5 API
in Python

Waste classification



System Pipeline

- 1 Capture Object
- 2 Send Label to GPT
- 3 Receive Eco Tips
- 4 Display & TTS Playback



Module Details

Classes

10 waste types recognized

Dataset

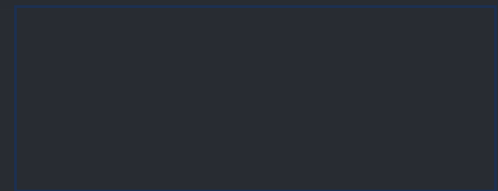
14275+ labeled images

Model











INT8 quantized CNN, 250 KB

Performance

707 ms inference, 61.8% accuracy




Data-Training

>  white-glass	>  metal
>  trash	>  clothes
>  shoes	>  cardboard
>  plastic	>  biological
>  paper	>  battery

10 Classes


DATA COLLECTED

14,275 items



TRAIN / TEST SPLIT

80% / 20%



Dataset

 ACCURACY

61.8%

 LOSS

1.20

Confusion matrix (validation set)

	BATTE	BIOLO	CARDE	CLOTH	GLASS	METAL	PAPER	PLAST	SHOES	TRASH
BATTE	64.7%	1.3%	0%	10%	0.7%	6.7%	2.7%	6%	5.3%	2.7%
BIOLO	0.6%	47.6%	0%	24.7%	2.4%	2.4%	2.4%	12.4%	6.5%	1.2%
CARDB	3.6%	0.7%	18.1%	23.9%	19.6%	2.2%	4.3%	14.5%	5.8%	7.2%
CLOTH	0.2%	1.2%	0.4%	94.0%	1.3%	0.4%	0.4%	1.5%	0.7%	0%
GLASS	0.8%	0.8%	0%	12.4%	47.1%	5.0%	0.8%	24.0%	0%	9.1%
METAL	5.1%	2.2%	0%	18.1%	18.1%	23.9%	4.3%	20.3%	5.1%	2.9%
PAPER	6.0%	2.4%	1.2%	20.2%	6.0%	2.4%	42.9%	13.1%	2.4%	3.6%
PLASTI	2.3%	2.3%	0%	26.2%	14.6%	3.8%	1.5%	43.1%	3.1%	3.1%
SHOES	1.9%	5.8%	0%	22.9%	2.6%	1.6%	2.6%	5.8%	56.5%	0.3%
TRASH	5.1%	1.7%	1.7%	14.5%	35.9%	0%	0%	19.7%	1.7%	19.7%
F1 SCC	0.67	0.55	0.29	0.82	0.35	0.31	0.53	0.30	0.65	0.25

Metrics (validation set)

METRIC	VALUE
Area under ROC Curve ?	0.90
Weighted average Precision ?	0.64
Weighted average Recall ?	0.62
Weighted average F1 score ?	0.60

Training result (Edge Impulse)

GPT API Integration & Output

Prompts

```
prompt = (  
    f"The item is '{label}' with {confidence*100:.1f}% confidence. "  
    "In one concise sentence (no more than 20 words),"  
    " say whether it's recyclable, hazardous, or other, "  
    "and briefly describe how to dispose of it."  
)
```

Latency & Output

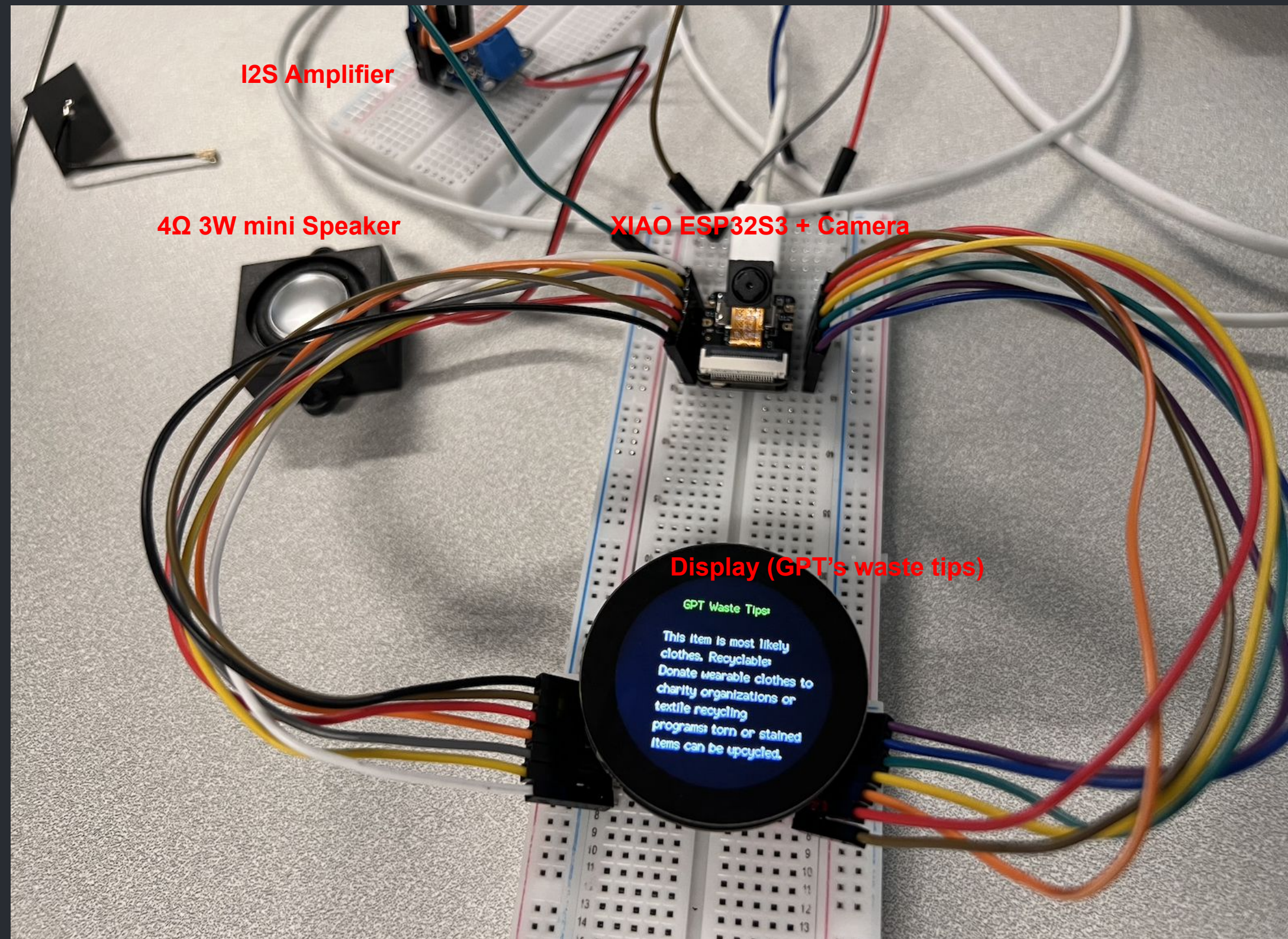
- ~750 ms round-trip
- Text on Display + TTS voice

Received: {'label': 'clothes', 'confidence': 0.41797}

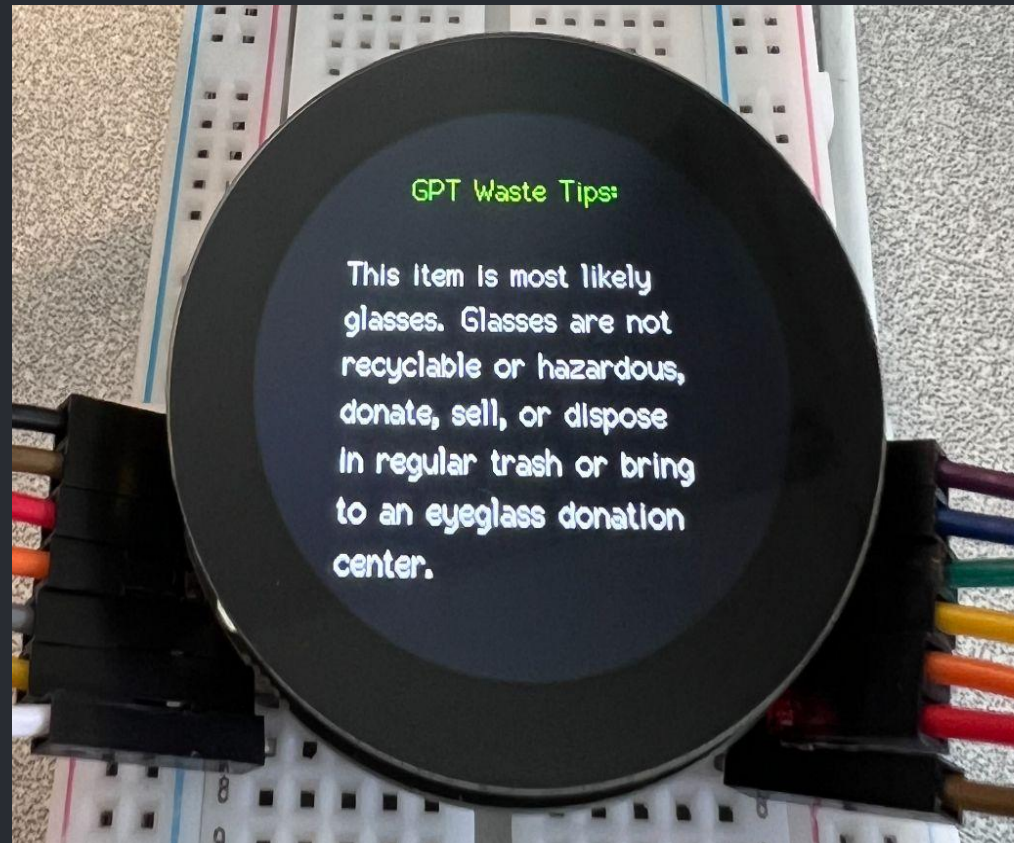
Reusing previous GPT response.

GPT says: This item is most likely clothes. Recyclable: Donate wearable clothes to charity organizations or textile recycling programs; torn or stained items can be upcycled.

Overall Structure



Results



15s

GPT reply time period

1s

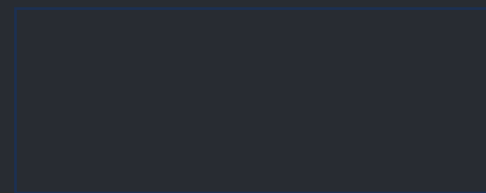
Camera Detection Latency

1.1s

End-to-End Q&A

DEMO

[\[YouTube\]Smart_Waste_Advisor](#)





Conclusion & Q&A

Project Complete

Real-time, voice-interactive
waste advisor

Performance

High accuracy, fast
responses, strong approval

Next Steps

Continue to improve accuracy, ready for pilot deployment in
public places