



# An Intelligent Scanning Vehicle for Waste Collection Monitoring

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Fight climate change by reducing greenhouse gas emissions

- Many initiatives:  
UN Agenda 2030 for Sustainable Development,  
European Green Deal, etc.
- Waste management causes considerable emissions
- Goal: **Increase recycling rates & avoid waste**



Our innovative garbage truck:

- Assesses composition of residential waste in real-time
- Delivers individual feedback to improve recycling rates



longer lasting  
products that can be  
repaired, recycled and  
re-used

[EU Green Deal]



cleaner energy and  
cutting-edge clean  
technological  
innovation

# Avoid Waste to Increase Recycling Quotes



# Awareness Reduces Waste Contamination

4

RGB Input



CNN Prediction



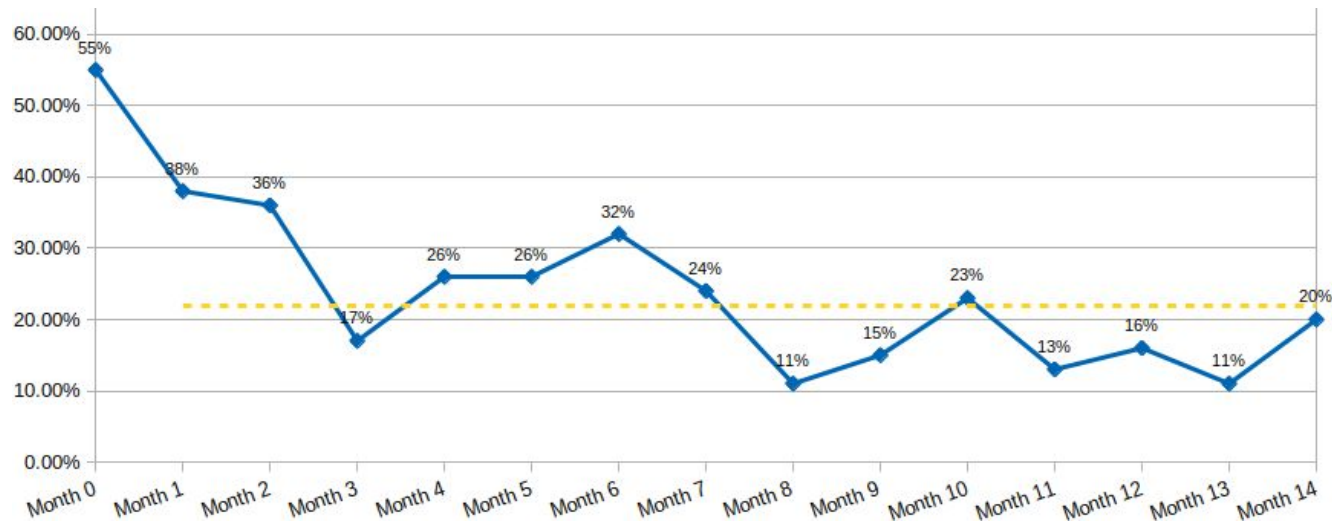
Ground Truth



Evaluation period of 14 months with 40 households

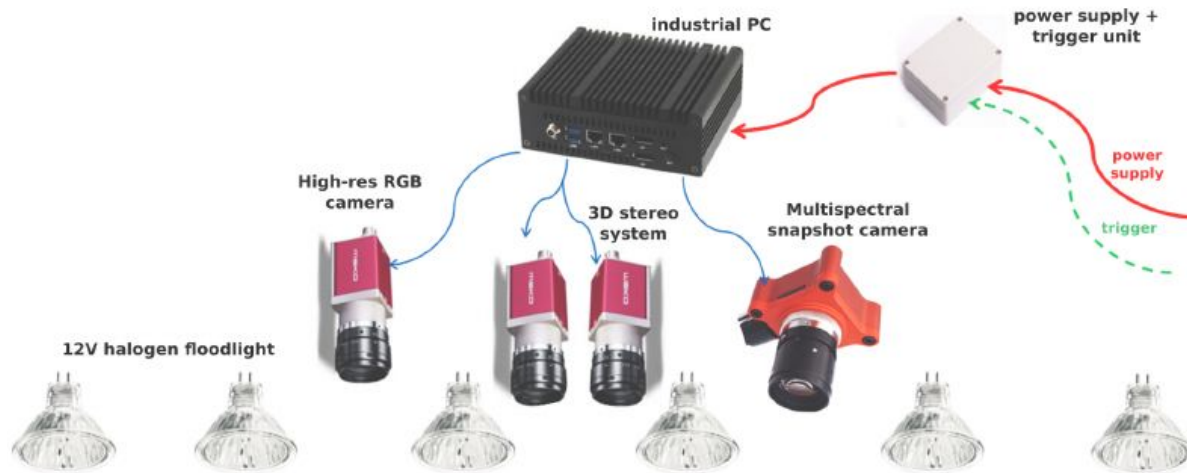
Due to immediate feedback, households improved waste separation rates by ~30%

Proportion of **contaminants** in residual waste:





- Modern garbage truck equipped with complex hardware.
  - Multiple modalities: **rgb**, **stereo** and **multispectral** cameras.
  - **GSM module** for localization
  - Rugged and sealed **metal casing**.
- SOTA image recognition software deployed in the cloud.
  - **Secure** connection for safe data transfer.
  - **Scalable** cloud orchestration depending on workload.
  - **AI** model with human-like performance.
- Direct feedback to the households for change in behavior.
  - **App** or **SMS** notifications.
  - **Informative** text about the waste distribution along with hints on how to improve.
  - **Long-time monitoring** for improved community waste management.



Custom-designed hardware system with external trigger.

- **RGB camera:** High resolution rgb camera for capturing details in shape and appearance.
- **Multispectral camera:** Multi-channel camera in visible spectrum and near-infrared for capturing information in extended wavelength ranges.
- **Stero system:** Two grayscale cameras for depth perception.
- **Halogen floodlights:** For uniform illumination across the recorded area.
- **Industrial PC:** Recording unit capable to work in vibrating and temperature-critic environments.



Dataset of 3000+ labeled images collected over 14 months.

- Manual segmentation labels collected for **3107 images** (2908 train, 60 val, 139 test).
- **Collection over more than 14 months** to incorporate seasonal fluctuations.
- **6 dominant waste categories:** *organic, garbage\_bag, paper, PET, plastic* and *residual*.

class	img count	img area (mean $\pm$ std) [%]	img area range [%]
<i>background</i>	2908/2908	71.67 $\pm$ 9.77	0.61 – 93.86
<i>ignore</i>	1882/2908	2.68 $\pm$ 5.65	0.00 – 67.06
<i>organic</i>	956/2908	1.79 $\pm$ 4.27	0.00 – 39.39
<i>garbage_bag</i>	2364/2908	6.92 $\pm$ 5.42	0.00 – 49.07
<i>paper</i>	2449/2908	2.04 $\pm$ 2.39	0.00 – 18.85
<i>pet</i>	1787/2908	0.62 $\pm$ 0.77	0.00 – 9.67
<i>plastic</i>	2844/2908	6.57 $\pm$ 5.33	0.00 – 33.91
<i>residual</i>	2908/2908	11.85 $\pm$ 5.29	5.02 – 58.13

a) train

<i>background</i>	139/139	68.85 $\pm$ 10.21	39.03 – 100.00
<i>ignore</i>	72/139	1.78 $\pm$ 2.16	0.00 – 10.21
<i>organic</i>	96/139	19.84 $\pm$ 16.05	0.03 – 58.46
<i>garbage_bag</i>	93/139	6.39 $\pm$ 5.31	0.05 – 23.51
<i>paper</i>	82/139	3.10 $\pm$ 2.83	0.04 – 13.99
<i>pet</i>	59/139	0.87 $\pm$ 0.89	0.08 – 4.77
<i>plastic</i>	90/139	6.46 $\pm$ 5.08	0.05 – 32.46
<i>residual</i>	112/139	7.30 $\pm$ 6.47	0.00 – 35.78

b) test

## Accuracy & IoU on the test set.

w: weighted by covered area (instead of averaging over all classes)

class	ACC	IOU
<i>background</i>	98.35 ± 3.62	96.03 ± 5.15
<i>organic</i>	56.86 ± 35.91	53.24 ± 33.64
<i>garbage_bag</i>	68.42 ± 28.26	54.66 ± 26.24
<i>paper</i>	50.36 ± 28.77	40.13 ± 24.69
<i>pet</i>	35.61 ± 25.80	27.56 ± 20.60
<i>plastic</i>	49.97 ± 22.05	38.81 ± 18.80
<i>residual</i>	67.26 ± 26.01	40.32 ± 22.71
<b>average</b>	<b>53.36 ± 26.55</b>	<b>43.84 ± 25.41</b>
<b>average<sup>w</sup></b>	<b>82.77 ± 14.06</b>	<b>77.22 ± 13.93</b>

## Proportion of contaminants in residual waste:

