Università degli Studi di Padova

IT+Robotics


Deep Learning


Industrial Applications


Green Transition

AI and Robotics for waste sorting and recycling

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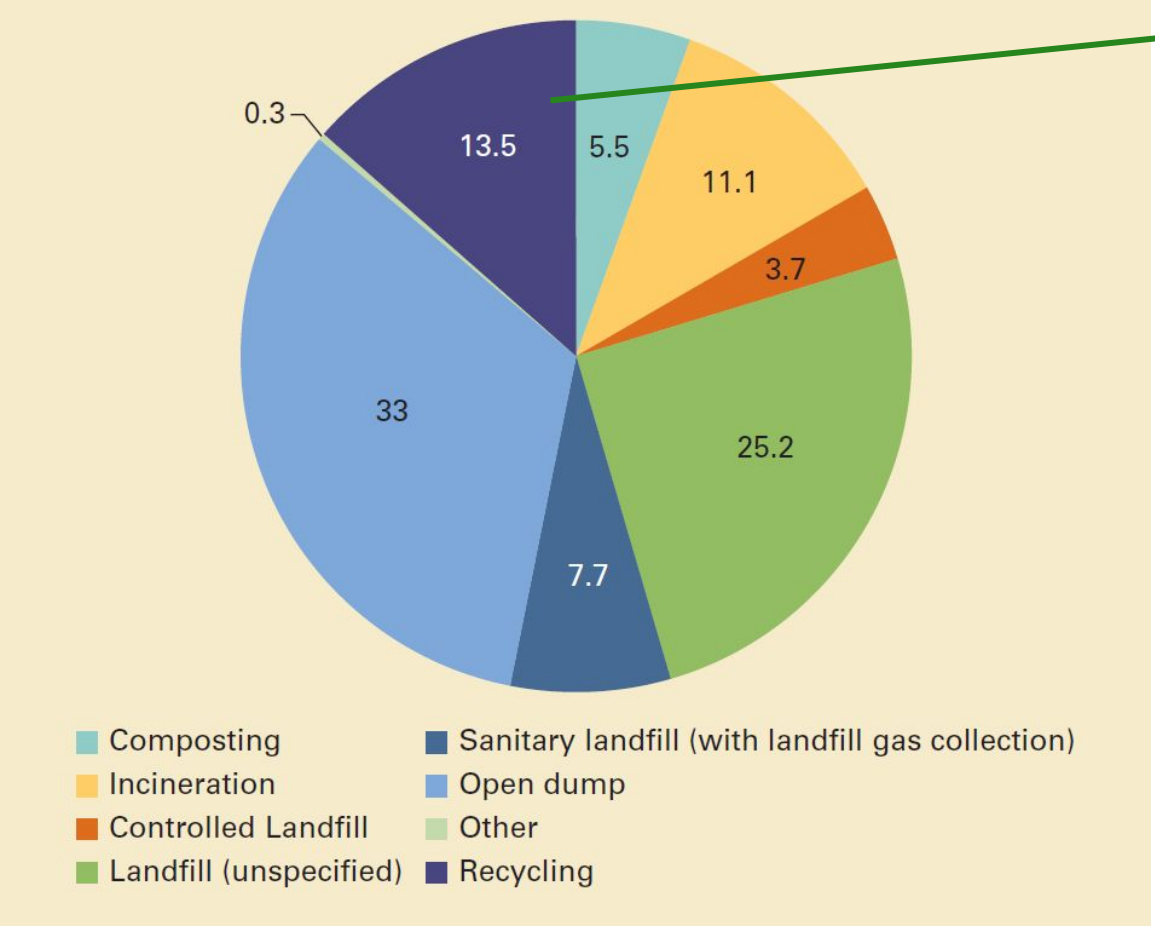
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Intelligent Autonomous Systems Lab

Waste Management: a resource?

Global treatment and disposal of waste (percent)

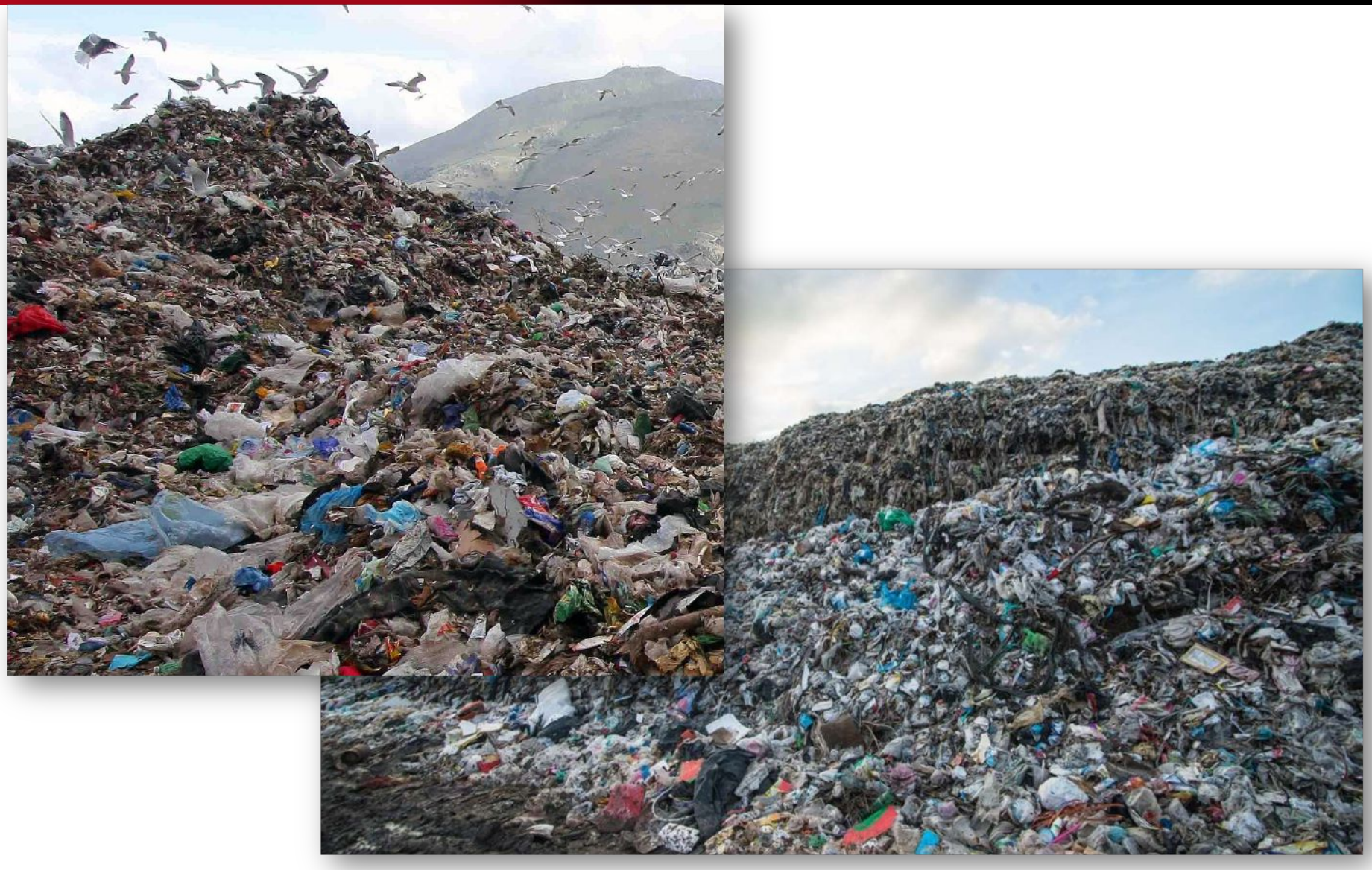


Only 13.5% of waste are recycled.

Recycling needs **sorting**.

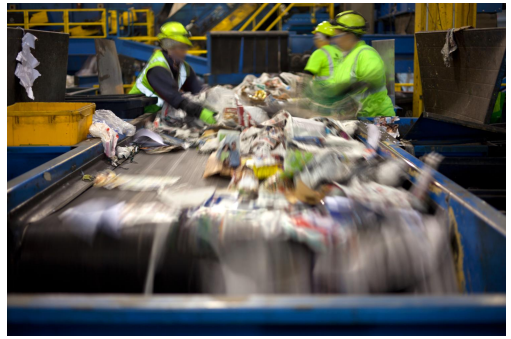
https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

The problem statement



The problem statement

Current Approaches in Sorting Plants



Mechanic Sorting exploits physical properties (size, density, ecc..)

- Very rough
- No material discrimination
- Handle high volumes

Opto-Pneumatic Sorting exploits optical properties and air jets

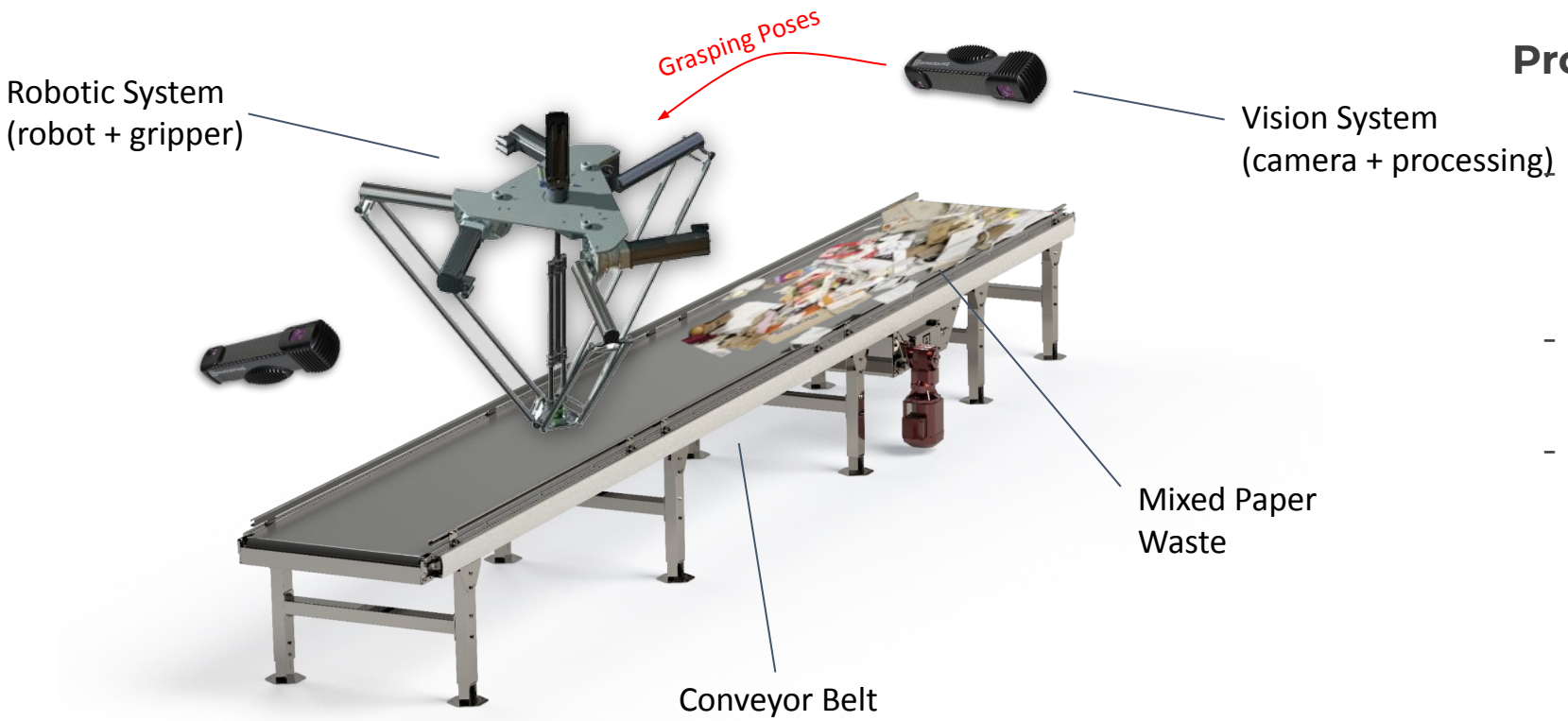
- Material discrimination
- Fast processing
- Imprecise object handling, especially in clutters

Manual Sorting

- Very flexible
- Handling of complex objects and clutters
- Low processing speed
- Unhealthy work conditions

Increasing Intelligence

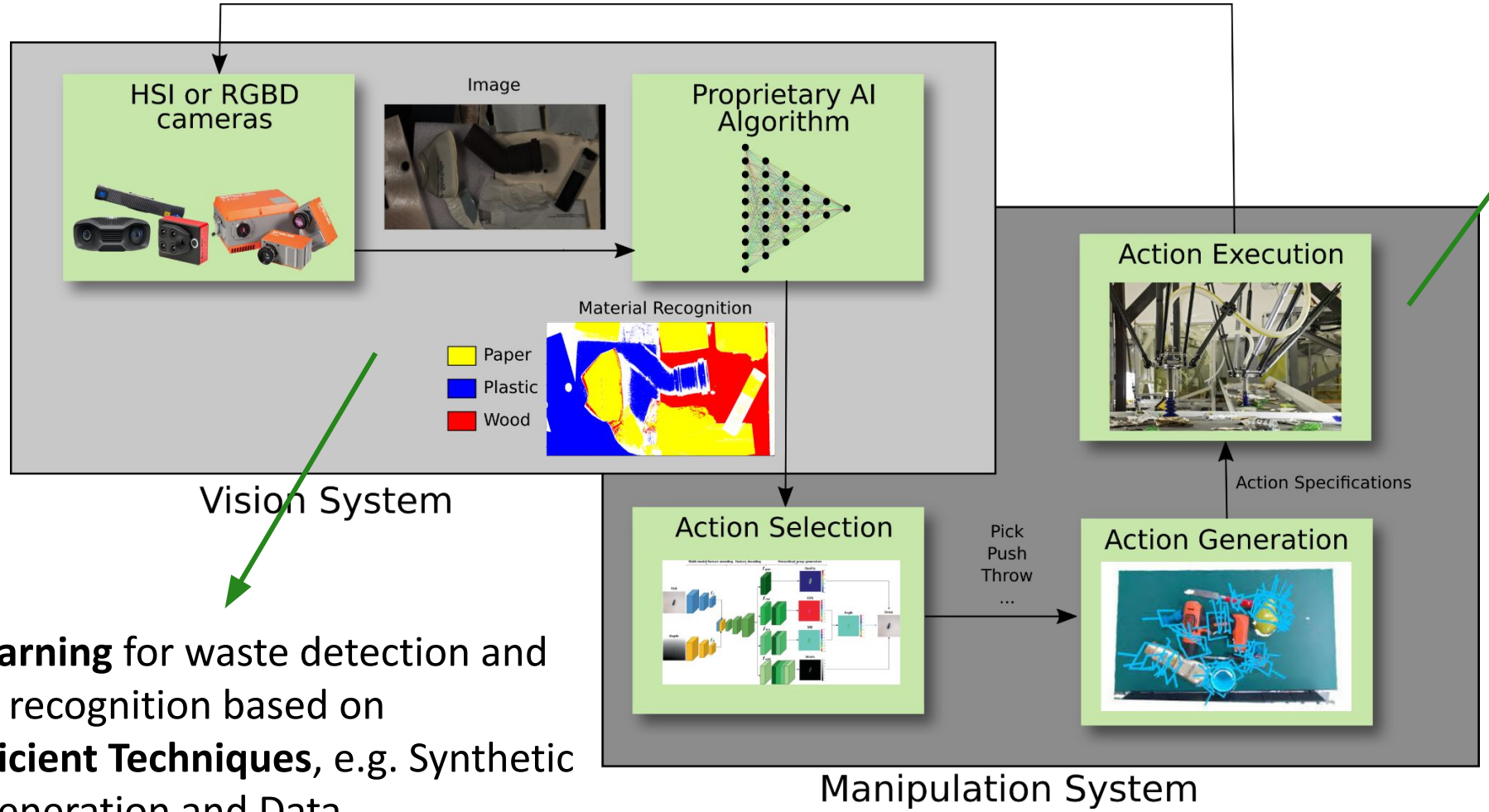
The basic solution and the project



Project Evolution:

- **Novembre 2021:** finanziamento PON per una borsa di dottorato triennale (60k€)
- **Luglio 2022**: premio Call4Ideas di SMACT (10k€)
- **Ottobre 2022: StractCup Veneto**:
  - 4° premio assoluto
  - Menzione speciale Gruppo GEDI
- **Marzo 2023:** submission to EU call

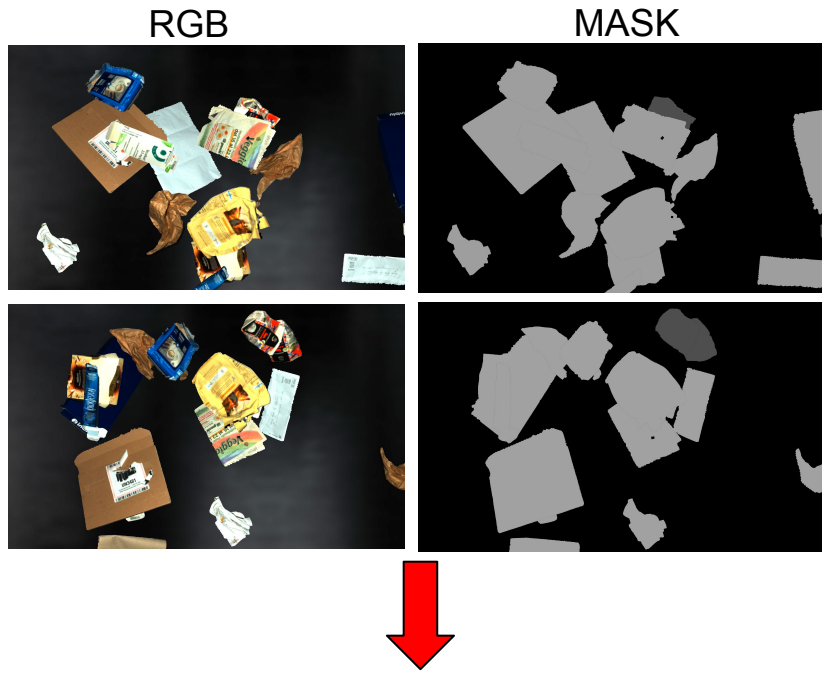
A Robotic Waste Sorting System Concept



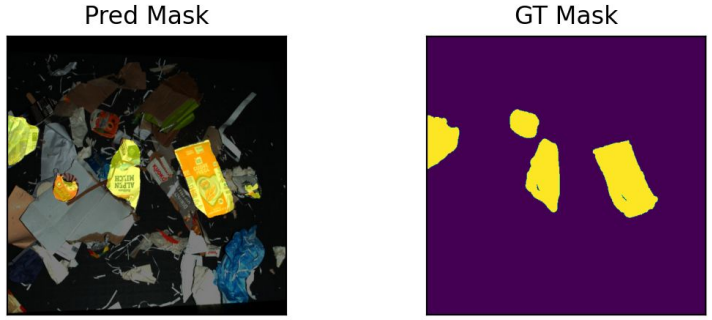
Deep Learning for waste detection and material recognition based on **Data-Efficient Techniques**, e.g. Synthetic Image Generation and Data Augmentation.

Handling complex objects and clutters in a human-like fashion through **Self-Supervised and Reinforcement Learning** and a mixture of real-world and simulated data.

Synthetic Data Generation



Results after training a CNN on synthetic data



Preliminar Results:

- mIoU: 80% on test in laboratory environment

Our first case of study

1. **Tetrapak removal from paper stream**
2. **Cardboard removal from paper stream**

A better selection of the three fractions improves the economic value of the waste

Preliminary results on waste detection

Task:

- Segment contaminants in a paper stream.
- Data comes from an open source dataset, but are closed to our case of use.

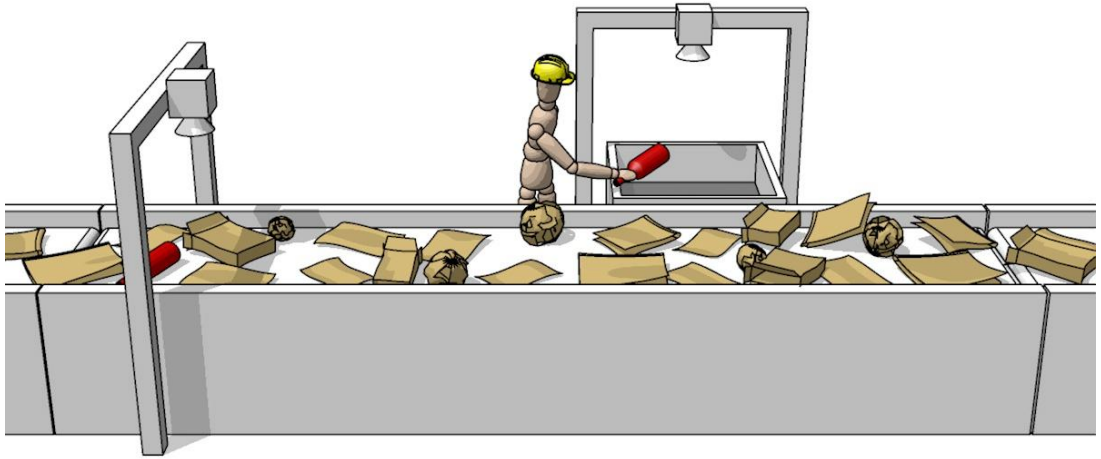
Outcomes:

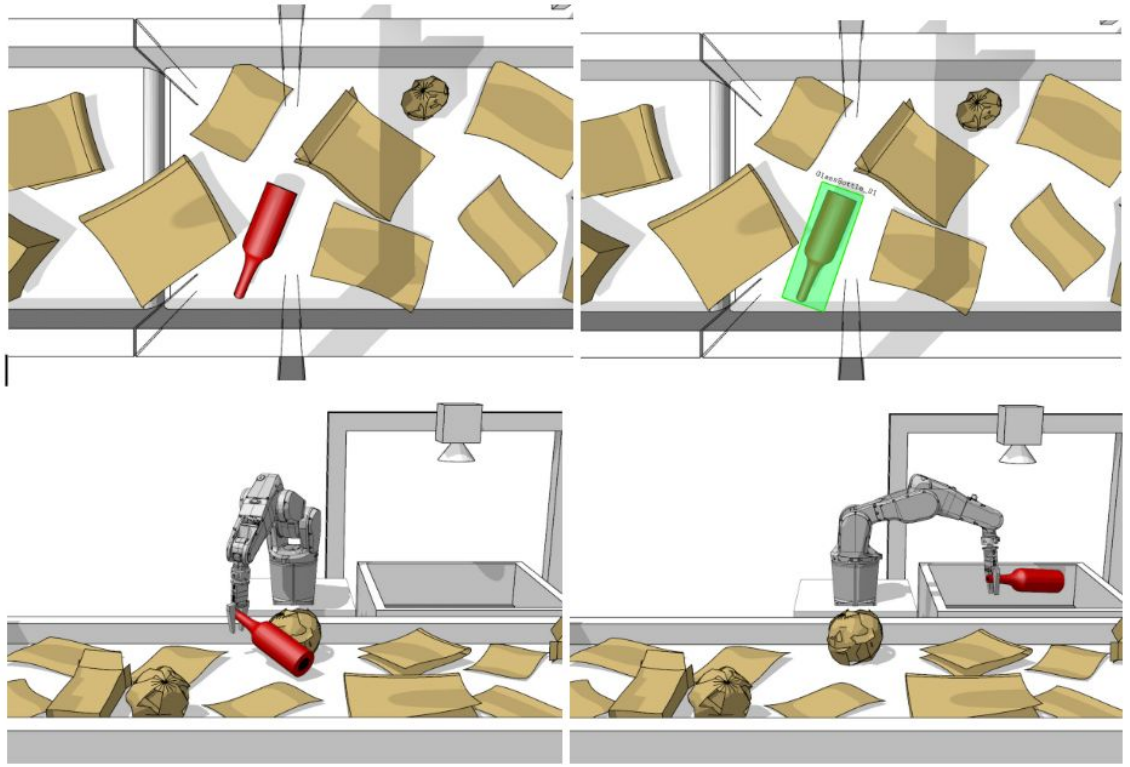
- Segmentation network run at ~40 fps on an high-end GPU
- Qualitative and quantitative (mIoU ~60%) results are promising
- This is a good enough to compute grasping points

GROUND TRUTH

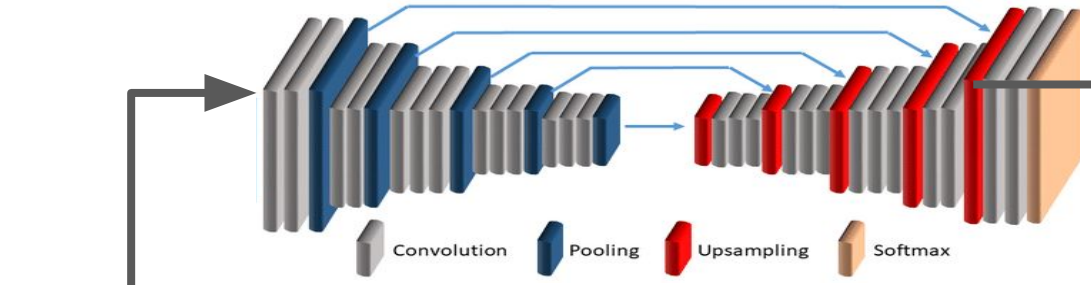
PREDICTION

Automatic Labelling





Manual Labelling



Before Manual Contaminant Removal

After Manual Contaminant Removal

Label from Difference

Preliminar Results:

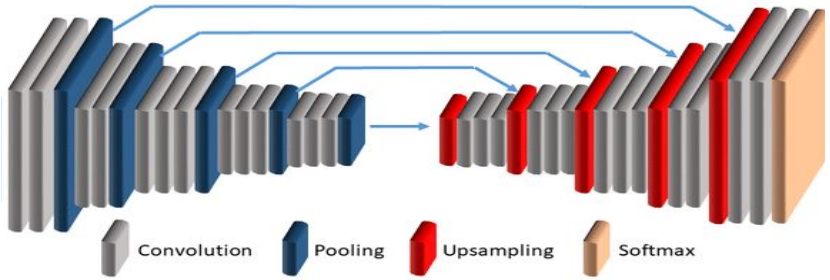
- mIoU: 50% training a standard segmentation network

Manual Labelling + Data Augmentation

Manual Labelling

Augmentation with GAN

Train the CNN



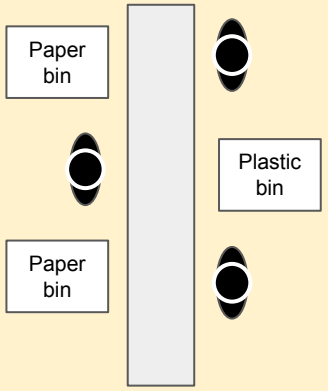
Preliminar Results:

- mIoU: 80% on test data

New project = Automatic Labelling

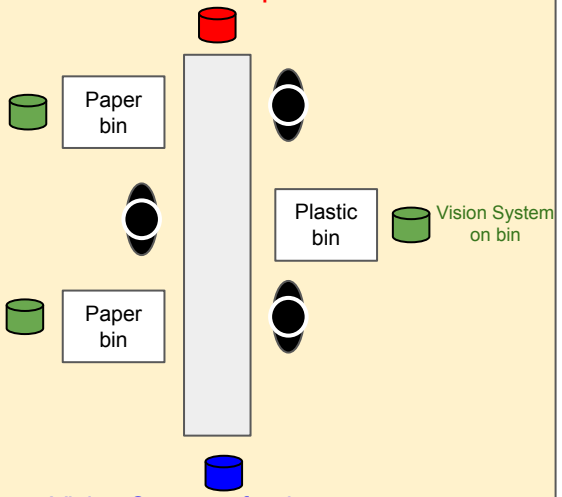
Self-Supervised and Adaptive Vision System to Recognize and Grasp Waste

Current situation: manual sorting



Data Acquisition for training

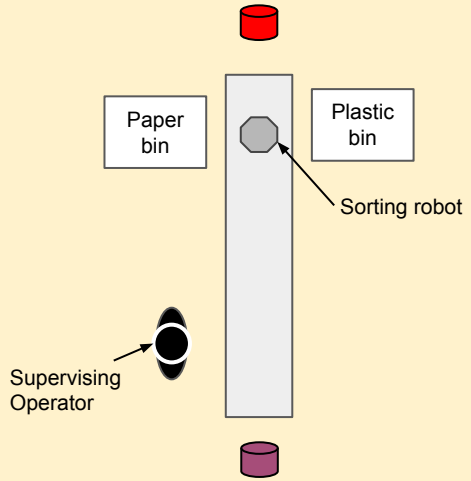
Vision System before human operators



Vision System after human operators

Running system

Trained Vision System



Vision System for Continual Feedback

Less operators

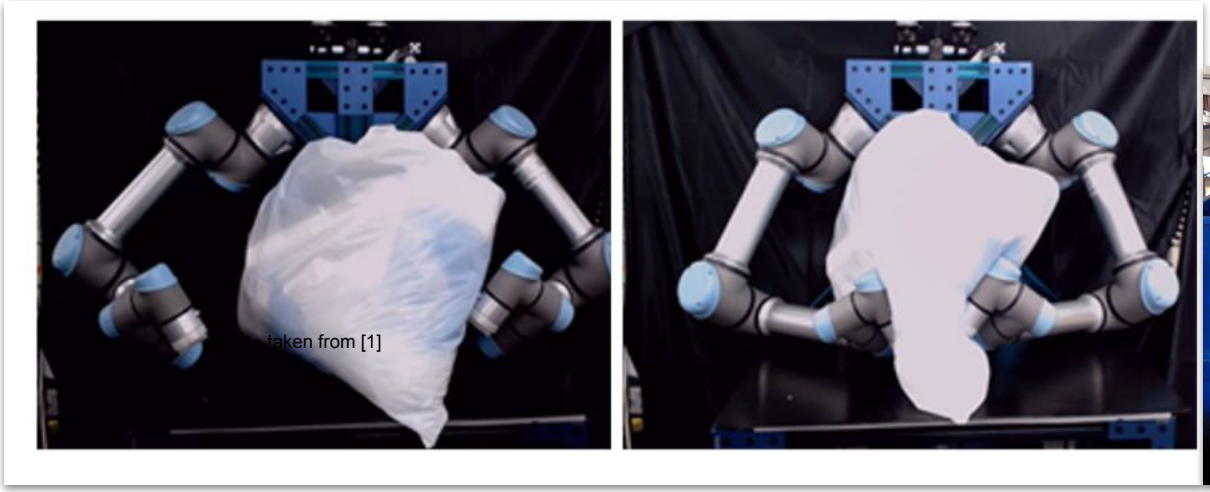
Less burden for the cooperatie operator

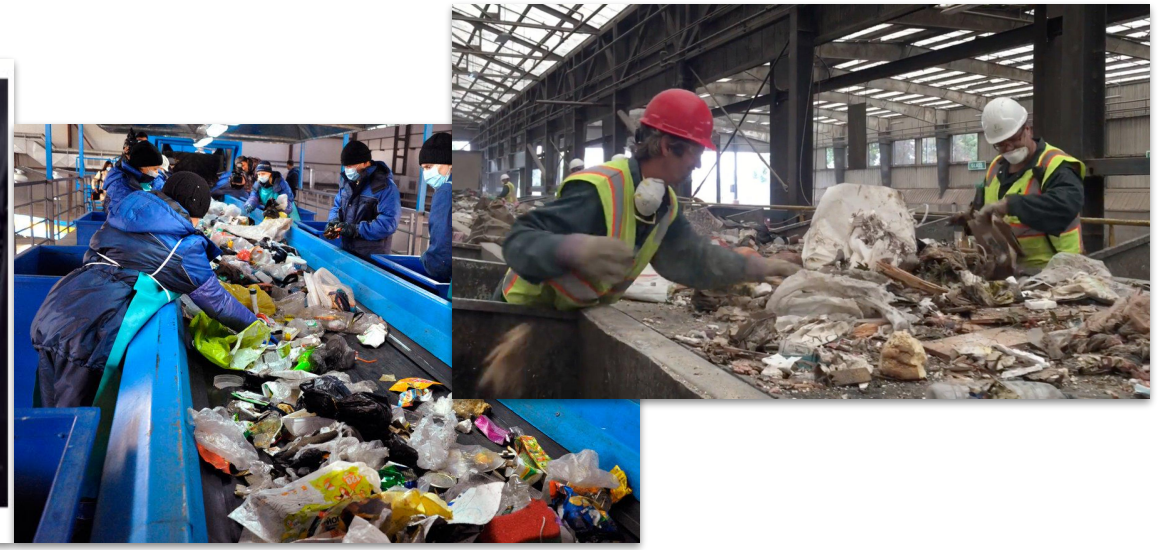
Higher productivity

Dual-Arm Robots for Human-like Manipulation

(1) Manipulation of Bulky Objects, very common in Industrial Waste or C&D Waste (but also large cardboards in paper sorting).

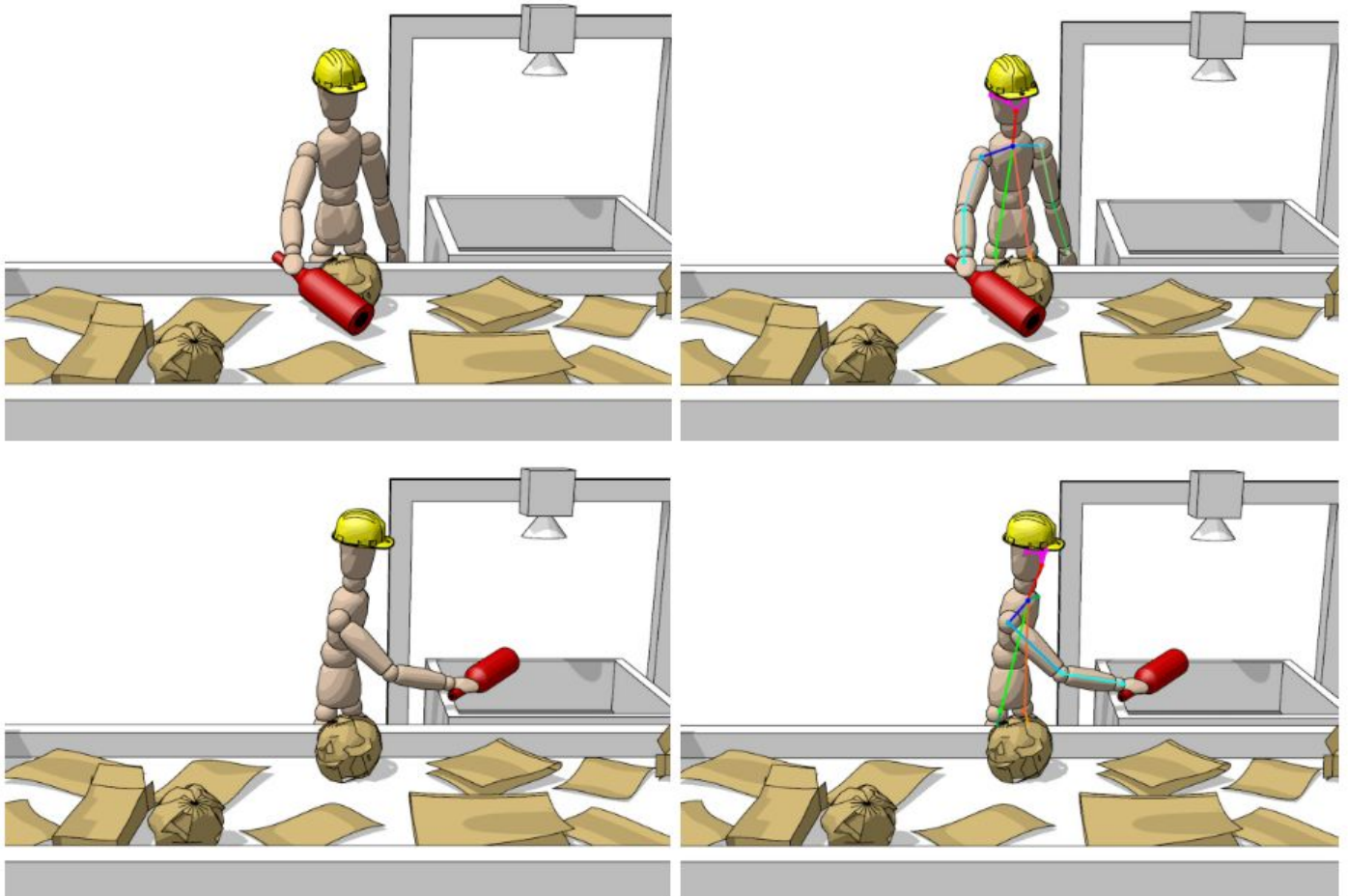
(2) Rummaging and disentangling are very common action performed by humans that robot cannot do.





[1] T. Kiyokawa, J. Takamatsu and S. Koyanaka, "Challenges for Future Robotic Sorters of Mixed Industrial Waste: A Survey," in *IEEE Transactions on Automation Science and Engineering*, doi: 10.1109/TASE.2022.3221969.

- **Imitation learning** algorithms for item manipulation: the robots learn the correct way to handle objects with complex geometry, flexible materials, or with big sizes by directly observing the operators



Conclusions and Future Works

Objectives:
- Developing a vision system to recognize waste in real-world scenario
- Higher performance in complex objects and clutters

What we have done:
- Data collection
- Synthetic Data Generation and Augmentation

On going:
- Improving Automatic Data Labelling
- Further Data Collection
- Setting up a Demonstrator with a Robotic Arm

To Do:
- Manipulation Algorithm development

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