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Robots for selection and sorting of waste

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***Abstract*—Our litter contains a large number of raw materials which are wasted. The different materials must be separated to be economically enhanced and today technology does not allow you to do this efficiently. Most often it is necessary to use personnel who work in unhealthy conditions to recover only a portion of the recoverable material. Our project aims to create a robotic sorting system for sorting the different materials in our waste. This is achieved thanks to advanced computer vision and robot manipulation techniques. Waste sorting is not only a challenging technical problem, but it is a problem with several implications. Environmental implications, because of waste disposal. Social implications, due to the harsh working conditions of workers and the high turnover of staff. Economic implications, to make profitable recycling and recovery of waste. In this paper, we present the basic building blocks on which we are creating our solution to the robotic waste sorting problem.**

***Index Terms*—waste sorting, robotic waste sorting, circular economy**

I. Introduction

We aim to develop a robotic system for sorting waste (Robotic Waste Sorting System, RWSS) to be inserted within the current plants sorting, where manpower is currently used to improve separation some materials. Sorting waste on a conveyor belt is repetitive work, wearing and unhygienic and also has an environmental/economic cost because it is part of the potentially recoverable material (up to 20% in some cases) fails to be recovered.

Industrial robot manipulators are increasingly fitted with exteroceptive sensors and autonomous planning capabilities to modify their motion according to external stimuli. In this project, we are developing an AI-powered robot manipulator for waste sorting. The goal is to increase efficiency and lower the cost of waste separation in order to reduce the amount of waste directed to the incinerator. Machine vision techniques based on hyper-spectral imaging are coupled with deep learning for items classification according to the item's material. Reactive motion planning techniques and markerless human motion tracking techniques are under investigation to achieve an efficient collaboration between humans and robots. Different robot geometries will be investigated for increasing the speed and the efficiency of the sorting process.

The use of an RWSS allows to reduce or avoid the use of human operators, freeing up the workforce for other more rewarding and value-added functions, and would make it more efficient and economically more sustainable material recovery. Moreover, it can reduce staff turnover which is very high in this sector of the unhealthy work environment. The development of waste sorting robots is not new. However, the products currently available have several limitations. In particular, it is assumed that the objects to be separated are placed on the conveyor belt in a not overlapping situation. This necessity limits the separation yield because it is not always possible to guarantee that condition and it is necessary to put more machinery before it to better distribute the waste on the belt, which requires other investments to modify the plant line.

In our project, we aim to overcome these limitations by building a system able to manipulate complex and disordered piles of objects. The product is under development (TRL 2). The first prototypes and level installations industry are expected by the end of 2023.

II. Related works

Sorting through automated systems is a technological achievement of several years ago. Today, automation is very present in medium and large plants [1]. At the beginning these machines were built by adapting machines from the mining or agri-food industry, while today producers are increasingly specializing, creating special systems for sorting waste: mechanical sorters, optical-pneumatic sorters, magnets, etc. These are able to handle large flows of materials but have poor accuracy. For these traditional plants, the separated outgoing fractions have a non-optimal recovery level (about 70-80%) [2]. In addition, many of these machines can perform a binary separation or separate the incoming flow into two fractions (the fraction to be recovered and the "residue") and are very sensitive to any contaminants that can even block the plant. This is why today human operators are still widely used in sorting plants to buffer the low yields of the machines currently on the market.

There are also some companies producing robot waste sorting systems based on robot manipulators. Only a couple of these company seems to have mature systems[1]. The products they offer, albeit with some differences, use an advanced vision system to guide an industrial robot in a pick & place operation. However, these machines need objects well distributed on the conveyor belt and cannot handle complex and intermingled objects.

III. Workcell

The system we are developing is sketched in Fig.1. It is a modular system to be adapted to the current machine in

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[1]https://zenrobotics.com/, https://www.amprobotics.com/

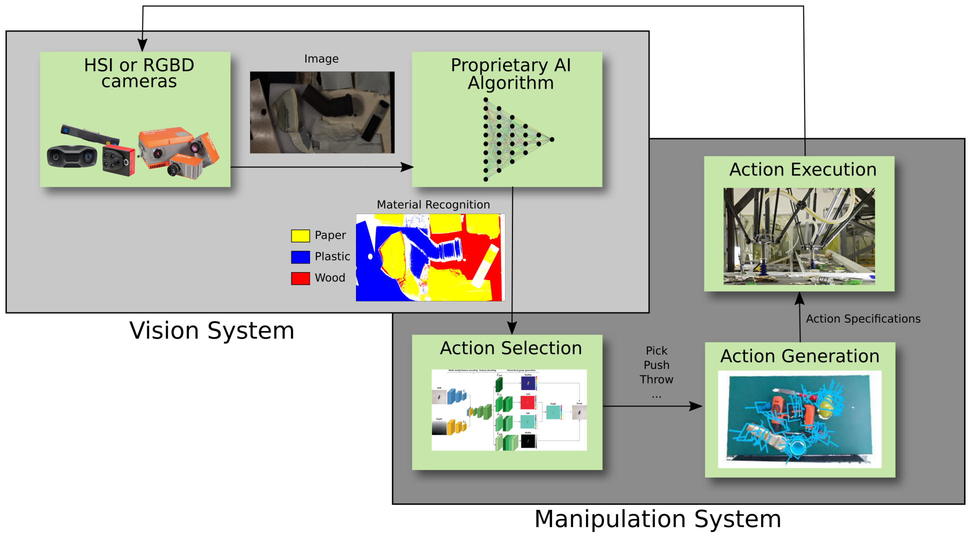

Fig. 1. A sketch of the proposed system for robotic waste sorting system based on a robot manipulator and a vision system based on deep'learning.

the sorting plant and especially to the conveyor belt. It is designed to work alongside human operators and to perform specific selections. In the first stage we devise to have several RWSS installed along the conveyor belt, each one devoted to selecting a specific material. The system is composed of two main blocks: the vision system and the handling system.

The vision system integrates various sensors, depending on the materials to be processed, and is based on a deep learning approach for object segmentation [3], [4] and material classification. Since traditional hyper-spectral imaging used for material recognition outputs very redundant data, our aim is to develop an algorithm able to use less data, without affecting performance. Consequently, we could achieve higher processing speed and lower hardware costs. The perception system is modular and it will use different algorithms and different cameras depending on the material to be processed. In the first step, we are focusing on careful and precise sorting of paper, cardboard, and Tetrapack^{TM}. We aim at achieving an accuracy of the sorting of 98% against the 80% of current opto-mechanical-pneumatic sorters.

The handling system is the most innovative block in our system. Current systems, just perform standard pick & place operations common in industrial robotics. We are developing an advanced algorithm for grasping and disentangling in order to be able to pick objects also from complex and intermingled piles of materials. In this direction, Reinforcement Learning and Self-Supervised Learning have shown promising results in laboratory settings [5]. We want to extend these approaches to work in real-world settings, e.g. considering objects with irregular geometries.

Another promising advancement we are going to test in the next months is the use of tossing motion for the robot. After the robot picks the objects, instead to move the end-effector over to the correct container and *place* the object, the robot is is throwing the object into the container to save time in the cycle time. Tossing involves a complex correlation between the shape of the object and the release pose and speed, which are almost impossible to model in a closed form using equations of motion. Deep learning can be used to capture this information citeb13, allowing to compute the right release specifications without an explicit motion model.

We also started to record a dataset of RGB-D and hyper-spectral images to starting develop and test the algorithms. Considering the high cost related to data collection, data augmentation techniques will be applied to avoid overfitting.

IV. Conclusions

We presented an automatic system to process waste to sort the different fractions to be recycled with very high precision. The system is based on a modular solution with a robot manipulator and a vision system. The advanced algorithms we are developing in this project will enable us to overcome the current limitations due to the long cycle time and high costs of the machine vision systems.

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