The solution for a safe & automatic Municipal Waste Sorting: the Smart Autonomous Robot with Artificial Intelligence

B. Riesco Garcia[1], C. Fernández González[1], L. Saralegui Gómez[2], E. González Prieto[3], B. Montes Parra[3]

[1] CI3 (Centre for Innovation in Smart Infrastructures), Avenida Buendia 11, 19005 Guadalajara, Spain
[2] Ferrovial Corporación, C/ del Príncipe de Vergara, 28002 Madrid, Spain
[3] Ferrovial Servicios, Passeig de la Zona Franca, 111,Torre Auditori, 08038 Barcelona, Spain
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Corresponding author email: briesco@ci3.es

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Introduction

The arrival of artificial intelligence and robotic technology will revolutionize the way facilities for municipal waste sorting are designed and run, leading to an increased operational efficiency resulting in a more sustainable way of managing municipal waste. Current European municipal waste sorting installations are highly automated thanks to equipment such as bag openers, trommels, ballistic separators, optical sorters, magnets, eddy current separators and pneumatic collection systems. However, several separation tasks still need to be done manually (hand picking), as it is the case of quality control processes over recovered material and manual sorting over oversize and rejection flows, the latter still containing a significant amount of recyclables that if not properly sorted would be incinerated or landfilled. In both cases, these are tasks that are carried out in work environments with low ergonomics (noise, direct contact with waste, lifting and moving heavy objects) and whose performance decreases during the work shift.

The aim of this work is to improve the automation of solid municipal waste treatment plants by substituting hand picking operations by a robot based in artificial intelligence as an opportunity to increase current recovery ratios and purity of recovered materials; collect new materials from current rejected flows and improve workers' well-being conditions, who could then concentrate on robot maintenance, amongst other tasks. Particularly, this work presents the main results of the training and operation of the first robotic sorting system based on artificial intelligence, applied to the separation of bulky municipal solid waste (MSW) and installed in a full-scale waste treatment plant. This study is being performed in the framework of the project "ZRR for municipal waste", a demonstrator project founded by Climate-KIC.

Gundupalli et al (2017) presented a market analysis to identify available commercial solutions to fully automate the mechanical waste treatment process. Among the options analysed, the system ZRR[2] is a Robotic Recycler that is considered to be the world's first artificial intelligence (AI) powered robotic waste sorting device. These robots, equipped with computer vision and deep learning algorithms, accurately separate chosen waste fractions from solid construction and demolition waste streams. A single ZRR robot arm is able to pick up to 4 different fractions reaching up to 98% purity. However, the robot ZRR has only been applied to construction and demolition (C&D) waste, being designed specifically to increase the efficiency and lower the cost of waste separation for typical construction materials. In the current study, the robot ZRR will be applied, for the first time, to municipal solid waste streams, a much more demanding scenario due to different sorting conditions and different waste composition and morphology needing therefore to widen the scope of the technology.

In particular, theZRR robot would need to enlarge the present list of materials that is capable to recognize and sort for the C&D application and that are metals (Ferrous & Non-Ferrous), Wood, Rigid plastics (mixed and tubes & pipes), Inert (mixed, concrete, bricks, limestone, asphalt...), OCC and plastic bags by colour. Furthermore, the technology would also need to adapt the grasping system to the new waste characteristics.

In order to work with a MSW flow, during this project the robot will have to be trained to recognize and sort new materials: textile, cardboard (OCC), high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), tetrapack or pruning & green waste. Additionally, due to working with MSW, the robot will work with more demanding conditions that might disturb recognition: higher conveyor speeds, multilayer distribution of waste over the conveyor, the presence of dust, leaches and organic waste.

Material and methods

The experiments were performed using a robot ZRR2 (ZenRobotics[2], Finland) formed by 2 robotics arms over a conveyor and equipped with several sensors including a laser, a metal detector, high resolution RGB camera, NIR (near infrared spectrum) sensor, VIS (visual light spectrum) sensor and a software based on deep learning. The whole system was installed in the municipal waste treatment plant Ecorparc 4, located in Els Hostalets de Pierola, Barcelona (Spain). This plant yearly receives an average of 300.000 tons of the reject fraction from municipal solid waste. Particularly, the robot was installed over the bulky waste flow, a waste stream that was not recovered up to now. The whole system has been located on a platform over 8 different hoppers (4 hoppers per robot arm) and its integration in the current plant sorting process needed to take into account different issues, as for example, to warranty a monolayer flow to the robot inlet or as to enable the possibility to test the technology with waste streams other than the design (bulky flow).

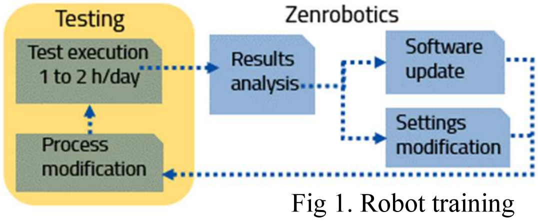

Fig 1. Robot training

Once achieved proper feeding conditions, the ZRR robot artificial intelligence needed to be trained to recognize 13 different materials or waste fractions: ferrous metals, non-ferrous metals, textile, cardboard, HDPE, LDPE, PP, Wood, PET, Paper, ohers mixed plastic, tetrapack, pruning & green waste. To do this, the robot was fed during 2 hours a day with the selected material.

After the training, the performance of the robot was tested in terms of fraction purity and waste recovery using 2 types of tests, stand- alone tests and production tests. In the first, the robot was manually fed during 15-30 minutes with previously classified waste from the flow. At the end of the experiment, all the recovered fractions, as well as the rejection, were weighted, performance calculated and required adjustments done. In the production tests, the robot was fed in real working conditions with the design flow during a period of time.
With the designed tests, the robot performance was evaluated measuring the recognition efficiency, pick efficiency, robot availability and fraction purity as well as assessing the influence of the main operation variables over robot performance.

Fig. 1 illustrated the procedure of work followed during robot testing. First, the robot testing is performed changing process parameters. Then the results are analyzed and the robot software, based on deep learning algorithms, is updated by ZenRobotics.

Results and discussion

As a result of the systematic training and operation, the recognition of the robot was raised to 13 materials, almost doubling the capability of recognition of the robot.
Subsequently, it is envisaged that the capacity of the system will be expanded and that it will be capable of identifying new materials in the waste stream, through the implementation of updateable, smart, self-learning software
So far, along the tests carried out it is being achieved an average of 90% purity for the 13 material. Further tests will study how to improve recovery efficiency by optimizing waste plant process parameters, such as: speed tape, distribution material tape, and disposition of the hoppers.
Main difficulties observed during the operation of the robot were related to the different composition and morphology of municipal waste in comparison with C&D waste, that caused lower recognition and lower picking efficiency.
Beyond the bulky waste flow, the project foresees to test other waste streams in order to demonstrate the feasibility to artificial intelligence and robotics as a sound sorting technology that would allow current facilities to improve current waste sorting process, making it possible to recover more waste fractions and with higher purity. These materials will re-enter production processes as secondary raw materials and therefore the demand for virgin raw materials would be reduced in line with the principles of the circular economy. Thus, the artificial intelligence and robotic technology for waste sorting facilities is set to become a powerful tool that contributes to ensuring the supply of essential resources in a society whose rate of growth hinders its sustainability

Conclusions

There is a growing technical capacity to create new high-value products from municipal waste if it is conveniently separated. European Municipal Waste treatment plant obtains a growing source of incomes for selling these sub-products previously considered waste and sent to landfill with its associated economical cost due to disposal fees and environmental cost.
In consequence, solutions to recognize and sort an increasing list of materials are a market need and even a social demand. So far, the ZRR2 has shown a 90% purity in the 13 wastes tested. If the robot ZRR2 demonstrates a stable performance and the adaptation to the operation conditions of a real waste treatment plant is satisfactory, the sustainability of the solution is guaranteed:
- Environmentally, it reduces landfill and increases recovery and reuse.
- Economically, recovering sub-products is profitable for the plant. The more the plant recover and with higher quality, the more incomes the plant will obtain. And finally, from the social perspective, it is demanded to find new sources of feedstock to create high-value products. In addition, workers' wellbeing will be improved due to minimizing: 1) interaction with waste; 2) exposure to smell and noise; 3) creating high-value job based on technology.
As conclusion, a solution for a safe & automatic municipal waste sorting is the smart autonomous robot with artificial intelligence.

List of references

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2 https://zenrobotics.com/solutions/robots/