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AI-powered Robotic Material Recovery in a Box

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Abstract
Recently, robotic technology has been greatly involved in waste separation providing a powerful, robust solution for the processing of the constantly increasing amounts of post-consumer waste. Existing solutions are installed in large -scale Material Recovery Facilities (MRFs) that target high waste volumes and are not cost-effective for smaller, less accessible areas. In contrast to bulk processing, close to source waste sorting has shown to improve material recovery in terms of quality and quantity, however lacking the exploitation of available high-tech solutions. To bridge this gap, the recently started RECLAIM project aims to develop a portable, robotic MRF (prMRF) tailored to small-scale material recovery. RECLAIM adopts a modular multirobot/multi-gripper approach for material recovery and an AI-powered computer vision module for material categorization. Furthermore, the project puts forward a novel Recycling Data-Game that encourages citizens to participate in project RTD activities by providing annotations to be used in training the AI modules used for recyclable categorization.

Keywords: Waste robotics, Waste Categorization, Recycling Data Game, Citizen Science

1. Introduction

Recent technological developments have facilitated the modernization of industrial Material Recovery Facilities (MRFs), which can be crucially supported by smart and automated waste treatment equipment (Wilts et al., 2021). This approach can be adopted by large-scale MRFs that are typically installed near urban areas to carry out municipal waste treatment (Raptopoulos et al., 2020). Despite the high productivity of these industrial solutions, transportation of waste to these large plants is costly and makes material recovery more difficult due to the compression applied on the waste during transport, to reduce their volume. However, there are still several cases where waste treatment needs are not efficiently catered for by the existing model. These include natural disasters, social and athletic events with occasionally high-volume waste, rural or distant areas and transport hubs. To meet the recycling needs of such cases, a new market trend has recently emerged, focused on implementing light, flexible and portable waste management units that can be quickly deployed in the areas in need, to undertake waste treatment and particularly the recovery of valuable recyclable waste[1] [2] [3]. Despite the strong demand for these systems, to date they lack the integration of smart, high-tech solutions that could significantly enhance their productivity. As a result, waste sorting in these niche sectors is still today powered by manual sorting.

The **RECLAIM** project (reclaim-box.eu) exploits mature and well-tested AI-driven robotic waste management technology that will be improved and embedded in a state of the art "portable, robotic MRF" (prMRF) that will be capable of significantly enhancing local-scale material recovery activities providing them with industrial-level efficiency.

2. The RECLAIM approach

To achieve its goal, the RECLAIM project undertakes concrete steps to create new solutions in four technology

[1] https://blog.kiverco.com/kiverco-introduces-unique-modular-recycling-plant
[2] https://wrtltd.co.uk/mobile-picking-station/
[3] https://ecoballa.com/?p=127&lang=en

pillars that crucially facilitate the recovery of valuable materials. The relevant pillars are summarized below.

PIL-1: Advanced AI for material identification, localization and categorization (AI-ILC) - exploit and improve existing AI technologies to develop effective solutions combining visual and hyperspectral information to accomplish high-performance recyclable waste identification, localization and categorization, applicable in real and harsh environments to support material recovery (Koskinopoulou et al., 2021).

PIL-2: Modular, low-cost, high performance, multi-robot/multi-gripper recyclable recovery - **RECLAIM** promotes a new modular architecture for robotic recyclable recovery based on high productivity Robotic Recycling Workers (RoReWos) equipped with different grippers specializing in different material types. The use of RoReWo Teams installed in the prMRF is expected to double the "picks per invested euro" rate for the composite system.

PIL-3: Portable robotic Material Recovery Facility (prMRF) - the combined placement of established recycling processing mechanical equipment and the AI-powered robotic sorters in a container box that can be easily transported to points of interest, is ready for operation within few hours, is capable of efficient recovery of recyclable materials with a minimal number of recycling workers, is functional and sustainable for several years after the project end.

PIL-4: Environmental gaming for social awareness and data collection - increase social awareness to recycling via a novel Recycling Data-Game (RDG) that highlights the related challenges and encourages citizens to participate in project activities through a citizen science approach for providing data to AI-ILC training. Orthogonal to the above, RDG will provide the means to communicate the general principles of AI and Data Science to the public.

The above technological developments promote the decentralized treatment of recyclable waste which is expected to accomplish increased recovery rates and high material purity, given that it targets better quality, fresh, and uncompressed waste. At the same time, the environment-oriented gaming infrastructure increases social sensitivity on recycling and makes citizens aware of the benefits of the circular economy.

3. Focused Deployments

RECLAIM aims at deploying a prMRF at multiple pilot sites to assess its performance under real and particularly demanding conditions, recovering materials from post-consumer packaging waste. In particular, the prMRF will be deployed in the group of Ionian islands, Greece, that provide the opportunity to assess its performance in multiple and complementary use-case scenarios. The Ionian group consist of seven main islands being very popular touristic destinations. All islands face major difficulties in waste management especially during the summer period. Still, the relatively limited size of such islands and the high seasonal characteristics of waste production do not favor the investment on a full-size MRF. To date, the packaging waste generated by residents and visitors is typically compacted and packaged to be transported to the mainland for material recovery, except the Corfu Island where a small MRF is operated. The residue of this waste treatment has to either return to the islands for landfilling or stay in the mainland for landfilling with particularly high costs. In addition to the increased logistics expenses, especially in the case of roundtrip transfer (island-mainland-island), the quality of recyclable materials transferred to the mainland for processing often decreases due to unproper temporary storage and compression. This causes increased material degradation/entanglement, making harder to the recovery of valuable materials and lowering recycling rates. As a result, valuable recyclables end up in landfills instead of being recycled.

Similar to this particular case in Greece, the use of prMRF for the direct treatment of fresh, uncompressed, high-quality waste and the recovery/sorting of recyclables in a decentralized manner is of outmost importance for all rural areas. RECLAIM provides a valid strategy to drastically increase the recovery rates for valuable materials by sorting close to the source and to reduce the logistics costs by avoiding back and forth transport.

The landscape of the Ionian islands group provides the unique opportunity to asses both the underlying technologies and business case for the prMRF. The RECLAIM partner ION has the responsibility of waste management in all the Ionian islands and will provide valuable support to explore how prMRF can be used to tackle the individual needs of different islands. In particular, ION has specified three scenarios of particularly high interest for the Ionian islands group but also for a broad range of areas in Europe facing similar challenges. The three scenarios are summarized below.

Scenario-1: Material recovery from mixed recyclables streams. The main recycling approach followed in Greece regards the use of bins where citizens collect mixed post-consumer municipal packaging waste which are then separated in material recovery facilities. As mentioned above, especially for Ionian Islands this process has low efficiency, and entails high logistics expenses and increased materials loss. RECLAIM will assess prMRF operation in the treatment of mixed recyclable packaging waste streams focusing particularly on PMD stream (Plastics, Metals, Drinking Cartons) performing positive separation of multiple material types. This is the most challenging scenario due to the high material complexity to be investigated in RECLAIM and will be addressed during the whole duration of the project.

Scenario-2: Cleaning of citizen separated, material-specific streams. In a part of Corfu (part of the Ionian islands group) the citizen-powered separation of recyclables is promoted, which assumes the use of multiple, material-dedicated bins for recyclable packaging waste collection is separated streams (this is the recycling approach also adopted by many North European countries). The collected material steams need to be further processed to increase their purity and thus their value in the secondary market. RECLAIM will assess prMRF operation in the treatment of material-specific streams, performing negative separation to remove unwanted objects. This scenario will be explored during the months M13-M36, in parallel with Scenario-1,

providing the opportunity to make prMRF appropriate for both positive and negative material selection. By comparing scenario 1 and 2 the advantages and disadvantages of separation by citizens will be evaluated, as separation by citizens also results in higher local collection costs for the separate packaging waste streams.

Scenario-3: Close to source material recovery. The inherent portable nature of the prMRF enables its installation close to areas with high productivity of waste, such as transportation hubs (e.g. ports, airports), festivals, sport events, exhibitions, etc. Unfortunately, so far, the fresh, high-quality waste produced in such areas is collected with garbage trucks to be integrated with ordinary municipality waste. RECLAIM will exploit the portability of the prMRF to explore the option of local, close to source robotic material recovery/sorting, and contrast its efficiency in relation to the current practice. This scenario will be explored in the last 6 months of the project, by installing the prMRF at a central location that will also serve as an open and live demonstrator to EU citizens (inhabitants and tourists), local authorities, governments, circular economy stakeholders and potential investors.

4. Conclusions

RECLAIM paves the ground for the implementation of new, effective, decentralized waste management policies. This is accomplished by developing low cost, portable, easy to install and increased productivity prMRFs, which accomplish local and effective treatment of recyclable waste. Accordingly, prMRF is expected to have a key role in developing a global, leakage-free circular economy model that achieves full material recovery on post-consumer waste anywhere, even in the most remote areas.

5. References

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