Transforming Materials Recovery Facility using A.I.-Driven Smart Modular System

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Primary topic: Technologies for Transforming Materials Recovery Facilities
Secondary topic: Design for Remanufacturing & Recycling for the Circular Economy

Abstract: Efficient resource recovery is crucial for supporting manufacturing industries, reducing waste, lowering material costs, and strengthening the economy. This paper presents a novel artificial intelligence (AI)-driven approach to recovering valuable materials from municipal solid waste (MSW) including consumer batteries, and other critical materials in the form of e-scrap using low-cost, custom-built high-speed robotic actuators. By integrating advanced image-based AI sorting algorithms with 2-3 axis actuators, this approach enables high throughput, precise and scalable recovery of materials, driving the transformation of materials recovery facilities (MRFs) and supporting a more circular economy.

AI models were trained on diverse image datasets capturing visual patterns and features across various material types. A unique aspect of the system is its efficiency: a single image is captured for AI analysis, enabling the identification and classification of all targeted materials, including plastics, metals, paper, fabric, glass, consumer batteries (Li, Ni, Alkaline), and critical material in form of e-scrap. These can be recovered in one pass relying solely on image data for classification and sorting. The robotic actuators are designed for high-speed and cost-effective operations with multiple end-effectors specific to each of the above materials, enabling efficient handling and separation of materials at industrial scales.

This modular system drives significant improvements in recovery rates and material purity while maintaining low operational costs, and can be easily retrofitted in current MRFs. It transforms MRFs by enabling the recovery of a wide variety of materials and can be extended to refine separation further within each category. This patented one-pass recovery approach enhances processing speed and throughput, facilitating the recovery of high-quality secondary materials while reducing reliance on virgin resources, minimizing greenhouse gas emissions, and aligning with global sustainability and decarbonization goals.

Future work will focus on expanding the system to industrial-level demonstrations by optimizing both algorithms and hardware for greater efficiency and scalability. Additionally, the system will be enhanced to accommodate more material categories and subcategories, enabling refined separation and broader applicability. By addressing economic and technological challenges, this research provides a scalable and impactful solution for resource recovery, contributing to a resilient and sustainable manufacturing economy. The integration of AI and robotics demonstrates significant potential to revolutionize MRFs and advance the circular economy through efficient, cost-effective, and precise material separation.

This project is funded in part by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under award number DE-EE0011361.