Development of an Economically Viable AI-Enabled Sorting Technology for Complex Plastic Waste Streams

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Primary topic: Emerging Recovery & Recycling Technologies
Secondary topic: Technologies for Transforming Materials Recovery Facilities

Abstract: This paper presents a novel, economically viable approach to sorting complex plastic waste streams through the innovative integration of artificial intelligence and sensor fusion technology. Current recycling facilities struggle to effectively sort materials categorized as #3-#7 plastics due to their varied compositions, multi-layer structures, and the limitations of single-sensor sorting technologies. We demonstrate a breakthrough method that enables accurate sorting of these materials using a low-cost vision-based system trained on comprehensive multi-sensor data. Our approach uniquely transfers chemical compositional information, gathered through a combination of Near-Infrared (NIR), Mid-Infrared (MIR), and X-Ray Fluorescence (XRF) spectroscopy during the training phase, into visual features recognizable by a convolutional neural network (CNN). **This patented technology (US Patent 11,969,764, 2024; US Patent US20240109103A1)** eliminates the need for expensive sensor arrays during operational deployment while maintaining high classification accuracy.

The system achieves classification accuracies exceeding 95% for primary categories and 85% for complex multi-layer materials, significantly outperforming traditional single-sensor approaches. Operating at speeds of up to 100 pieces per minute, our technology demonstrates a 60% reduction in capital equipment costs compared to conventional multi-sensor systems, while reducing operational costs by 40%. The developed hierarchical classification system enables the creation of novel, market-driven material streams from previously non-recyclable plastics, potentially unlocking new market opportunities worth an estimated $2-3 billion annually in the United States alone.

Our methodology consists of three key components: (1) initial multi-sensor fingerprinting for comprehensive material characterization, (2) development of novel classification hierarchies using both supervised and unsupervised learning approaches, and (3) training of a vision-based CNN that replicates chemical-based sorting decisions. The system's effectiveness has been validated through extensive industrial trials, demonstrating its capability to create valuable material streams for various applications, including chemical recycling feedstocks, automotive parts, and packaging materials.

This research represents a significant advancement in recycling technology, offering a practical solution to the technical and economic challenges of sorting complex plastic waste. The developed technology not only improves the efficiency and economics of plastic recycling but also

contributes to broader sustainability goals by enabling the recovery and reuse of materials currently destined for landfills or incineration.

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under award number DE-EE0009266.