Assessing Recyclability for Selective Disassembly of Waste Printed Circuit Boards

Muhammad Mohsin, Stefano Rovetta, Francesco Masulli, Xianlai Zeng

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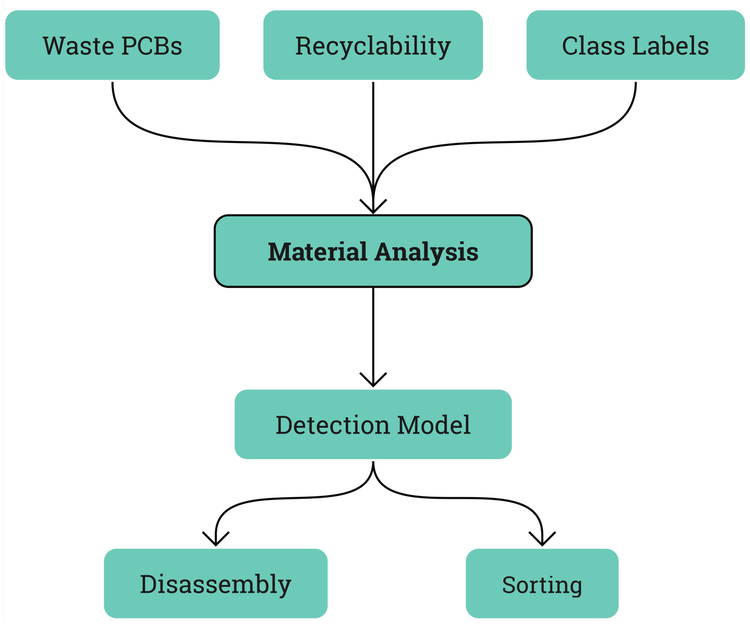
Introduction

Estimating the recycling potential of Critical Raw Materials (CRMs) in electronic components present on Waste Printed Circuit Boards (WPCBs) is essential for selective dismantling. In this work, we employed a novel recyclability approach to assist the automatic disassembly and sorting of WPCBs. This approach will help the computer vision system to accurately identify and sort electronic components during the automated disassembly and sorting process, aiding in iterative training and validation of individual components.

Materials and Methods

We used a recyclability-level approach to classify different electronic components based on material analysis and training the deep-learning model for automatic disassembly and sorting. Custom dataset V-PCBs is developed for deep learning-powered computer vision system to detect and localize different electronic components at different resolution scales and density levels as shown in figure .



Recyclability Measurement

We used an innovation model [3] based on the statistical entropy function to measure the recyclability of electronic components. The recyclability R can be calculated using the following equations:

$$H = -\sum_{i=1}^{n} (P_i \cdot \log_2 P_i) \tag{1}$$

$$\sum_{i=1}^{n} P_i = 1 \tag{2}$$

$$D = \sum_{i=1}^{m} D_i = \begin{cases} \sum_{i=1}^{m} P_i, & \text{Physically mixed goods} \\ \sum_{i=1}^{m} \left[1 - \left(\frac{j_i - 1}{N}\right)\right] j_i, & \text{Chemically Combined goods} \end{cases} \tag{3}$$

$$R = \frac{100 \cdot D}{N \cdot H} \tag{4}$$

Recyclability Metrics for Various Electronic Components

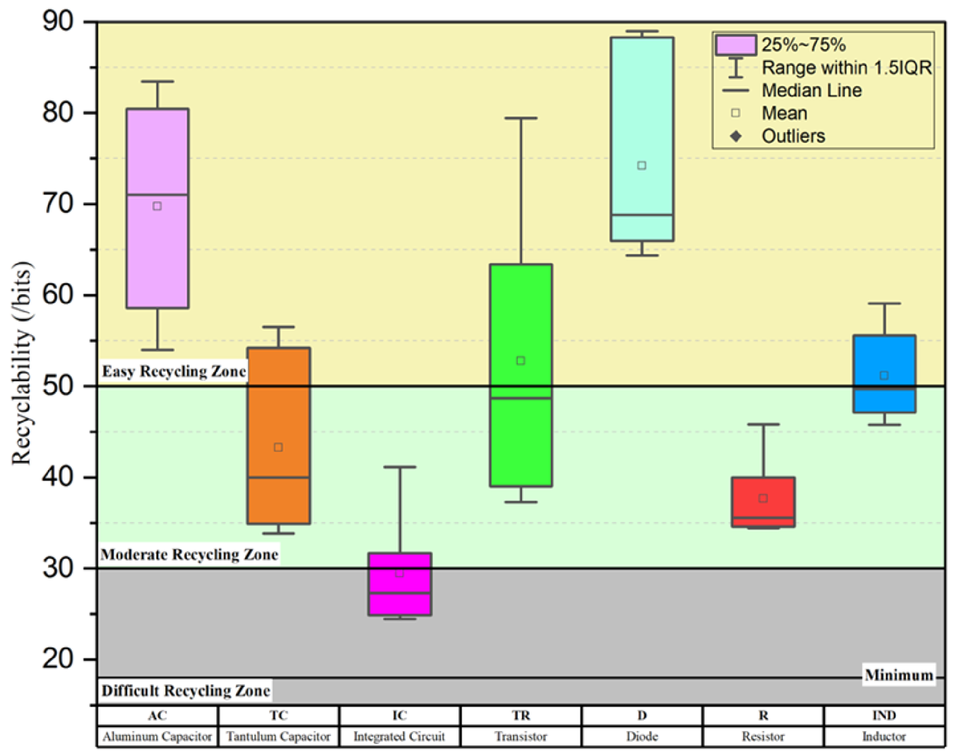
Component	H (bit)	D	R (bit)
Aluminum Capacitor	0.80 - 1.25	4.05	68 ± 14
Tantalum Capacitor	1.18 - 1.91	4.00	45 ± 11
IC	1.04 - 1.75	3.85	33 ± 8
Diode	0.69 - 0.96	5.40	76 ± 12
Transistor	0.85 - 1.81	3.10	58 ± 21
Resistor	1.51 - 2.00	4.15	39 ± 6
Inductor	1.10 - 1.42	3.25	52 ± 7

Experimental Results

The recyclability level is divided into three main types based on their recycling potential:

- Difficult Recycling Zone
- Moderate Recycling Zone
- Easy Recycling Zone

This multi-criteria solution helps the automatic computer-vision system to select and automate the disassembly process of waste printed circuit boards. Figure shows the recyclability map of seven selected electronic components present on WPCBs.



Conclusions

This study introduces a novel approach to assess the recyclability of electronic components present on WPCBs [1]. By integrating recyclability multi-criteria into the automated disassembly process, it optimizes the selection of high-value materials [2]. This method significantly enhances recycling systems, contributing to sustainable waste management.

References

[1] Muhammad Mohsin et al. “Measuring the Recyclability of Electronic Components to Assist Automatic Disassembly and Sorting Waste Printed Circuit Boards”. In: *arXiv preprint arXiv:2406.16593* (2024).

[2] Muhammad Mohsin et al. “Virtual Mines–Component-level recycling of printed circuit boards using deep learning”. In: *arXiv preprint arXiv:2406.17162* (2024).

[3] Xianlai Zeng and Jinhui Li. “Measuring the recyclability of e-waste: an innovative method and its implications”. In: *Journal of Cleaner Production* 131 (2016), pp. 156–162.

Contact

Muhammad Mohsin
muhammad.mohsin@edu.unige.it
Stefano Rovetta
stefano.rovetta@unige.it

VEGA research laboratories

UniGe | DIBRIS