

## Transfer learning-based method for automated e-waste recycling in smart cities

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### Abstract

**INTRODUCTION:** Sorting a huge stream of waste accurately within a short period can be done with the support of digitalization, particularly Artificial Intelligence, instead of traditional methods. The overlap of Artificial Intelligence and Circular Economy can flourish many services in the environmental technology domain, in particular smart e-waste recycling, resulting in enabling circular smart cities.

**OBJECTIVES:** We analyse the growing need for automated e-waste recycling as an essential requirement to cope with the fast-growing e-waste stream and we shed the light on the impact of Artificial Intelligence in supporting the recycling process through smart classification of devices, where the smartphone is our case study.

**METHODS:** Our study applies transfer learning as a special technique of Artificial Intelligence by fine-tuning the output layers of AlexNet as a pre-trained model and perform the implementation on a small-size dataset that contains 12 classes from 6 smartphone brands.

**RESULTS:** We evaluate the performance of our model by tuning the learning rate, choosing the best optimizer, and augmenting the original dataset to avoid overfitting. We found that the optimizer of Stochastic Gradient Descent with Momentum and  $3 \times 10^{-4}$  as a learning rate brings almost 98% model accuracy with generalization.

**CONCLUSION:** Our study supports automated e-waste recycling in decreasing the error-rate of e-waste sorting and investigates the advantages of applying transfer learning as the best scenario to overcome the rising challenges.

**Keywords:** Artificial Intelligence, Transfer Learning, Circular Economy, Automated E-Waste Recycling, Smart Cities.

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### 1. Introduction

The enormous use of digitalization has a profound impact on every domain. Many concerns are raised with the growth of urbanization, like pollution, traffic congestion, rising welfare costs, and last but not least growing waste streams. The concept of Circular Economy (CE) was primarily aimed to enhance the recovery of end-of-life of products lifecycle by optimal recycling them, reusing them as raw materials, reducing the need to extract new resources, and closing the product loop. Smart Cities have been suggested as a solution to tackle the aforementioned problems, driven by digitalization, and to promote a sustainable environment

through CE. In line with this, we discuss the role of digitalization, particularly Artificial Intelligence (AI), in the environmental technology domain and investigate how automated electrical and electronic waste (or the so-called e-waste) recycling can support shifting towards a sustainable environment, thus achieving CE goals. To achieve them efficiently, the classification of waste can maximize the performance of the whole process. Waste classification is a significant step for efficiently sorting and separating into different models and types. Therefore, the need for smart sorting is growing to support smart recycling.

The remainder of the paper is divided into the following sections: Section 1 introduces our research motivation, the importance of automated e-waste recycling driven by digitalization, and to achieve sustainable smart cities. Section

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