Development of a High-Fidelity 3D Dataset for Automated Construction and Demolition Waste Sorting

S.A.R.R. Suraweeraarachchi[1]*, U.G.U.P. Samarasekara[2], H.D.S.M. Jayawardhana[1], J.A.S.C. Jayasinghe[2], U. Jayasinghe[3], C.S. Bandara[2]

[1]*Department of Mechanical Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, 20400, Sri Lanka*
[2]*Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, 20400, Sri Lanka*
[3]*Department of Computer Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, 20400, Sri Lanka*
**e19393@eng.pdn.ac.lk*

The development of robotic sorting systems for construction and demolition waste relies heavily on physics-based simulations. However, a scarcity of specialized 3D datasets capturing the unique physical and visual features of such waste widens the simulation-to-real gap. To bridge this gap, this research introduces a scalable, multi-stage pipeline to generate high-fidelity, physics-enabled 3D models of irregular construction and demolition waste debris across various categories. Initially, the Segment Anything Model was used to isolate individual debris from a representative construction waste image dataset. These individual debris were reconstructed into 3D meshes using the TripoSG framework. Using Blender software, these meshes were post-processed by applying material textures, targeted transparency mapping for transparent and translucent materials, and precise scaling. Furthermore, material specific densities were assigned to each 3D object and additional modifiers were applied to account for hollow geometries. The processed 3D objects were integrated into the Webots simulation environment to evaluate robotic grasping performance and contact mechanics. The implemented pipeline successfully produced over twenty high-fidelity 3D waste objects categorized into five distinct material classes. Qualitative assessment in the Webots environment confirmed that the physics-based modeling resulted in realistic mechanical behaviors during robotic grasping of the 3D objects, with predictable friction-based interactions with the robotic gripper. The objects maintained consistent trajectories and realistic contact dynamics when placed on a simulated moving conveyor belt. Furthermore, YOLO-based object detection algorithms accurately identified the items with a precision of 91.20% and a mean average precision of 88.54%, proving that the applied visual textures provided sufficient feature depth. In conclusion, this research provides a scalable framework for generating high-fidelity 3D irregular construction and demolition waste, as well as a comprehensive 3D construction waste dataset which would serve as a resource for developing reliable autonomous construction waste sorting systems.

Keywords: construction and demolition waste, high-fidelity 3D dataset, robotic sorting, sim-to-real gap, Webots simulation

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