A Novel Evaluation of the Impact of Object Deformation on Real-Time Vision-Based Waste Classification Utilizing Low-Cost AI Systems

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Computer vision based artificial intelligence systems are increasingly explored as low-cost solutions to traditional systems in today's modern age. One such system is the current sensor-based recycling technologies. These depend on physical traits of the particular recyclable and require a number of complex machinery that requires precision and expertise to operate. While the convolutional neural network (CNN) that was created, modeled, and trained last year has demonstrated strong classification performance under controlled conditions, its reliability in real-time environments is less tested. Physical factors such as object deformation, orientation, and continuous motion may introduce visual variability that degrades inference accuracy. This project investigates how object deformation and uniform continuous motion affect the inference reliability of a low-cost CNN operating at constant conveyor speeds. A neural network trained on static images of recyclable materials was deployed in a real-time camera-based system using consumer-grade hardware. Model outputs (including class confidence matrices and inference latency/time) were recorded as objects passed through the camera's field of view. The highest value recorded for inference latency was approximately 450 milliseconds, around half a second. The average across all tested classes was found to be approximately 152.6 ms. This suggests that, if accurate, this CNN could make inferences in a timely enough manner to be plausible in real-world deployment. In terms of accuracy, the large majority of classes were accurately identified, even after severe deformation. Many of the inaccuracies can be attributed to significantly lower amounts of training data and visually ambiguous items.

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