Waste Classification with CNN

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***Abstract*—This paper presents a convolutional neural network (CNN)-based approach to waste classification. By leveraging an image dataset of organic and recyclable waste, the model achieves significant accuracy in identifying waste categories. The proposed system can assist in waste segregation to promote efficient recycling and sustainability.**

Keywords—*Waste classification, CNN, deep learning, image processing, recycling.*

I. Introduction

The increasing amount of waste generated globally has posed significant challenges for environmental sustainability and waste management. Effective waste segregation is essential for recycling processes, reducing landfill burden, and minimizing pollution. However, manual segregation is labor-intensive and error-prone, underscoring the need for automated systems. Recent advances in deep learning have revolutionized image recognition, providing tools for automating tasks such as waste classification.

This paper explores the application of convolutional neural networks (CNNs) in automating the identification of waste types. By categorizing waste as organic or recyclable, this system can support waste management facilities in achieving better recycling rates. Using a Kaggle-provided dataset, we designed a CNN model that processes images, extracts features, and predicts waste categories with high accuracy. This study aims to bridge the gap between AI research and practical environmental applications, emphasizing the importance of technology in promoting sustainability.

II. Dataset

The dataset utilized in this study was sourced from the Kaggle project "Waste Classification with CNN" (Kaggle link). It consists of images labeled as either "organic" or "recyclable," making it suitable for binary classification tasks. The training set includes 22,564 images, while the test set comprises 2,513 images. Each image is labeled with its corresponding category to facilitate supervised learning.
To ensure consistent input to the CNN model, all images were resized to a standard resolution of 224x224 pixels. This preprocessing step reduces computational complexity while retaining essential features. Additionally, data augmentation techniques, such as rotation, flipping, and scaling, were employed to increase dataset diversity. These techniques help mitigate overfitting by enabling the model to generalize better to unseen data. By providing a comprehensive dataset, this project underscores the importance of leveraging well-curated data for effective machine learning applications.

III. Methodology

A. Dataset Description

The dataset used for this project consists of images categorized into two classes: Organic and Recyclable. The training set contains 22,564 images, and the test set contains 2,513 images. All images were resized to 224x224 pixels for uniformity.

B. Data Processing

Data preprocessing is a crucial step in preparing the dataset for training. First, the images were resized to 224x224 pixels to standardize their dimensions, allowing seamless input into the CNN model. Next, pixel values were normalized to fall within the [0, 1] range by dividing each pixel value by 255. This normalization ensures consistent feature scaling, improving model convergence during training. To increase model robustness, data augmentation was performed. Augmentation techniques, such as flipping, random rotations, and brightness adjustments, were applied to artificially expand the dataset and simulate variations commonly encountered in real-world data.

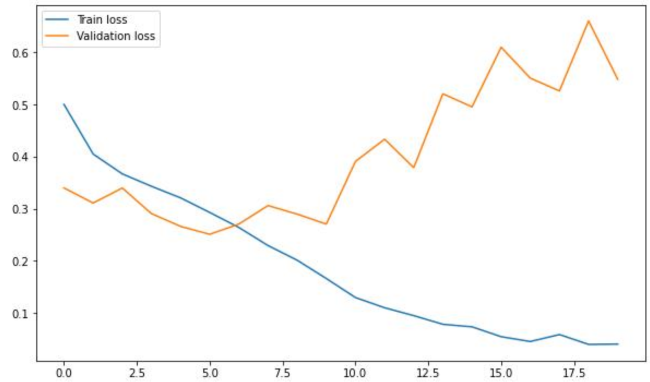
C. Model Architecture

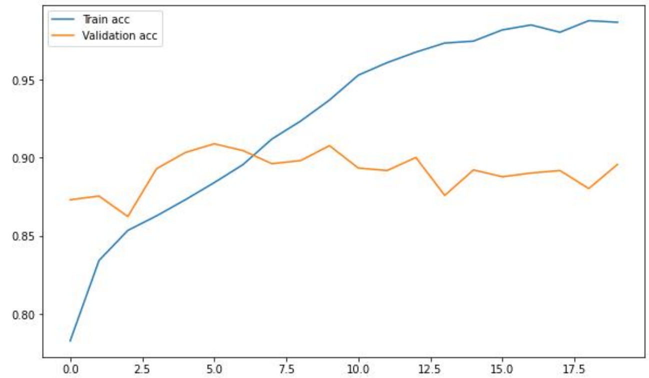
The CNN architecture employed in this study consists of multiple convolutional layers for feature extraction, interspersed with max-pooling layers to reduce dimensionality. The first convolutional layer uses 32 filters, followed by layers with 64 and 128 filters, respectively. Each convolutional layer employs a ReLU activation function, enabling the model to learn complex patterns in the image data. A fully connected dense layer with 256 neurons processes the extracted features, followed by a softmax output layer for binary classification. To prevent overfitting, dropout layers with a dropout rate of 50% were included. The model was compiled using the Adam optimizer, known for its efficient gradient descent performance, and binary cross-entropy loss for accuracy in binary classification.

D. Training Setup
The model was trained for 20 epochs with a batch size of 256. The dataset was split into training and validation sets, with accuracy and loss metrics tracked during training.

IV. Results

The model was trained on the augmented dataset for 20 epochs using a batch size of 256. The training process demonstrated consistent improvement in accuracy and reduction in loss during the initial epochs. By the 20th epoch, the model achieved a training accuracy of 98.85% and a validation accuracy of 90.57%. Validation loss was recorded at 0.548, indicating effective generalization of the model.



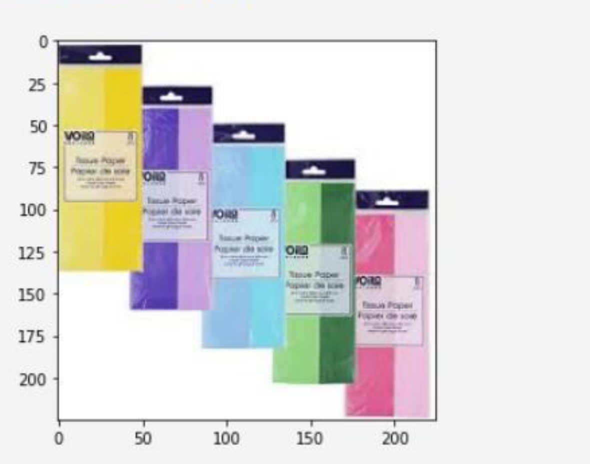


To visualize the training progress, plots were generated for accuracy and loss metrics. The accuracy plot revealed a steady upward trend, while the loss plot showed a downward trajectory. Furthermore, the model's predictions were tested on unseen images, achieving precise classification of organic and recyclable waste categories. These results underscore the CNN model's effectiveness in recognizing complex patterns in waste images, making it a viable tool for automated waste management. Figures below present sample dataset images and model performance metrics.

Additionally, the dataset distribution is visualized using pie charts, highlighting the balance between the two classes. Example outputs from the model on test images are shown, validating its efficacy.

This image -> Recyclable

This image -> Organic



V. Discussion

The results indicate that CNN-based models can effectively classify waste images with high accuracy. However, challenges like misclassification due to similar visual characteristics between classes remain. Future improvements could involve using larger datasets and more complex architectures, such as transfer learning with pre-trained models.

VI. Conclusion and Future Work

This project successfully implemented a CNN model for waste classification, achieving over 90% accuracy. The work demonstrates the potential of deep learning in automating waste management. Future work could extend this approach to include additional classes and real-time deployment in smart waste bins. This paper highlights the potential of deep learning for addressing real-world environmental challenges. The proposed CNN model for waste classification achieves high accuracy in identifying organic and recyclable waste categories, making it a promising solution for automating waste segregation. By leveraging a well-curated dataset and advanced machine learning techniques, this study bridges the gap between AI research and practical waste management applications. Future work may involve expanding the model's scope to include more waste categories, such as hazardous or e-waste. Additionally, integrating the model into real-time waste management systems using IoT-enabled devices could further enhance its practical utility. This research emphasizes the transformative potential of AI in fostering sustainable waste management practices and serves as a foundation for future innovation in this field.

VI. Acknowledgment

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VII. References

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