Project Report

Solid Waste Classification System

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Abstract

Solid waste management has become one of the most critical global challenges due to rapid urbanization and population growth. Improper waste segregation leads to environmental pollution, inefficient recycling, and increased landfill usage. This project presents a Solid Waste Classification System using Machine Learning, specifically leveraging Convolutional Neural Networks (CNN) with a pre-trained MobileNetV2 model. The proposed system automatically classifies waste into multiple cat... A dataset sourced from Kaggle in JSON format was used to train and evaluate the model. The model achieved an accuracy of 95% on the test dataset. The project also integrates a Flask-based web application to provide a user-friendly interface for uploading and classifying waste images in real time. This work demonstrates how artificial intelligence can be applied effectively to environmental sustainability and waste management.

Introduction

The generation of solid waste has increased drastically due to urbanization, industrialization, and population growth. Manual waste segregation is not only time-consuming and inefficient but also exposes workers to health hazards. An automated system that classifies waste using machine learning techniques can greatly improve recycling efficiency and reduce human effort. The Solid Waste Classification System using Machine Learning aims to classify various types of waste automatically using image data. By employing Convolutional Neural Networks (CNN), the system learns to extract visual features from waste images and categorize them accurately. The project integrates deep learning with web technologies to deliver a complete real-time solution that can be deployed in smart cities, recycling centers, or public waste collection points.

Proposed Work / Methodology

The proposed system uses supervised learning with a Convolutional Neural Network (CNN) to classify waste images into predefined categories. The major phases of the methodology include: 1. Data Collection and Preprocessing The dataset was collected from Kaggle, consisting of thousands of labeled waste images stored in JSON format. Each image was annotated with its respective waste category. The dataset includes 12 major categories: Plastic, Battery, Metal, Biological, Brown Glass, Cardboard, Clothes, Green Glass, Paper, Shoes, Trash, and White Glass. The images were preprocessed through resizing, normalization, and augmentation techniques to improve model generalization and handle dataset imbalance. 2. Model Selection and Training A Convolutional Neural Network (CNN) architecture was chosen for its strong performance in image classification tasks. Specifically, the MobileNetV2 pre-trained model was used due to its lightweight design and efficient feature extraction capabilities. The model was fine-tuned on the Kaggle waste dataset using TensorFlow and Keras frameworks. 3. Model Evaluation After training, the model was evaluated on unseen test data. Performance metrics such as accuracy, precision, recall, and F1-score were used to assess the system's effectiveness. The trained model achieved an overall accuracy of 95% with strong generalization capabilities. 4. Web Application Development A Flask-based web interface was developed to make the model accessible and user-friendly. The backend communicates with the trained CNN model and performs real-time classification when an image is uploaded by the user. The system displays the predicted category instantly. 5. System Architecture The project follows a client-server architecture: - Frontend: HTML, CSS, and JavaScript for the user interface. - Backend: Flask framework for routing, image handling, and model prediction. - Database: MySQL for storing user and image metadata.

Data Structures and Algorithms Used

Data Structures: - Arrays and Matrices (NumPy): Used to store and manipulate image pixel data efficiently. - JSON Objects: Used for dataset storage and annotation handling. - DataFrames (pandas): Used for preprocessing and organizing dataset attributes. - Database Tables (MySQL): Used to store metadata and classification results. Algorithms: - Convolutional Neural Network (CNN): Used for feature extraction and classification. - MobileNetV2: A lightweight pre-trained CNN model used for transfer learning. - Activation Functions: ReLU for hidden layers, Softmax for output layer. - Optimization Algorithm: Adam optimizer for efficient gradient descent. - Cross-Entropy Loss Function: Used to minimize classification error.

Result Analysis

The performance of the model was evaluated using test data. The following results were obtained: Accuracy: 95% Precision: 94% Recall: 93% F1-Score: 94% The confusion matrix indicated that the model performed exceptionally well across all waste categories, with minimal misclassifications between similar classes like glass and plastic. The MobileNetV2-based CNN architecture demonstrated high accuracy with reduced computational cost, making it suitable for deployment on web or mobile platforms. A Flask web interface allows users to upload waste images and receive instant classification results, making it both practical and scalable. The use of Flask-CORS ensures secure cross-origin requests, and Werkzeug provides secure file upload functionality.

Conclusion

The Solid Waste Classification System using Machine Learning successfully automates the process of waste segregation. By employing a CNN-based deep learning model (MobileNetV2), the system achieved 95% classification accuracy, demonstrating high reliability and efficiency. The integration of the trained model with a Flask web application enables real-time waste classification, providing a complete end-to-end solution for smart waste management. This approach can be deployed in municipal systems, recycling facilities, or IoT-based waste bins to promote environmental sustainability. Future enhancements may include: - Extending the model to handle video-based waste detection in real time. - Deploying the model on mobile devices using TensorFlow Lite. - Expanding the dataset to cover more waste categories and real-world variations. This project demonstrates the potential of AI and machine learning in solving pressing environmental problems and contributes toward building smarter, cleaner, and greener cities.

Tools and Libraries Used

Flask - Web application framework Flask-CORS - Cross-origin resource sharing TensorFlow/Keras - Deep learning framework MobileNetV2 - Pre-trained neural network model OpenCV (cv2) - Image processing NumPy - Numerical computations Pillow - Image handling MySQL Connector - Database connectivity Werkzeug - File upload security