Assignment No 3

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Problem Statement: Implement Image Classification using Convolutional Neural Networks (CNNs) for Multiclass Classification

Objective

The objective is to build an image classification system using Convolutional Neural Networks (CNNs) for multiclass classification, where input images are categorized into one of several classes (e.g., animals, vehicles, or handwritten digits). The goal is to leverage CNNs for automatic feature extraction and classification with high accuracy.

Theory

Image Classification is the process of assigning a label to an image from a predefined set of categories. Traditional machine learning required manual feature extraction, but CNNs automate this process.

Key theoretical points:

* Convolutional Layers: Apply filters to extract local features (edges, shapes, textures).
* Pooling Layers: Reduce dimensionality and retain important features.
* Fully Connected Layers: Combine extracted features for decision-making.
* Softmax Activation: Used in the output layer for multiclass classification; provides probability distribution across multiple classes.
* Loss Function: Categorical Cross-Entropy is used to optimize performance.

Methodology

1. Dataset Preparation:
   * Collect and preprocess dataset (e.g., CIFAR-10, MNIST, custom images).
   * Normalize pixel values and perform data augmentation if necessary.
   * Split dataset into training, validation, and testing sets.
2. Model Design (CNN Architecture):
   * Input layer: accepts image data.
   * Convolutional layers: extract low-to-high-level features.
   * Pooling layers: downsample feature maps.
   * Dropout/Batch Normalization: prevent overfitting and stabilize learning.
   * Dense layers: fully connected layers for classification.
   * Output layer: softmax activation with n neurons (where n = number of classes).
3. Training:
   * Use optimizers like Adam/SGD.
   * Loss function: Categorical Cross-Entropy.
   * Train for multiple epochs with backpropagation.
4. Evaluation:
   * Test on unseen images.
   * Metrics: Accuracy, Precision, Recall, F1-Score.
5. Prediction:
   * Input an image → CNN extracts features → Softmax assigns class label.

Advantages

* Automated feature extraction without manual engineering.
* Highly effective for image-based tasks.
* Scalable to large and complex datasets.
* Can generalize well with proper training.

Limitations

* Requires large labeled datasets for training.
* High computational cost (needs GPUs for faster training).
* Prone to overfitting without regularization.
* Model interpretability is limited (black-box nature).

Applications

* Healthcare: Medical image analysis (X-ray, MRI, CT scans).
* Autonomous Vehicles: Traffic sign and object detection.
* Retail/E-commerce: Product categorization.
* Agriculture: Plant disease detection.
* Security: Face recognition and surveillance.
* Everyday AI: Handwritten digit recognition (MNIST), object classification (CIFAR-10).

Working / Algorithm

1. Input image is resized and normalized.
2. CNN applies convolutional filters to extract features at different levels.
3. Pooling layers downsample features to reduce dimensionality.
4. Flattened feature maps are passed to fully connected layers.
5. Output layer applies softmax activation, producing probability values for each class.
6. The class with the highest probability is chosen as the final prediction.

Conclusion

Convolutional Neural Networks provide a powerful and efficient solution for multiclass image classification. They outperform traditional machine learning methods by automatically learning spatial hierarchies of features. Although resource-intensive, CNNs form the foundation of modern computer vision applications and are widely used in domains like healthcare, automotive, agriculture, and security.