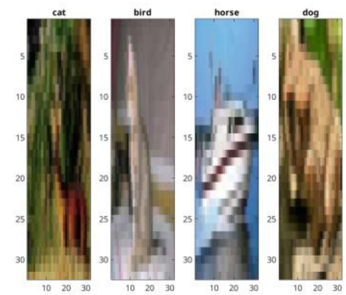
Evaluating Supervised Learning Models for CIFAR-10 Image Classification

Introduction

In this project, we tackle the problem of supervised image classification using the CIFAR-10 dataset. The aim is to classify images into various categories, such as animals and objects, by training machine learning models to identify patterns in pixel data. Image classification is crucial in many applications, including autonomous vehicles, facial recognition, and content-based image retrieval. For this coursework, we explore multiple machine learning algorithms, including K-Nearest Neighbors, Support Vector Machine, and Decision Tree classifiers to evaluate their effectiveness in classifying images from CIFAR-10. We will identify the most accurate and computationally efficient model for this task.

Data and Preparation



The dataset consists of 60,000 32x32 color images in 10 classes, with 6,000 images per class. We randomly selected three classes for classification. The dataset was then split into training and testing sets, each containing 9,000 images, to ensure balanced class representation. Images were reshaped to a 2D format for training with machine learning models. We standardized pixel values to improve model accuracy and consistency. A Mersenne Twister RNG was seeded with a student ID for reproducibility. These images represent samples used in our training and testing processes ("cat," "bird," "horse," and "dog"). These images exemplify the challenge in distinguishing between classes due to variability in color, shape, and texture, highlighting the importance of selecting robust models for classification.

Methodology

For this image classification task we evaluated three different models. KNN is a simple model that relies on calculating distances between data points, making it suitable for small- to medium-sized datasets. We experimented with both Euclidean and Cosine distance metrics to explore similarity measures. While KNN can be computationally expensive for large datasets, it is useful here to provide a baseline for performance and to assess class separability based on distance. Support Vector Machine is a powerful classifier, especially suited for tasks where classes are linearly separable or can be separated using kernel functions. We employed the linear SVM for multi-class classification making it computationally efficient while maintaining robustness. SVM is often effective on high-dimensional data like the reshaped CIFAR-10 images and generally provides high accuracy. Decision Trees capture non-linear relationships between features, making them well-suited for tasks with complex, hierarchical data structures. They are prone to overfitting but visualize the decision-making processes, which is valuable in error analysis and understanding feature importance.

Results

The KNN model with Euclidean distance achieved an accuracy of 51% with a confusion matrix highlighting misclassifications among similar classes. The KNN with Cosine distance produced similar results but had marginal differences in accuracy and time. The SVM model achieved the highest accuracy indicating its suitability for this dataset, although it required significant computation time. The Decision Tree model was faster than both KNN and SVM but had lower accuracy making it less effective for complex patterns in image data. Key observations include that SVM excelled in accuracy, while Decision Tree provided a computationally inexpensive alternative with reduced precision.

```
Training label distribution:
   1.0e+03 *

    0.0010         0         0
    0.0020         0         0
    0.0030    3.0120    0.0335
    0.0040         0         0
    0.0050    2.9850    0.0332
    0.0060    3.0030    0.0334

Testing label distribution:
   1.0e+03 *

    0.0010         0         0
    0.0020         0         0
    0.0030    2.9880    0.0332
    0.0040         0         0
    0.0050    3.0150    0.0335
    0.0060    2.9970    0.0333
```

Conclusion

The SVM model is recommended for this classification task due to its superior accuracy, despite its computational demands. This model is best suited for applications where accuracy is prioritized over speed. While the Decision Tree model was faster, its lower accuracy limits its use in scenarios requiring high precision. Future research could explore other deep learning approaches, such as convolutional neural networks to improve classification accuracy further while potentially reducing the computational complexity compared to SVM.