Task: 2 - Multi-class classification using KNN classifier

Dataset: CIFAR-10

Introduction

The objective of this task is to implement a K-Nearest Neighbors (KNN) algorithm from scratch to classify images from the CIFAR-10 dataset. CIFAR-10 consists of 60,000 32 x 32 color images across 10 distinct classes. The core challenge involves evaluating the model's performance across various K values and distance metrics to identify the optimal configuration for image recognition.

Methodology

- **Preprocessing**: Images were flattened from 32 x 32 x 3 tensors into 3,072-dimensional vectors and normalized to a range of [0, 1].
- **Experimental Design**: A grid search was performed across K in {3, 4, 9, 20, 47} and five distance metrics: Euclidean, Manhattan, Minkowski (p=3), Cosine Similarity, and Hamming Distance.

Experimental Results

The model was tested using the required K values: 3, 4, 9, 20, and 47.

Accuracy Comparison Table:

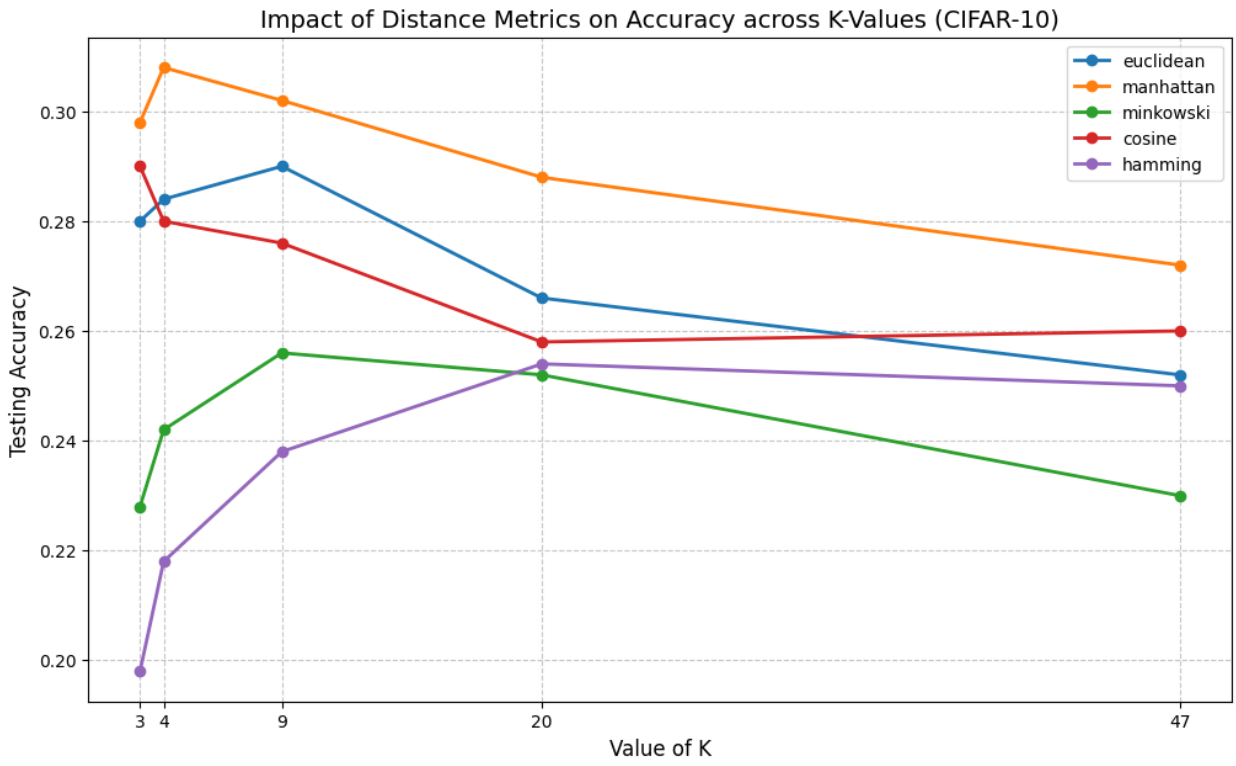
K Value	Euclidean	Manhattan	Minkowski	Cosine	Hamming
3	28.00%	29.80%	22.80%	29.00%	19.80%
4	28.40%	**30.80%**	24.20%	28.00%	21.80%
9	29.00%	30.20%	25.60%	27.60%	23.80%
20	26.60%	28.80%	25.20%	25.80%	25.40%
47	25.20%	27.20%	23.00%	26.00%	25.00%

3.2 Best Model Summary

Based on the testing accuracy, the best-performing model was identified:

- **Best K:** 4
- **Best Distance Metric:** Manhattan Distance
- **Highest Accuracy:** 30.80%

The plot below illustrates the impact of different distance metrics on accuracy across varying values of K.



Detailed Evaluation of the Optimal Model

The model achieving the highest performance utilized a **Manhattan distance metric** with **K=4**. Below are the comprehensive evaluation metrics.

Confusion Matrix Analysis

The confusion matrix provides a detailed breakdown of correct and incorrect classifications for each of the 10 classes (0-9). Rows represent the **Actual Class**, while columns represent the **Predicted Class**.

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0: Airplane	**25**	0	6	1	6	0	2	2	13	2
1: Automobile	4	**9**	4	3	8	0	3	0	8	2
2: Bird	8	0	**21**	3	9	4	4	0	2	0
3: Cat	2	0	10	**10**	9	8	8	0	2	0
4: Deer	3	0	10	2	**14**	1	5	0	4	1
5: Dog	6	0	11	4	12	**8**	5	1	1	0
6: Frog	1	1	15	4	19	0	**12**	0	2	0
7: Horse	1	1	8	7	12	3	3	**8**	3	1
8: Ship	8	3	3	1	5	1	0	0	**35**	1
9: Truck	5	2	6	4	7	0	2	3	15	**12**

Precision and Recall Performance

These metrics define the model's reliability for each specific class.

- **Precision:** Out of all instances predicted as a certain class, how many were actually that class?

- **Recall:** Out of all actual instances of a class, how many did the model correctly find?

Class ID	Class Name	Precision	Recall
0	Airplane	0.40	0.44
1	Automobile	0.56	0.22
2	Bird	0.22	0.41
3	Cat	0.26	0.20
4	Deer	0.14	0.35
5	Dog	0.32	0.17
6	Frog	0.27	0.22
7	Horse	0.57	0.17
8	Ship	0.41	0.61
9	Truck	0.63	0.21

Precision and Recall

- **Highest Precision:** Class 9 (Truck) - **0.63**
- **Highest Recall:** Class 8 (Ship) - **0.61**
- **Average Precision:** ~0.33
- **Average Recall:** ~0.31

Inferences and Observations

Based on the plots and results, the following inferences were observed:

1. **Metric Impact:** Manhattan Distance consistently outperformed Euclidean distance for this high-dimensional image data, suggesting that absolute differences are more descriptive of pixel-wise similarity in CIFAR-10.
2. **Neighborhood Size:** Accuracy generally peaked at lower K values (4 or 9) and decreased as K reached 47. This indicates that local features are more representative than global averages for these images.
3. **Computational Complexity:** KNN is a "lazy learner" and requires significant time for distance calculations during the testing phase, especially as the number of features increases.
4. **Feature Limitations:** The maximum accuracy of ~31% indicates that raw pixel values alone are insufficient for perfect classification, as they do not account for spatial patterns or shapes.