K-Nearest Neighbors (KNN) in RISC-V Assembly

1. Label Storage

a. Training Labels
Training labels are stored during the init_sample_data routine, specifically in init_train_labels:

```
    00000300 <init_train_labels>:
    300: auipc x20, 0x10002
    304: addi x20, x20, -768 ; x20 points to the label array
    ...
    318: rem x24, x21, x23 ; class = index % 10
    320: sb x24, 0(x25) ; store label
```

- x21: Training sample index
- x23: Constant 10 (number of classes)
- x24: Label calculated as index % 10
- x25: Destination address of the label

Labels are stored as bytes using sb.

b. Ground Truth Labels
Generated similarly during init_test_labels (assumed symmetry with training).

c. Predicted Labels

```
    0000028c: sb x8, 0(x14) ; stores the predicted label
```

- x8: Predicted class with most votes
- x14: Address to store prediction

2. Prediction Process (Predict + Compare)

a. Nearest Neighbor Search
- dist_loop and pixel_loop compute Euclidean distances.
- x10 accumulates the squared pixel differences.
- Clamped to a max (65535).
- Distances stored via: sw x10, 0(x12)

b. Selecting K Nearest Neighbors
- K=5 smallest distances are tracked.
- Structure: {distance, label} (8 bytes each)
- Inserted via:

```
    sw x10, 0(x15)
    sb x17, 4(x15)
```

c. Weighted Voting

```
    div x14, x13, x11 ; weight = 1000 / distance
    add x17, x17, x14 ; add to vote count
```

d. Determining Final Class

```
    bge x10, x14, next_class ; max vote logic
```

3. Comparison with Actual Label and Accuracy

```
    lbu x13, 0(x12) ; actual label
    sb x8, 0(x14) ; predicted label
    bne x8, x13, not_correct
    addi x5, x5, 1 ; hit counter
```

- x8: predicted label
- x13: actual label
- x5: number of correct predictions

Final result via: addi x10, x5, 0 followed by ecall.

4. How is >90% Accuracy Achieved?

- Training/test images have a predictable pattern: pixel = class + pixel_index.
- Images of same class have small distances.
- Weighted voting emphasizes closer neighbors.
- With 128 training & 10 test samples, neighbors are correctly matched.

5. Summary of Register/Memory Usage

Purpose	Base Register	Instruction	Memory
Training Labels	x20	sb x24, 0(x25)	128-byte array
Test Labels	x20	sb (assumed)	10-byte array
Predicted Labels	x14	sb x8, 0(x14)	10-byte array
Final Comparison	x13, x8	bne x8, x13	Memory comparison