Q6,7 - Zhangsheng Lai (1002554)

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Q6. Alternative ways to represent input images as vectors In question 1 earlier, we see that the alternative ways to represent the input images a vectors include using (1) the mean and standard deviation of the color channel (2) color histogram, where the second option has a few sub-variations, but we shall consider only the 3D histogram which is what was used in the earlier questions.

On the surface, it seems like using the pixels to represent images may seem like a good idea as there is little loss of the information, compared to using (1) which gives a point estimate and variance of the image, which is not descriptive enough of the image as much of the information is lost. However, if we use the pixel values from the input images, each image is represented by a `(3072,)` vector; which is a high dimensional input which our simple model might not be able to handle.

By considering using the 3D histogram features, we reducing the dimensions of the features that is fed to our model but at the same time, we reduce the loss of information. The 3D histogram describes the joint distribution of the red, blue and green values for different intervals, depending on the number of bins choosen to generate the historgram. In my implementation, 8 bins were chosen, thus each bin is of interval size 32 and reduces the dimensions of the features to 512, much managable than the pixel values. The information loss is also reduced as it sorts the pixels into the different bins, which gives us the distrbution of the pixels with respect to the red, blue, green levels.

Thus we observe the following when we use the 3D histogram feature when compared against the pixel features:

- Q2 (logistic loss): Test accuracy improved from 50% to 57.5%
- Q3 (hinge loss): Test accuracy improved from 55% to 67.5%
- Q4 (k nearest neighbors): Test accuracy dropped from 47.5% to 42.5%

Q7. Training using augmented dataset Using Google image search, 20 images from each class was added to the original training set, increasing the size of training set to be twice larger than the initial. As the new images added to the training set is not of the same dimensions as the original images, we cannot use the pixel values as the features. The features from the 3D histogram will be used as the features. As we are doing a multi-class classification, the one-vs-all approach like in question 5 will be used here.

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In [1]: import cv2
        import os
        import numpy as np
```