CENG 483

Introduction to Computer Vision

Fall 2023-2024

Take Home Exam 1

Instance Recognition with Color Histograms

Full Name: **Derya TINMAZ**

Student ID: **2380947**

1 3D Color Histogram (RGB)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
128	0.75	1.	0.06
64	0.99	1.	0.13
32	1.	1.	0.125
16	1.	1.	0.115

Table 1: Top-1 accuracy results using 3D color histogram (RGB).

- As the quantization interval decreases from 128 to 16, the accuracy scores generally improve for all query data sets. This is because a smaller quantization interval means that more distinct color values are considered, resulting in a more detailed representation of the image data.
- Query 2 consistently has the highest accuracy (1.) across all quantization intervals, indicating that the 3D color histogram method performs very well in recognizing patterns in this data set.
- Since query set 2 is left-rotated support images, these results show that changing the orientation of the image does not effect the rgb color histogram similarity, because when an image is rotated, the arrangement of colors may change, but the color content itself remains relatively consistent.
- Query 1 also performs well, with accuracy scores above 0.75 in all cases.
- Since query set 1 is a zoomed version of the support images, these results show that zooming the image has some impact on the rgb histogram result, depending on the interval.
- On the other hand, Query 3 consistently exhibits the lowest accuracy, as it consists of color-changed versions of the support images. This observation suggests that the 3D color histogram method may not be well-suited for capturing the characteristics of this particular dataset. This is expected, as histograms compare colors to identify similarities.

2 3D Color Histogram (HSV)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
128	0.835	1.	0.195
64	1.	1.	0.18
32	1.	1.	0.14
16	1.	1.	0.125

Table 2: Top-1 accuracy results using 3D color histogram (HSV).

- In the HSV color space, the top-1 accuracy scores are consistent across all quantization intervals, indicating that the performance remains very stable as the quantization interval changes.
- In contrast, the RGB color space showed a more noticeable improvement in accuracy as the quantization interval decreased, suggesting that HSV may be less sensitive to the quantization level.
- Similar to the RGB results, Query 2 has the highest accuracy (1.0) in the HSV space. This indicates that the HSV-based 3D color histogram is very effective in recognizing patterns in this data set.
- Since query set 2 is left-rotated support images, these results show that changing the orientation of the image does not effect the similarity in the hsv color space.
- Query 1 also maintains a high accuracy of 1.0 in the HSV space, just as it did in the RGB space.
- Since query set 1 is a zoomed version of the support images, these results show that zooming the image has less impact on the hsv histogram than rgb histogram.
- Query 3, which had lower accuracy in the RGB space, still exhibits the lowest accuracy in the HSV space, which shows that color changed version of the support images' hsv histograms are also very different from the support images' histograms.
- In both HSV and RGB color spaces, the accuracy improves as the quantization interval decreases. However, the absolute accuracy values in the HSV color space tend to be higher compared to the RGB color space for the same quantization intervals.
- This difference may be due to HSV's representation, which separates color information into Hue, Saturation, and Value components, making it more robust to variations in lighting conditions. In contrast, RGB does not have this separation, and variations in lighting can affect the color representation.

3 Per-Channel Color Histogram (RGB)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
128	0.56	1.	0.04
64	0.9	1.	0.11
32	0.975	1.	0.17
16	0.98	1.	0.19
8	0.985	1.	0.195

Table 3: Top-1 accuracy results using per-channel color histogram (RGB).

- As the quantization interval decreases from 128 to 8, the top-1 accuracy scores generally improve for all query data sets. This is consistent with the behavior observed in previous discussions, where finer quantization intervals lead to better accuracy.
- Query 1, consisting of zoomed versions, also demonstrates good performance. Accuracy scores improve as the quantization interval decreases, particularly in the case of the 3D histogram, with only a slight decrease in performance.
- Query 2 consistently achieves the highest accuracy (1.0) across all quantization intervals. This indicates that the per-channel color histogram method performs exceptionally well in recognizing patterns in this left-rotated data set, just as the 3D histogram does.
- Query 3 still exhibits the lowest accuracy, but the scores improve as the quantization interval decreases, which suggests that finer quantization captures more information about the colors in this color changed query set.
- Similar to 3D histograms, the primary factor affecting the accuracy differences is the quantization level. A smaller quantization interval allows for a more detailed representation of colors, which can help in capturing finer details and variations in the images.
- Per-channel color histograms capture color information separately for each RGB channel, making them useful for recognizing channel-based patterns. In contrast, 3D color histograms capture the color distribution in a combined manner and may be less sensitive to channel-specific variations. This is the reason per-channel histograms performed slightly better on query set 3.

4 Per-Channel Color Histogram (HSV)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
128	0.645	1.	0.15
64	0.975	1.	0.235
32	1.00	1.	0.225
16	1.00	1.	0.215
8	1.00	1.	0.27

Table 4: Top-1 accuracy results using per-channel color histogram (HSV).

- In both HSV and RGB color spaces, top-1 accuracy improves as the quantization interval decreases. This similarity suggests that the effect of quantization on accuracy is consistent across color spaces.
- Query 2 consistently has the highest accuracy (1.0) in both HSV and RGB spaces, indicating that comparing rotated images is well-suited for both color representations.
- Query 1, the zoomed version, also exhibits high accuracy across quantization intervals in both HSV and RGB for most of the intervals.
- Query 3 consistently has the lowest accuracy in both color spaces, since it is color changed verison, and the accuracy generally improves as the quantization interval decreases.
- In both HSV and RGB color spaces, the accuracy improves as the quantization interval decreases. However, the absolute accuracy values in the HSV color space tend to be higher compared to the RGB color space for the same quantization intervals.
- This difference may be due to HSV's representation, which separates color information into Hue, Saturation, and Value components, making it more robust to variations in lighting conditions. In contrast, RGB does not have this separation, and variations in lighting can affect the color representation.

Best Configuration

- Color space: HSV color space
- Quantization interval for 3D color histogram: 64
- Quantization interval for per-channel color histogram: 8

5 Grid Based Feature Extraction - Query set 1

Histogram Type	Spatial Grid			
	2×2	4×4	6×6	8×8
3D	1.	1.	1.	1.
Per-Channel	1.	1.	1.	1.

Table 5: Top-1 accuracy results on query set 1.

- The top-1 accuracy results for Query set 1 in the HSV color space, using the 3D color histogram with an interval of 64 and per-channel color histogram with an interval of 8, were 1, without the use of grids.
- Using different sized grids did not change the results; it still works well for all grid sizes.
- In query set 1, the images are zoomed versions of the support images, and since there is no color or orientation change, it is able to detect patterns in the images well by averaging grid similarities.

6 Grid Based Feature Extraction - Query set 2

Histogram Type	Spatial Grid			
	2×2	4×4	6×6	8×8
3D	0.585	0.49	0.425	0.38
Per-Channel	0.71	0.62	0.545	0.56

Table 6: Top-1 accuracy results on query set 2.

- The top-1 accuracy results for Query set 2 in the HSV color space, using the 3D color histogram with an interval of 64 and per-channel color histogram with an interval of 8, were 1, without the use of grids.
- Query set 2 consists of rotated versions of support images.Without using grids, since the color distributions do not change, it worked well.
- Using grids significantly reduces performance because when dividing the image into regions of a rotated image and comparing it with the regions of the original image, the similarity decreases as expected.
- As the number of grids increases, the performance gets lower in both 3d and per-channel histograms.
- In all cases, the per-channel histogram worked better than the 3D histogram. I believe it is because in the HSV color space, 3D histograms look for relationships in terms of hue, saturation, and lightness combined, which is expected to be lower compared to per-channel similarity.

7 Grid Based Feature Extraction - Query set 3

Histogram Type	Spatial Grid			
	2×2	4×4	6×6	8×8
3D	0.245	0.3	0.32	0.325
Per-Channel	0.42	0.61	0.695	0.765

Table 7: Top-1 accuracy results on query set 3.

- The top-1 accuracy results for Query set 3 in the HSV color space, using the 3D color histogram with an interval of 64 was 0.18 and per-channel color histogram with an interval of 8 was 0.27, without the use of grids.
- Query set 3 consists of color-changed versions of the support images. That's the reason why the results for both 3D and per-channel histograms were poor, as they rely on color relationships and similarities between images, which were affected by the color changes in query set 3.
- The performance improved significantly when using grids despite the color changes in query set 3.
- I think the reason for the improved performance is that grid-based feature extraction considers the average of local similarities. When using the HSV color space and increasing the number of grids, patterns become easier to recognize because the analysis focuses on smaller areas.
- In all instances, the per-channel histogram outperformed the 3D histogram, similar to the previous query set. This is because 3D comparisons seek more complex similarities than per-channel comparisons.

8 Additional Comments and References

- The OpenCV (cv2) library is utilized to read images and convert them from the BGR color space to the RGB color space (not used for conversion to HSV color space).
- The functions numpy.bincount(), numpy.add(), and numpy.stack() are employed for efficient implementation.