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# CENG 483

## Introduction to Computer Vision

Fall 2023-2024

### Take Home Exam 1

#### Instance Recognition with Color Histograms

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## 1 3D Color Histogram (RGB)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
16	1.0	1.0	0.145
32	1.0	1.0	0.12
64	0.995	1.0	0.14
128	0.735	1.0	0.05

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

- By investigating query sets, images in the Query Set 1 are zoomed versions of the Support images. Furthermore, images in the Query Set 2 are rotated versions of the Support images and images in the Query Set 3 have different color values than Support images in the corresponding pixels. When we look at the experiments, for the Query Set 1, as quantization interval increases, Top-1 accuracy decreases after the interval 64. Since number of bins used in histograms decreases (more color values belong to the same bin) as interval increases, that is understandable. However, even in the interval 64, accuracy is still nearly equal to 1 (just 1 image is retrieved wrong). For Query Set 2, Top-1 accuracy is 1 for all quantization intervals since color values of images are identical (globally) with the Supporting counterparts even they are rotated. For Query Set 3, Top-1 accuracies are not good because color values of images are very different than the Supporting counterparts. Hence, even there is a 0.02 increase in accuracy in transition between intervals 32 and 64, accuracy decreases drastically in the interval 128.

## 2 3D Color Histogram (HSV)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
16	1.0	1.0	0.15
32	1.0	1.0	0.16
64	1.0	1.0	0.205
128	0.805	1.0	0.225

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

- Overall, Top-1 accuracies in 3D histogram for HSV color space are better than RGB counterparts. For Query Set 1, accuracy is 1 for the interval 64 and there is an increase by 0.07 for the interval 128 by the RGB counterpart. For Query Set 2, all accuracies are 1 so there is no change. For Query Set 3, Top-1 accuracies are higher for all intervals than RGB counterparts. Moreover, accuracy is increasing as interval is increasing. Although images in Query Set 3 have different color values than Support images, converting their color space to HSV increase the probability for matching their color histograms. Thus, for matching color histograms, working with HSV color space is a better choice.

## 3 Per-Channel Color Histogram (RGB)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
8	0.975	1.0	0.185
16	0.97	1.0	0.19
32	0.97	1.0	0.17
64	0.915	1.0	0.14
128	0.555	0.995	0.04

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

- For Query Set 1, Top-1 accuracy is decreasing as interval is increasing. Up to interval 64, accuracy is high (0.915 in the interval 64). However, in the interval 128, accuracy decreases dramatically (accuracy is down from 0.915 to 0.555). For Query Set 2, except the interval 128, accuracies are 1. For the interval 128, accuracy is 0.995 so there is 1 image that is retrieved wrong. Since the number of bins for each channel is 2 for the interval 128, other than the correct Supporting image, there is at least one more Supporting image that has the same number of color values belonging to same bins as the query image. That should be the reason for the false retrieved Support image. For Query Set 3, Top-1 accuracy is decreasing as interval is increasing. Although there is a 0.05 increase in accuracy from the interval 8 to 16, accuracy is going to decrease after the interval 16. Hence, it decreases drastically (0.1) in the interval 128.
- Overall, for Query Set 1 and 2, accuracies in 3D color histograms are slightly higher than per-channel color histograms. That is most probably because total number of bins in 3D color histograms per interval is higher than per-channel color histograms ( $\#bins * \#bins * \#bins$  vs  $\#bins + \#bins + \#bins$ ) and Query Set 1 images are zoomed versions of Support images (color values are similar to Supporting parts) and Query Set 2 images are just rotated versions of Supporting images (color

values are same). Also, in per-channel color histograms, we look each channel separately and take the average of total matching. However, for Query Set 3, accuracies are higher in per-channel color histogram than 3D color histogram.

## 4 Per-Channel Color Histogram (HSV)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
8	1.0	1.0	0.34
16	1.0	1.0	0.325
32	1.0	1.0	0.295
64	0.985	1.0	0.245
128	0.635	1.0	0.195

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

- For all intervals, Top-1 accuracies are higher in HSV color space than RGB color space. For Query Set 1, accuracy is higher for all intervals than RGB counterparts. For Query Set 2, all accuracies are 1. For Query Set 3, all accuracies are higher than RGB counterparts too. Hence, margin in accuracies (0.155 for intervals 8 and 128) are higher for Query Set 3 than other query sets. Therefore, working in HSV color space increases the probability for matching color histograms of images after applying some transformations on them.

## Best Configuration

- Color space: HSV
- 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			
	$2 \times 2$	$4 \times 4$	$6 \times 6$	$8 \times 8$
3D	1.0	1.0	1.0	1.0
Per-Channel	1.0	1.0	1.0	1.0

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

### 5.1 Questions

- What do you think about the cause of the difference between the results?

Query Set 1 images are zoomed versions of the Support images. Thus, even we divide images by spatial grids into cells, number of color values in the cells does not change dramatically. Hence, in both 3D color histogram and per-channel color histogram for all grid sizes, accuracy does not change and it is 1.

- Explain the advantages/disadvantages of using grids in both types of histograms if there are any.

According to the results of the experiments, there is no change for corresponding spatial grid sizes, all accuracies are equal to 1. Moreover, accuracy is 1 for HSV color space 3D color histogram with the interval 64 and per-channel color histogram with the interval 8 without using spatial grids.

## 6 Grid Based Feature Extraction - Query set 2

Histogram Type	Spatial Grid			
	$2 \times 2$	$4 \times 4$	$6 \times 6$	$8 \times 8$
3D	0.595	0.48	0.42	0.405
Per-Channel	0.66	0.54	0.46	0.45

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

### 6.1 Questions

- What do you think about the cause of the difference between the results?

Query Set 2 images are rotated versions of the Support images. Thus, if we divide images by spatial grids into cells, number of color values in the cells differs since we compare images cell by cell, not globally. Hence, for both histogram types, accuracy decreases as number of cells increases. However, accuracies in per-channel color histogram are slightly higher than 3D color histogram.

- Explain the advantages/disadvantages of using grids in both types of histograms if there are any.

It is a disadvantage to use spatial grids in Query Set 2 images since they are rotated versions of Support images. We do not compare images globally but cell by cell. Therefore, for both color histograms, accuracies are lower than non spatial counterparts.

## 7 Grid Based Feature Extraction - Query set 3

Histogram Type	Spatial Grid			
	$2 \times 2$	$4 \times 4$	$6 \times 6$	$8 \times 8$
3D	0.275	0.395	0.445	0.465
Per-Channel	0.525	0.68	0.735	0.77

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

### 7.1 Questions

- What do you think about the cause of the difference between the results?

Query Set 3 images have different color values than Support images for the corresponding pixels. For both histogram types, all accuracies are higher than non spatial grid counterparts. In non spatial grid counterparts, for 3D color histogram with the interval of 64, accuracy is 0.205 for Query Set 3 (HSV color space). Also, for per-channel color histogram with the interval of 8, accuracy is 0.34 for Query Set 3 (HSV color space). However, with using grids, minimum accuracy

for 3D color histogram is 0.275 ( $2 \times 2$  grid) and for per-channel color histogram is 0.525 ( $2 \times 2$  grid). Hence, accuracy increases as number of cells increases. Thus, dividing images into cells increases the probability of matching color histograms for images that have different intensity values. Lastly, accuracies in per-channel color histograms are higher than 3D color histograms for all spatial grid sizes. It is beneficial to prefer per-channel color histograms over 3D color histograms.

- Explain the advantages/disadvantages of using grids in both types of histograms if there are any.

Using grids for both histogram types is advantageous since it increases the Top-1 accuracies for Query Set 3 images. Since accuracies in per-channel color histograms are higher than 3D color histograms, using per-channel color histograms with spatial grid of size  $8 \times 8$  (0.77 accuracy) would be most beneficial for Query Set 3 images.

## 8 Additional Comments and References

Additional experiments are done with using spatial grids in RGB color space. For both histogram types, 16 is used as quantization interval.

Histogram Type	Spatial Grid			
	$2 \times 2$	$4 \times 4$	$6 \times 6$	$8 \times 8$
3D	1.0	1.0	1.0	1.0
Per-Channel	1.0	1.0	1.0	1.0

Table 8: Top-1 accuracy results on Query Set 1 (RGB color space with quantization interval of 16 for both histograms).

- As in the HSV color space counterpart, all accuracies are 1 for both histogram types for all spatial grid sizes in RGB color space. Therefore, there is no change. Since Query Set 1 images are zoomed versions of Support images, individual cells look similar and have similar number of color values.

Histogram Type	Spatial Grid			
	$2 \times 2$	$4 \times 4$	$6 \times 6$	$8 \times 8$
3D	0.83	0.79	0.71	0.645
Per-Channel	0.425	0.355	0.315	0.275

Table 9: Top-1 accuracy results on Query Set 2 (RGB color space with quantization interval of 16 for both histograms).

- Accuracies in 3D color histograms in RGB color space are higher than accuracies in 3D color histograms in HSV color space for all spatial grid sizes. However, for per-channel color histograms, results are the exact opposite. Hence, accuracies are higher in HSV color space. Also, for all histogram types, accuracy decreases as number of cells increases. Highest accuracy is achieved in RGB color space with using 3D color histogram and  $2 \times 2$  grid (0.83).

Histogram Type	Spatial Grid			
	$2 \times 2$	$4 \times 4$	$6 \times 6$	$8 \times 8$
3D	0.195	0.26	0.305	0.345
Per-Channel	0.31	0.425	0.465	0.5

Table 10: Top-1 accuracy results on Query Set 3 (RGB color space with quantization interval of 16 for both histograms).

- All accuracies in RGB color space are lower than HSV color space counterparts for both histogram types. Furthermore, accuracy increases as number of cells increases for both histogram types like the HSV counterparts. Hence, for Query Set 3 images, using HSV color space with spatial grids is better than RGB color space.

Additional notes:

- OpenCV library is used for reading and converting images into numpy arrays.
- `numpy.linalg.norm` function is used for l1 normalization.