CENG 483

Introduction to Computer Vision

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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
128	0.735	1.0	0.05
64	0.995	1.0	0.14
32	1.0	1.0	0.120
16	1.0	1.0	0.145

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

When we look at the datasets, we can easily conclude that the first query is zoomed in, the second query is just rotated, and the third query is simply filtered with color.

- **First Query**
  From our results, we can conclude that zooming the image a little bit does not significantly affect the outcome of 3D histograms. Even at high intervals, we can correctly identify the image from its counterparts. The limit can be observed in the table, as 64 or fewer intervals are providing better results.
- **Second Query**
  From our results, we can easily conclude that just rotation does not affect histograms across the entire image. This is because the counts of every RGB or HSV pixel remain unchanged during rotation. As a result, even with 128 intervals, we can correctly identify the image from its counterparts in query 2. In addition, given data set is working fine with 3-per channel rgb histograms, but in some data sets if colors are overlaping with each other in terms of rgb color spaces, then per-channel histograms may not give good results.

- **Third Query**
  From our results, it is apparent that the accuracy for the third query is very low due to the color changes. Consequently, at any interval, the possibilities are minimal. However, according to the table, the best-fit interval for query-3 is 16. Nevertheless, as discussed, these values are considerably low, and drawing reliable conclusions based on them may not be convenient.

2 3D Color Histogram (HSV)

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

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

- **All Queries**
  From our comparisons with RGB counterparts of the results, we can conclude that working on HSV histograms may give better results on color differences, but as we can see from the results in query1 and query2 it does not effect much if the images have same color pixels. However, we can not say it is precise conclusion, because the confidences are very low in both technique in query 3. Therefore, it is not possible to reach a definitive conclusion based on our results.

3 Per-Channel Color Histogram (RGB)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
16	0.97	1.0	0.19
8	0.975	1.0	0.185
4	0.975	1.0	0.185
2	0.975	1.0	0.16
1	0.975	1.0	0.155

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

Differences between queries

- **First Query**
  From our results, we can conclude that zooming the image a little bit have slight affect on per channel histograms, but as we can see from the table these color differences does not result in changes between different interval size histograms. We may say that it is possible to find correct image with higher interval is more accurate, but we have not much results to make it reliable.

- **Second Query**
  From our results, we can easily say that just rotation is not effecting RGB per channel histograms in complete image, because every rgb or hsv pixel counts does not change in rotation. As a result of that, even in low intervals we can find the correct image from it's counterparts in query 2.

- **Third Query**
  From our results, we can say that for the third query, our accuracy is very low due to the color changes, so in any interval we can see that possibilities are very low. However, from the table we can say that best fit interval for query-3 is 16. Still as we discussed these values are very low, arriving such conclusion it is not reliable.

Differences between 3D and per-channel color histograms

- **First Query**
  As we already discussed, zooming the image causes some small color changes between images. With this fact and from the results on table, we can say that using 3D histogram may give better results than per-channel histogram due to the 3D histogram's capability of saving more information than per-channel histogram. As a result of this capability we can detect images more confidential with 3D histograms.

- **Second Query**
  As we discussed already, in the second query images are just rotated, so there is no change in count of different color pixels. As a result, if there is no changes in pixel color numbers, then there is no change in histograms. It does not differ from 3D or per-channel histograms because in terms of histograms images are same. However, the results may change significantly in some other data sets, because 3D histogram is more capable to hold information than per-channel histograms, and per-channel histograms are not convenient.

- **Third Query**
  We have discussed that in query 3 images' colors are changed with filter, therefore histograms of corresponding images have more differences than respect to query-1 and query-2. We can see from the tables, results of per channel histograms are slightly better than the 3D histograms. The possible cause of this is that when we apply filter on image, all the color values change, and detecting this total change is hard with using more informative color histograms because the images are completely different. However, using low level intervals and less informative histograms may cause in higher rate of finding same images. Besides these results still we can not conclude a precise conclusion.

4 Per-Channel Color Histogram (HSV)

Q. Interval	Query Set		
	Query 1	Query 2	Query 3
16	1.0	1.0	0.325
8	1.0	1.0	0.340
4	1.0	1.0	0.330
2	1.0	1.0	0.325
1	1.0	1.0	0.300

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

Differences between RGB and HSV

- **First Query**
  From our results, we can say that hsv results are looks much better than rgb results, potential cause for this is, RGB per channel values may overlap each other if the colors in some pixels mixed in another pixel. However, in the HSV space colors may not overlap that much. Therefore, it gives more precise results.

- **Second Query**
  From our results, there is no difference between RGB and HSV because as we already discussed in query 2 all the pixels are match with our original image, so histograms of 2 counterpart image is completely same.

- **Third Query**
  From our results, we can say that HSV results are far better than the RGB results. Most potential cause for this is, HSV histograms are better for detecting color filters than the RGB images. Also, the filter applied may cause smaller change in hsv space than the RGB space. However, still results are not precise enough to conclude a realiable reason for this effect.

Differences between 3D and per-channel color histograms

- **First Query**
  For the first query, results are almost similar, so we can not arrive a conclusion from the results both of the histograms are found images precisely.

- **Second Query**
  For the second query, as we sayed before images are same in histograms so there is no changes between per-channel and 3D histograms in this data-set. Results may change in different data-sets which are not working well with per-channel histograms.

- **Third Query**
  For the third query, results are much better in per-channel histogram respect to 3D channel. As we discussed above, there may be two possible causes for this difference. However, from the data given to us we may say that color filter that applied on query-3 may cause smaller difference on HSV space than RGB space, so we can not say differences come from the 3D - per-channel comparison but come from color space difference.

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			
	2×2	4×4	6×6	8×8
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.

- There are no any difference between different grid sizes.
- As the results are completely same, there is no advantages can be find in this case.

6 Grid Based Feature Extraction - Query set 2

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Histogram Type	Spatial Grid			
	2×2	4×4	6×6	8×8
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.

- In Query 2, the images are rotated with respect to the reference ones. As a result, the pixels remain the same but are in different locations. If we apply a histogram to the entire image, we obtain exactly the same histograms. However, when we divide the images into pieces due to the location differences of pixels, separating parts of the images and applying histograms to each of them separately results in major differences in comparisons.

- If we are looking for similarity in the entire image, and our image is just rotated or slightly changed in terms of the location of pixels, dividing the image and calculating histograms differently is a very inconvenient way to use. Because when we divide our image into pieces, due to different pixel locations, we are causing our exact same image to be cut into different images with its counterparts. Therefore, while histograms are the same at the beginning, by the end of the division of the image, they differ from each other, and the average of these different histograms gives worse results than just one histogram.

7 Grid Based Feature Extraction - Query set 3

Histogram Type	Spatial Grid			
	2×2	4×4	6×6	8×8
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.

- In Query 3, images are filtered with respect to our base images. There are no changes in pixel locations, but their colors have just changed uniformly across the entire image. Dividing the image into smaller pieces tends to yield different results due to the histogram logic. Applying a histogram to the entire image means we are comparing 96x96 pixels simultaneously by using the count of each color. However, when we divide the image into pieces, we are applying histograms to a smaller number of pixels, resulting in different histogram outcomes.

- The table shows that using a higher number of grids gives better results, indicating an advantage in employing grids for this dataset. When pixel locations stay the same and only colors change uniformly across the entire image, applying a grid is a more convenient way to detect similarity between images. The use of grids helps capture subtle color changes more effectively by dividing the image into smaller sections. In summary, a grid-based approach enhances sensitivity in scenarios where pixel locations are constant but colors change uniformly across the entire image.

8 Additional Comments and References

In the given data-set, per-channel histograms are working well, but if we change the data-set, results may change significantly. As a result of experiments, applying different histograms leads to varied outcomes. Each of these different histograms may outperform the others in different situations. Therefore, if we intend to use histograms to detect something, we should first choose the most suitable histogram type for our experiment.