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
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).

- In this part of the experiment, I have chosen 4 quantization intervals such as 16, 32, 64, 128 to create 3D color histograms with color space RGB. Applying those different configurations on Query 1, Query 2, Query 3; I have calculated the similarities and found the Top-1 accuracy results as shown in Table 1.
  Looking at the results for Query 1, where images are the zoomed in versions of their counterparts in Support-96 dataset, increasing the interval causes the Top-1 accuracies to decrease. This difference is predictable as we lose RGB values' information by decreasing the quantization interval since more R,G,B values will fall into the same bins in the histograms. Zooming in causes a slight change in RGB values as most of the pixels stay the same and a few of them change.
  For Query 2, Top-1 accuracies are always 1.0 as the images in Query 2 are rotated versions of the Support-96 dataset and rotating the image does not change the count of RGB values and the bins they fall into. Histograms with grid size 1x1 only look at the overall image and does not give any information about which RGB values are in which location in the image. This results in Query 1 results being highly accurate for all configurations regardless of quantization intervals.
  In Query 3, Support-96 images' hue, saturation or value's are modified. It can be seen from the table that Top-1 accuracies are really low. It is only possible to find the corresponding instances correctly with a histogram of RGB color space only if the hue, saturation or values are modified slightly. Otherwise, changing the brightness, intensity of the color or the type of color of a pixel changes the RGB value of that pixel drastically and this results in lower accuracies.

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	0.165
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).

- In this part of the experiment, I have again chosen 4 quantization intervals such as 16, 32, 64, 128 to create 3D color histograms with color space HSV. Applying those different configurations on Query 1, Query 2, Query 3; I have calculated the similarities and found the Top-1 accuracy results as shown in Table 2.
  In this case, for the same reason with the 3D RGB Histogram, the accuracy values for the Query 1 decrease when the quantization interval increases due to information loss. However, overall accuracies increase with respect to RGB color space since zooming in causes less change in brightness and saturation values of the images than it does on RGB values of the pixels that are affected.
  For Query 2, there is no difference and accuracies are always high and the same with 3D RGB histograms. As I mentioned in part 1, this is because there is no correlation between rotating the image and total H,S and V counts for pixels in the histograms.
  Looking at the Query 3 top-1 accuracy results, there is a remarkable difference with 3D RGB results. In opposite to RGB color space, the accuracies increase when the quantization interval size decreases. As I mentioned in part 1, Query 3 images are modified versions of Support-96 images in terms of hue, saturation or value channels. Hence, when we increase the intervals, the histograms will be less sensitive to H,S,V changes since in both versions those H,S or V values will fall into the same bins. Also the accuracies for Query 3 are in general higher than it's 3D RGB conuterpart as HSV color space's tolerance for H,S,V changes will be higher than RGB color space's tolerance.

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).

- In this part of the experiment, I have chosen 5 quantization intervals such as 8, 16, 32, 64, 128 to create per-channel color histograms with color space RGB. Applying those different configurations on Query 1, Query 2, Query 3; I have calculated the similarities and found the Top-1 accuracy results as shown in Table 3.
  For Query 1, as it was mentioned, zooming in causes a change in RGB values of few pixels. This

causes some images to be recognized incorrectly even if the quantization interval size is 8. The accuracy decreases as the interval size is increasing like in most of the previous cases but it is decreasing way faster than it is in 3D because per-channel histograms in general, holds less information than 3D ones. Per-channel does not include any color relationship or combination information. Hence, there is a gap between accuracies of 3D and per-channel histograms for quantization interval 128.
In Query 2, the accuracies are high as it was in other cases too. There is a small decrease if we choose the interval size as big as 128. Even if rotating does not change the total counts in the bins of the histogram, since the interval size is too big, the information loss on color values caused from that has to be taken into consideration.
Looking at the accuracy results of Query 3, it can be seen that they are very similar to 3D RGB histogram results. Any change in hue, saturation or brightness values cause a huge shift on RGB values most of the time. Therefore, all type of RGB histograms whether it is 3D or per-channel, are very sensitive to the changes made in Query 3. Also, the accuracies are again decreasing with quantization interval size. Overall, RGB histograms are not suitable for datasets with changes made on H,S,V values like Query 3 and should not be chosen if we want more accurate results.

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).

- In this part of the experiment, I have again chosen 5 quantization intervals such as 8, 16, 32, 64, 128 to create Per-channel color histograms with color space HSV. Applying those different configurations on Query 1, Query 2, Query 3; I have calculated the similarities and found the Top-1 accuracy results as shown in Table 4.
  Comparing the results for Query 1 with its per-channel RGB counterpart, as mentioned in 3D case, overall accuracies increase with respect to RGB color space since zooming in causes less change in brightness and saturation values of the images than it does on RGB values of the pixels that are affected. The Accuracy results for Query 1 are lower than their 3D HSV counterparts when the interval size is relatively bigger. This is mostly because the 3D color histograms hold more detailed information about color combinations and they are more tolerant to changes in interval size. When the number of bins in per-channel histograms are chosen too small, many of the R,G and B values will correspond to same bins on the histogram which results in information loss way more than it does in 3D histograms due to size differences. For Query 2, the results are the same with 3D HSV histogram and is 1.0 for all intervals. It is hard to interfere any potential causes from those results but it is possible to conclude that the rotation of instances does have very small or no effect on histograms as mentioned before. Therefore Query set 2 will have high accuracy results in almost every configuration. In Query 3, HSV configuration gives higher accuracies than their RGB counterparts since the images are changed in either hue, saturation or brightness values which hugely affects the RGB values. When the similarities are calculated through each channel histograms, since change in most of the images are done on one channel according to my observations, only one of the channel's values will be different than the original image in the Support-96 dataset. The intersection

of other channels where the changes are not made will give high similarities and taking the average of those channels, we will get better results. So, the per-channel HSV color histogram is more accurate than 3D HSV in this case. The accuracies decrease as interval size increases due to the information loss in the channel's where no change is made.

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.

5.1 Questions

- In this part of the experiment, I have chosen the best configurations according to the experiments above. I took the quantization interval as 64 for 3D histograms and as 8 for per-channel histograms. The color space is chosen as HSV as it gave higher accuracies in every part. Applying those configurations on Query 1 for grid sizes 2x2, 4x4, 6x6, 8x8. I have calculated the similarities and found the Top-1 accuracy results as shown in Table 5.
  Throughout the experiment, for Query 1, we have got high accuracies for all types of histograms and color spaces when the interval sizes are chosen properly. There was no remarkable difference on results with any configurations to make comments on their effects on accuracies but small differences leads us to think that 3D HSV is more suitable. As the best configurations for quantization interval and color space is chosen in this part of the experiment, we got 1.0 accuracy regardless of the grid sizes. Since no changes are observed, it is hard to make any conclusions on Query 1. However, I think that in the case where not best configurations are chosen, for both of the color histogram types, the accuracies would increase as the grid size increases since the images in Query 1 dataset are only the zoomed in versions of Support-96 images. I think that way, since more grids mean better localization of color information and it holds more information on the distributions of colors in specific regions and that information could be useful for Query 1 due to its characteristics. However, increasing the grid number would take more time due to computations it requires as it will result in calculating and comparing more histograms.

6 Grid Based Feature Extraction - Query set 2

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	0.535	0.46	0.45

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

6.1 Questions

- In this part of the experiment, I have again chosen the best configurations according to the experiments above. I took the quantization interval as 64 for 3D histograms and as 8 for per-channel histograms. The color space is chosen as HSV as it gave higher accuracies in every part. Applying those configurations on Query 2 for different grid sizes, I have calculated the similarities and found the Top-1 accuracy results as shown in Table 6. For Query 2, per-channel case gives higher results as the calculations for it was done with interval size 8 which has more detailed information on H,S,V values than the 3D color histogram with interval size 64. I think that this difference is merely due to quantization interval configuration. Comparing the grid numbers in detail, in the case of per-channel color histogram with HSV color space, the accuracy was 1.0 for interval size 8 and in the case of 3D color histogram with HSV color space, the accuracy was also 1.0 for interval size 64 when the grid size was chosen to be 1x1. Looking at Table 6, it can be observed that the accuracies decreased drastically with the increase of grid number. The Query set 2 is highly sensitive in case of any change in localization for both of the color histogram types since the images in that dataset are rotated versions of their counterparts in Support-96. Before, when we were looking at the images with grid size 1x1, only the count of H,S,V values were important and their locations were not considered. By using grids, we have gained more information on locations of the pixels and creating different histograms for different parts of the image caused the histograms for Query 2 to be considerably different. Local informations played a huge role in those histograms and this resulted in huge changes in Top-1 accuracies due to Query 2 dataset's characteristics of rotation. Increasing the grid number is definitely disadvantageous for Query set 3 because it is increasing the complexity of computations while decreasing the Top-1 accuracies.

7 Grid Based Feature Extraction - Query set 3

Histogram Type	Spatial Grid			
	2×2	4×4	6×6	8×8
3D	0.28	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

- In this part of the experiment, I have again chosen the best configurations according to the experiments above. I took the quantization interval as 64 for 3D histograms and as 8 for per-channel histograms. The color space is chosen as HSV as it gave higher accuracies in every part. Applying those configurations on Query 2 for grid sizes 2x2, 4x4, 6x6 and 8x8, I have calculated the similarities and found the Top-1 accuracy results as shown in Table 7. As mentioned in part 6, per-channel

histogram gives better results than 3D histogram because of the chosen quantization interval sizes for both configurations. Also, the color space being HSV plays a huge role as discussed at the end of part 4 while comparing 3D and per-channel HSV histograms. In the case of per-channel color histogram with HSV color space, the accuracy was 0.34 for interval size 8 and in the case of 3D color histogram with HSV color space, the accuracy was 0.205 for interval size 64 when the grid size was chosen to be 1x1. Looking at the table 7, it can be seen that the Top-1 accuracies are increasing extremely. This is mainly because increasing the number of grids allows for a more detailed characterization of color information, making it easier to distinguish between different images or variations in color. Since we are already using HSV color space and Query 3 consists of images that has changes on those values only, more information on the color type, intensity of color and brightness values of the local parts of the instances is achieved by calculating and comparing more histograms taken from the grids. Even if it takes more time and requires more computation, using more number of grids is advantageous in this case due to it's adaptability to changes in specific regions and the ability to capture local color variations and patterns.

8 Additional Comments and References

- In this experiment, we tried to recognize instances by utilizing color histograms. Throughout the experiment in which we have tried different configurations that includes changes in color space type, color histogram type, quantization interval sizes and grid numbers on query sets with totally different characteristics, we have observed very different and interesting results for Top-1 accuracy values.

  Overall, we can infer that quantization interval plays a huge role on the accuracies of the results and it has to be chosen carefully. Moreover, we have observed that 3D histograms and HSV color space give higher accuracies in general with some exceptional cases. Also, we have seen the affect of dividing the instances into different number of grids. Those effects highly depend on the characteristics of the dataset we are applying the configuration on like in 3D or HSV cases. Hence, we can conclude that the configuration we need to choose from all those variations has to be chosen by taking the type of datasets we have in our hand into consideration.