CENG 483

Introduction to Computer Vision

Spring 2018-2019

Take Home Exam 1

Content Based Image Retrieval

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1 Grayscale Histogram

I evaluated the given queries with the dataset by using grayscale histogram with 8 different quantization levels (i.e. bin counts) for grid level 1. Mean Average Precisions (mAP) of each quantization level are below:

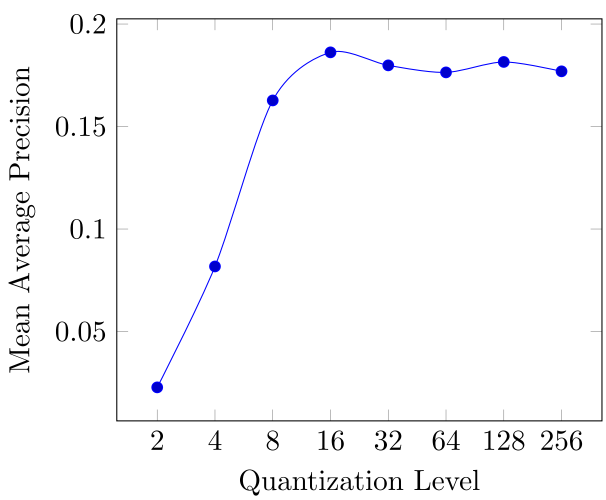

Figure 1: Mean Average Precision with different quantization levels for grid level 1 grayscale histogram

Bin	mAP
2	0.02276
4	0.08175
8	0.16273
16	0.18619
32	0.17984
64	0.17641
128	0.18151
256	0.17693

Table 1: Mean Average Precision with different quantization levels for grid level 1 grayscale histogram

It is obvious that lower quantization levels such as 1, 2, 4 have lower mAP as each bin corresponds to large interval of grayscaled value, and this doens't result in distinguishing the differences in different images. I've expected same result with large number of bin count such as 256; however, 256 bin count has slight difference with the best configuration in this part. 256 bin count's mAP is 0.17693 whereas the best configuration which is 16 bin count's mAP is 0.18619. I've concluded that large interval for grayscale bins affect the Mean Average Precision most. The best configuration in grayscale histogram for grid level 1 is quantization level 16.

2 3D RGB Histogram

I evaluated the given queries with the given dataset by using 3D RGB histogram with 6 different quantization levels (i.e. bin counts) for grid level 1. Mean Average Precisions (mAP) of each quantization level are below:

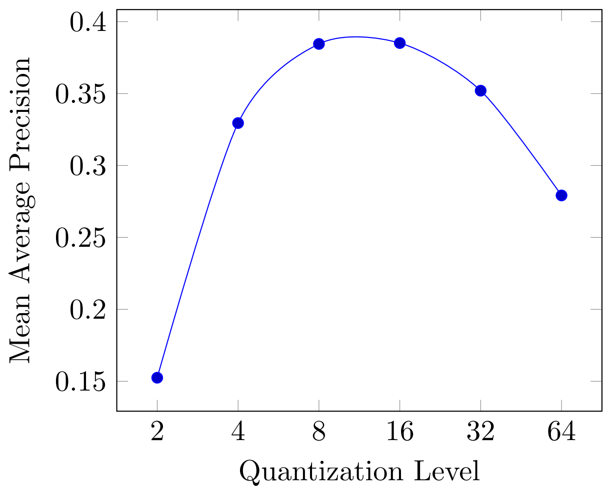

Figure 2: Mean Average Precision with different quantization levels for grid level 1 gradient histogram

Bin	**mAP**
2	0.15246
4	0.32950
8	0.38451
16	0.38512
32	0.35201
64	0.27919

Table 2: Mean Average Precision with different quantization levels for grid level 1 gradient histogram

As it is in the grayscale histograms, lower bin count such as 2 has the lowest mAP precision due to its insufficient distribution in 3D color histogram. However, in this case, higher bin count such as 64 has lower mAP because it has 64^3 bin which is unnecessarily many. The best configuration in 3D RGB histogram for grid level 1 is quantization level 16.

3 Gradient Histogram

Gradient histograms are obtained from images' edge map. Image gradient is obtained from applying vertical and horizontal filters (orthogonal derivatives) to the grayscaled image. I simply applied orthogonal derivatives to the image, and obtained orientation(θ) and magnitude(a) of a pixel at coordinates i and j as, where v and h are the filtered images with respect to orthogonal derivatives:

$$\theta_{ij} = arctan(v_{ij}/h_{ij}) \quad (1) \qquad a_{ij} = \sqrt{v_{ij}^2 + h_{ij}^2} \quad (2)$$

I tried two different derivative filters. Filter-0 is basic derivative filter and Filter-1 is Sobel filter. Derivative filter's can be seen below:

$$\text{Horizontal-Filter-0: } \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad \text{Horizontal-Filter-1: } \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$\text{Vertical-Filter-0: } \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \qquad \text{Vertical-Filter-1: } \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Intermediate results:

Figure 3: An image and its grayscale from the dataset

Figure 4: Horizontally, vertically filtered images and their blend, Filter-0

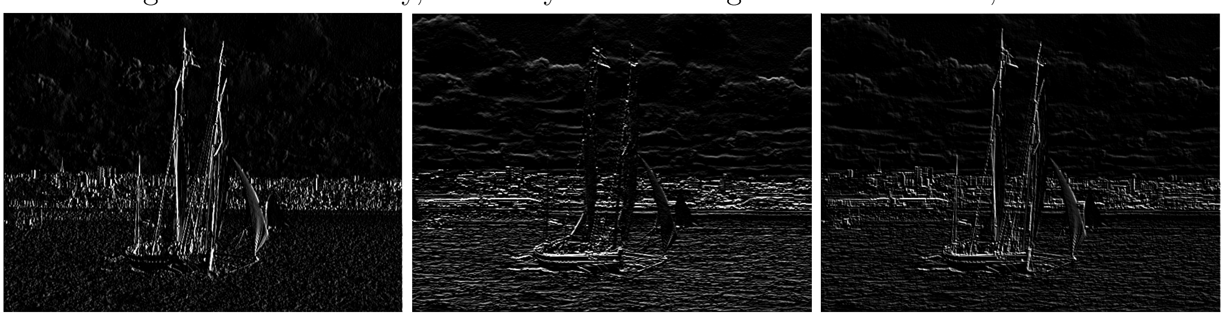

Figure 5: Horizontally, vertically filtered images and their blend, Filter-1

I evaluated the given queries with the given dataset by using gradient histogram with 8 different quantization levels (i.e. bin counts) and 2 different orthogonal derivatives for grid level 1. Mean Average Precisions (mAP) of each quantization level and filter are below:

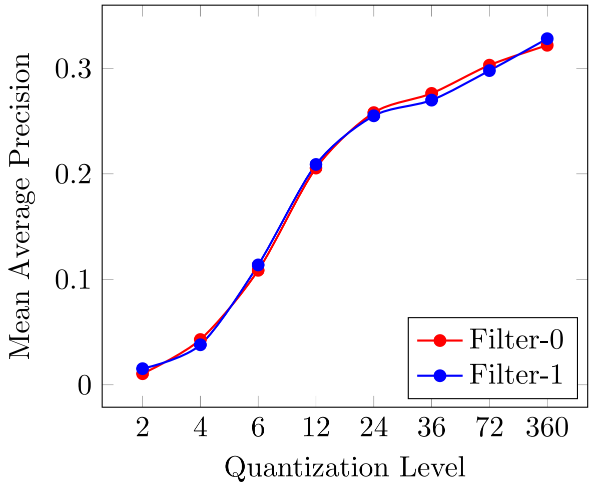

Figure 6: Mean Average Precision with different quantization levels and filters for grid level 1 gradient histogram

Bin	Filter	mAP
2	0	0.01051
	1	0.01530
4	0	0.04294
	1	0.03795
6	0	0.10854
	1	0.11364
12	0	0.20549
	1	0.20891
24	0	0.25805
	1	0.25502
36	0	0.27627
	1	0.26988
72	0	0.30302
	1	0.29787
360	0	0.32188
	1	0.32813

Table 3: Mean Average Precision with different quantization levels and filters for grid level 1 gradient histogram

Gradient histogram has different attitude from grayscale and 3D RGB histograms. Mean Average Precision is increased as the quantization level increased; however, this isn't the case in other histograms. From the mAP results, both filters have similar results. The best configuration in gradient histogram for grid level 1 is quantization level 360 with Sobel filter (Filter-1).

4 Grid Based Feature Extraction

4.1 Level 1

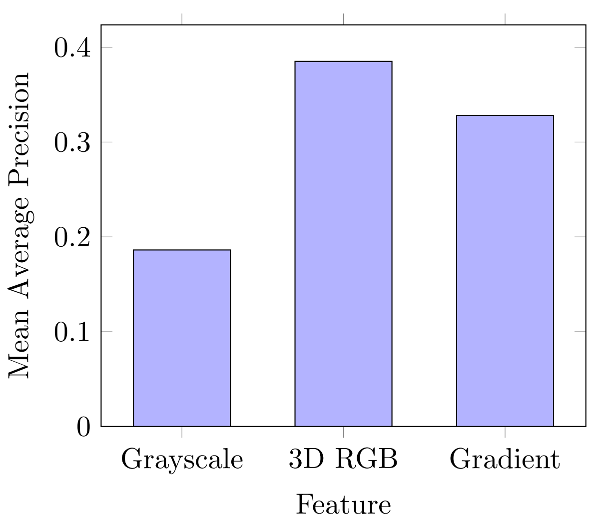

Figure 7: Best configurations of different features for grid level 1 in case of Mean Average Precision

Bin	Feature	mAP
16	Grayscale	0.18619
16	3D Color	0.38512
360	Gradient	0.32813

Table 4: Best configurations of different features for grid level 1 in case of Mean Average Precision

4.2 Level 2

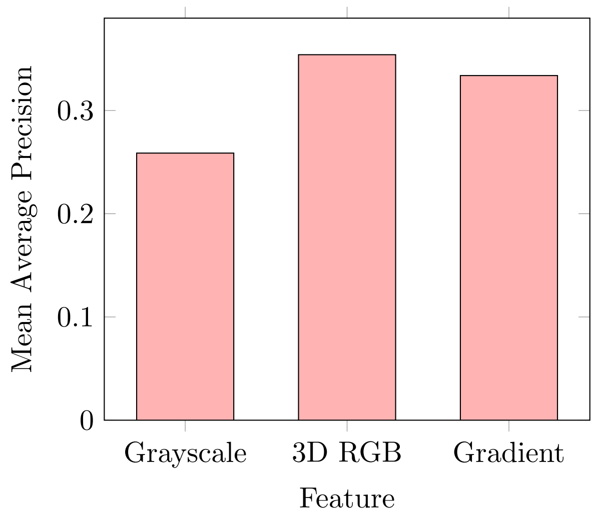

Figure 8: Best configurations of different features for grid level 2 in case of Mean Average Precision

Bin	**Feature**	**mAP**
16	Grayscale	0.25874
16	3D Color	0.35405
360	Gradient	0.33385

Table 5: Best configurations of different features for grid level 2 in case of Mean Average Precision

4.3 Level 3

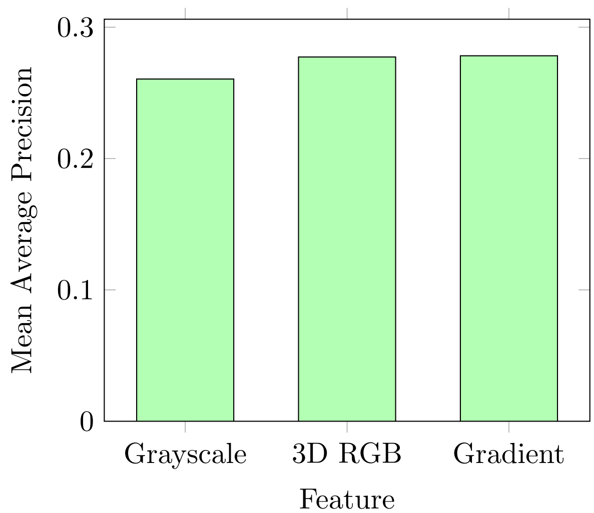

Figure 9: Best configurations of different features for grid level 3 in case of Mean Average Precision

Bin	**Feature**	**mAP**
16	Grayscale	0.26052
16	3D Color	0.27730
360	Gradient	0.27822

Table 6: Best configurations of different features for grid level 3 in case of Mean Average Precision

4.4 Questions

Differences between grid level in the same feature show variations. For example in grayscale histogram, mAP has increased significantly as grid level changed from 1 to 2. In 3D RGB histogram, mAP has decreased as grid level increased. Gradient histogram has also different distribution when grid level increased. Features have different behaviour when the histogram is applied to local regions. These can be observed from the graph and table below:

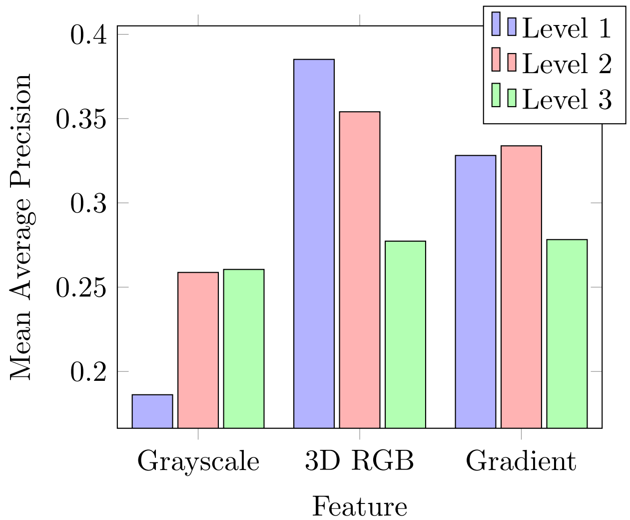

Figure 10: Mean Average Precision comparison among different features in different grid levels with level 1 best configurations

Level	Bin	Feature	mAP
1	16	Grayscale	0.18619
	16	3D Color	0.38512
	360	Gradient	0.32813
2	16	Grayscale	0.25874
	16	3D Color	0.35405
	360	Gradient	0.33385
3	16	Grayscale	0.26052
	16	3D Color	0.27730
	360	Gradient	0.27822

Table 7: Mean Average Precision comparison table of different features with feature's best level 1 configuration and with different grid levels

I concatenated the histograms in grid level 2 and 3. If I simply summed the histograms, I would have similar histogram as in grid level 1. Therefore, concatenating the histograms prevents this.

5 Your Best Configuration

- You may try different combinations including changing parameters above and even combining different methods. Simply give your best mAP for the validation set:

◦ I have tried different quantization levels, grid levels, and filters in gradient histograms. My best mAP for the validation set is 0.38512.

- Explain your setup for this best mAP. How can we reproduce your result using your code?

◦ My best configuration setup is **3D RGB Histogram** with **quantization level 16** in **grid level 1**. And the result can be reproduced by, it outputs the file into *./out* folder:

```
python3 cbir.py color 1 16 <QUERY_FILE> <IMAGES_FILE> <DATASET_PATH>
```

- **Visual Ranking Results:**

Figure 11: Given query image

Figure 12: Expected query result images

Figure 13: First four result images from the best 3D RGB configuration

 

Figure 14: Given query image Figure 15: Expected query result image

Figure 16: First four result images from the best 3D RGB configuration

- Explain mean average precision in your own words:
    - mAP is calculated by Euclidean Distances between histograms of query images and dataset images. In output, we have list of distances per query image and it gets higher mAP if the similar images have smaller distance to the query image than the other images. Therefore, smaller the Euclidean Distance means similar image in most cases.

6 Additional Comments and References

Even though 3D RGB Histogram has the highest mAP score, it is not completely reliable as it can be seen in Figure 14, 15 and 16. We will have different feature with different configurations for best mAP score. For example, 3D RGB Color Histogram would be better in undersea images whereas Gradient Histogram would perform better in city or building images. These configurations change from image to image; therefore, my best configuration won't probably work best in some cases. Some methods might be implemented where we can make use of those three features altogether.

My code was unfortunately working slow when calculating histograms. I precomputed all histograms in 1-2 nights, and used those precalculated Numpy arrays. In addition, I hadn't utilized the using of those array at first. Then, I started to put those arrays in memory for each image in the dataset and the outputting part has got fasten. Yet, it still works slow if there isn't any cached data. I've experienced the importance of libraries such as *cv2.calcHist()* etc.