Project 1. Content Based Image Retrieval Using Global and Local Features

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For this project three approaches for Content Based Image Retrieval (CBIR) where implemented. The first approach is based on the comparison of color histograms, the second solution uses spectral histogram to do the comparison, of images and the third approach uses SIFT features to compare images.

1 Description

In this section the three methods used for CBIR are described.

1.1 Color histogram

In this method we used the color (intensity filter) histogram to compare images. The following steps summarizes the method:

1. **Image pyramidization.** The images sizes where reduced to half their size in order to speed up the algorithm. The method used to compute the pyramids is *Gaussian pyramid*, the first step of the Gaussian pyramid algorithm is to blur the image using a Gaussian filter, and then scale down the image by creating one pixel from the average color of four pixels.

2. **Compute histograms.** The number of bins used for this method is 256, for each color band.

3. **Compute histogram distances.** The distance between each pair of image histograms were computed using histogram intersection:

$$dist(hist_a, hist_b) = \sum_{i=1}^{256} \min(hist_a(i), hist_b(i)) \tag{1}$$

4. **Images similarity**. The distance between the histograms of the images was used as the *similarity* parameter.

1.2 Spectral histogram

This method uses spectral histograms for CBIR. The proposed steps for this method are the following:

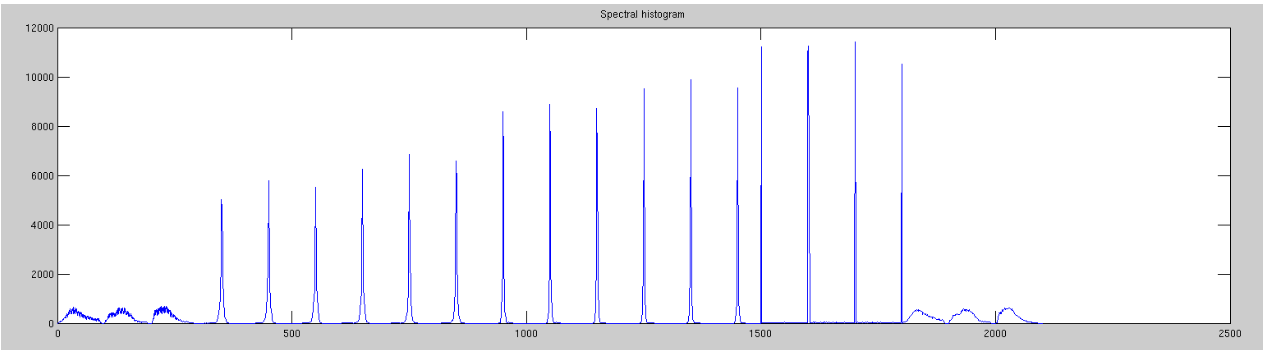
1. **Image pyramidization.** The images sizes where reduced to half their size in order to speed up the algorithm. The method used to compute the pyramids is *Gaussian pyramid*, the first step of the Gaussian pyramid algorithm is to blur the image using a Gaussian filter, and then scale down the image by creating one pixel from the average color of four pixels.

2. **Filter images**. Six filters plus the intensity filter are applied to each of the images. The filters used and their corresponding masks are:

$$\begin{aligned} \frac{\partial I}{\partial x} &= [0 \ -1 \ 1] \\ \frac{\partial I}{\partial y} &= [0 \ -1 \ 1]^T \\ \frac{\partial I}{\partial x \partial x} &= [-1 \ 2 \ -1] \\ \frac{\partial I}{\partial y \partial y} &= [-1 \ 2 \ -1]^T \\ LoG(I(x,y)) &= (x^2 + y^2 - \sqrt{2\sigma^2})e^{-(x^2+y^2)/\sqrt{2\sigma^2}} \\ Gauss(I(x,y)) &= \frac{1}{2\pi\sigma^2} e^{\frac{-(x.^2+y.^2)}{2\sigma^2}} \end{aligned} \tag{2}$$

   For the Laplacian of Gaussian (LoG) and Gaussian filters the size of the filter used is 5 with a sigma value of 0.7.

3. **Compute spectral histograms.** The number of bins used for this method is 100, for each color band and for each filter. For all the filters the range goes from [0 256], even when the values of some of the filters may go from [-256 256]. Several options for the range of the histograms were tested, and the range of [0 256] gave the best results. The 100 bins are evenly splitted from [0 256]. Figure 3 shows an example of the spectral histograms.



4. **Compute histogram distances.** The distance between each pair of image histograms were computed using histogram intersection:

$$dist(hist_a, hist_b) = \sum_{i=1}^{100} \min(hist_a(i), hist_b(i)) \tag{3}$$

5. **Images similarity**. The distance between the histograms of the images was used as the *similarity* parameter.

1.3 Computation time

The three methods were implemented in parallel (when possible) using the matlab function $parfor$. The third method, which uses SIFT features, takes a lot more time than the others and the computation time is presented separated at the end of this section.

For eficiency, the first two methods are implemented in the same code, but the program *Problem1And2CompTime* can be easily modified to display the time that takes for each method to compute the CBIR. The times shown on table 1.3 are for an specific run in a computer running Ubuntu 14.04, with matlab 2012a, with an i7 intel processor and 10 GB of ram. The times varies a little for each run but table 1.3 gives a good estimate of the time that each method takes.

	Color histogram (sec)	**Spectral Hist (sec)**
Read Images Filter them and compute histogram	9.38	30.01
Compute distances	6.69	10.78
Compute Precision Recall	1.47	1.45
Avg Precision and Rank	1.22	1.34
Total time	**17.54**	**43.58**

The method based on SIFT features take a lot longer to finish. In order to debug our proposed method, the computation of the SIFT descriptors were run once and then saved in a separated file (*/Variables/descriptors.mat*). In the same way the matching of the descriptors, which takes almost two hours to finish, was also saved in a separated file (*/Variables/scores.mat*). In this way we only had two compute the matching and the descriptors one time.

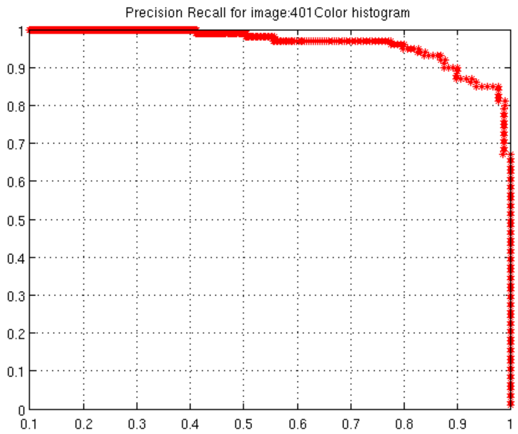
	SIFT (time sec)
Read all Images	12.47
Detect SIFT descriptors	83.3
Matching descriptors	approx. 7 sec/image $\sim$ 7000 sec $\sim$ 1:56 hrs
SIFT score	18.8
Precision recall	1.6
Average PR	1.44
Total	$\sim$ **2 hrs**

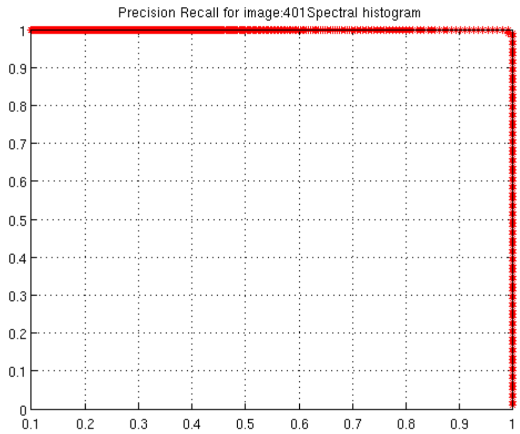
2 Results

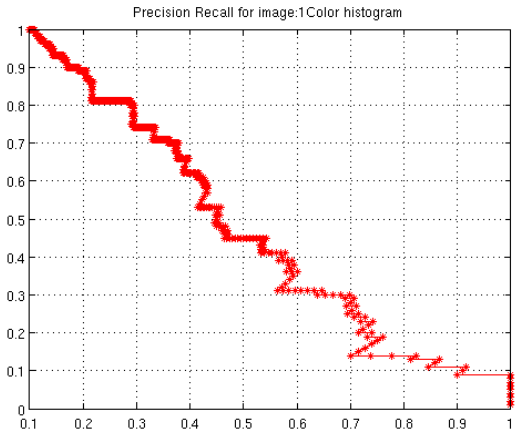
To better display the results obtained with each method, the results are plotted in one figure.

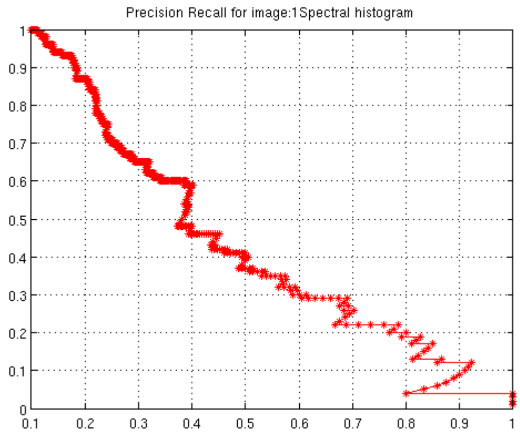
One good image 401

One bad image 1


Precision Recall for image:401Color histogram


Precision Recall for image:401Spectral histogram


Precision Recall for image:1Color histogram


Precision Recall for image:1Spectral histogram