Content-Based Image Retrieval

Assume you have a large database with images with variable visual content. Using this collection of images, you want to find those images that are similar with a given (query) image. For example: you have a large dataset with images from Iași grouped by neighborhood and a query image of the University "Alexandru Ioan Cuza". A CBIR algorithm provides a set of images similar with the query image.

Query image

Similar images

(Images from IIT_DB collection – Institute of Computer Science, Romanian Acad., Iaşi branch)

This type of problem can be approached by following the steps:

1. Extract feature vectors for all the images involved;
2. Choose a measure of similarity/distance to compare the feature vectors;
3. Compare the feature vector associated to the query image with all the feature vectors in the data collection using the measure chosen in step 2;
4. Sort the similarity/distance vector and display Top p most similar images from the collection with the query image;
5. Compute evaluation measures (see pages 3-4)

The Corel-1000 dataset is a collection of 1000 images grouped in 10 categories (images 000 to 099 are the images from the first class, 100-199 – second class and so on). The 10 categories are: Africa, Beaches, Building, Bus, Dinosaur, Elephant, Flower, Horses, Mountain and Food. Perform the following CBIR computations for the Corel-1000 dataset:

1. Divide the dataset in test-training sets in the following way: extract randomly 30 images from each category and place them in the test set (they form the query images), the other images form the training set.
2. Extract texture features using Grey Level Co-occurrence Matrices (GLCM) for all the images involved in the CBIR process. Test different displacement vectors for the GLCM.
   You can replace GLCM texture features with Local Binary Patterns features or other texture features
3. Add to the feature vector other information (at your choice) from the images that improve the chosen performance measure.
4. Chose a similarity/distance measure – Euclidean or Manhattan distances are the most popular choices.
5. Evaluate the CBIR results using one of the measures described in the posted article. Show (store) Top 5 retrieved images for some of the images in the test set (2-3 query images).
6. Don’t hesitate to ask your teacher if you have questions about this homework (visual questions included) ☺

Grey Level Co-occurrence Matrix for Texture Description

For building the grey level co-occurrence matrix (GLCM) associated to an (grayscale) image we must first specify a displacement vector ***d=(dx,dy)***. An element ***P(i,j)*** of the GLCM is the number of all pairs of pixels ***(p_1, p_2)*** separated by ***d*** having grey levels ***(i,j).***

$$p_1 = (x, y, i) \quad , \quad p_2 = (x + dx, y + dy, j)$$

$$P(i,j) = |\{(p_1, p_2);\ p_1 = (x, y, i),\ p_2 = (x + dx, y + dy, j)\}|.$$

Assume we have an ***5x5*** image with only 4 grey levels ***{0,1,2,3}***:

$$I = \begin{pmatrix} 0 & 1 & 2 & 3 & 3 \\ 1 & 2 & 1 & 0 & 2 \\ 2 & 1 & 3 & 3 & 0 \\ 0 & 0 & 2 & 2 & 1 \\ 1 & 1 & 2 & 0 & 2 \end{pmatrix} \quad , \quad d = (1,1)\ , P = \begin{pmatrix} 1 & 1 & 2 & 0 \\ 0 & 2 & 1 & 1 \\ 3 & 0 & 1 & 1 \\ 0 & 1 & 2 & 0 \end{pmatrix} \ (\text{or } P = \frac{1}{16} P).$$

For an image with 256 grey levels of intensity the GLCM is of size ***256x256***. Usually the elements of the GLCM are normalized by dividing them to the total number of pixel pairs.

The following descriptors are used for GLCM characterization:

1. Maximum probability

$$\max\{P(i,j);\quad i,j = 1,...,L\}\ ;$$

2. Correlation

$$\sum_{i=1}^{L}\sum_{j=1}^{L} \frac{(i - m_r)(j - m_c)P(i,j)}{\sigma_r \sigma_c} \quad (\text{if } \sigma_r \sigma_c \neq 0)$$

$$m_r = \sum_{i=1}^{L} i \sum_{j=1}^{L} P(i,j)$$

$$m_c = \sum_{j=1}^{L} j \sum_{i=1}^{L} P(i,j)$$

$$\sigma_r^2 = \sum_{i=1}^{L} (i - m_r)^2 \sum_{j=1}^{L} P(i,j)$$

$$\sigma_c^2 = \sum_{j=1}^{L} (j - m_c)^2 \sum_{i=1}^{L} P(i,j)\ ;$$

3. Contrast

$$\sum_{i=1}^{L}\sum_{j=1}^{L} (i - j)^2 P(i,j)\ ;$$

4. Uniformity (energy)

$$\sum_{i=1}^{L}\sum_{j=1}^{L} P(i,j)^2 ;$$

5. Homogeneity

$$\sum_{i=1}^{L}\sum_{j=1}^{L} \frac{P(i,j)}{1+|i-j|} ;$$

6. Entropy

$$-\sum_{i=1}^{L}\sum_{j=1}^{L} P(i,j)\log_2 P(i,j) ;$$

7. Dissimilarity

$$\sum_{i=1}^{L}\sum_{j=1}^{L} |i-j| P(i,j) .$$