Tutorial 2: Color-based Retrieval Techniques

(SEMESTER II: 2001-2002)

CS4241 Multimedia Information Systems

1. Assume that the LUV color space has been quantized into "n" colors, we can build the normalized color histogram $H(I)$ for image I:

$$H(I) = (h_{c_1}, h_{c_2}, \ldots, h_{c_n})$$

Assuming some fixed order of these n colors (say the index of the colors), we can build a *cumulative histogram* for image I:

$$\tilde{H}(I) = (\tilde{h}_{c_1}, \tilde{h}_{c_2}, \ldots, \tilde{h}_{c_n}) \qquad \text{where} \qquad \tilde{h}(c_j) = \sum_{c_l \leq c_j} \tilde{h}_{c_l}$$

Consider these two 5×5 images encoded using 6 colors with color codes between 0 and 5::

(A)

1	4	0	0	3
2	4	5	5	4
4	4	4	3	3
4	4	0	0	0
2	2	2	3	3

(B)

1	1	1	4	5
5	5	3	3	3
3	2	2	2	3
3	3	1	1	5
5	1	1	1	3

(a) Compute the cumulative histograms of image A and image B.

(b) Suggest a suitable distance measure for the cumulative histogram technique and use it to compute the distance between images A & B.

(c) What are the advantages and the disadvantages of the cumulative histogram technique?

2. Consider this image with three colors:

2	3	1	3	3	1	3
1	3	3	1	3	3	1
2	3	1	2	3	1	1
2	3	3	3	1	1	3
3	3	3	3	1	1	3
2	3	3	1	1	1	3
3	2	1	3	2	3	1

(a) Assuming 4-connectedness for connected components extraction and the value of threshold $\tau = 4$, compute the color coherence vector for this image.

(b) If 8-connectedness is assumed instead, what will be the new color coherence vector? Assume $\tau = 4$.

(c) Explain, with suitable expressions, how perceptually similar colors can be incorporated for color coherence vectors.

3. In the field of transportation, there is a distance measure known as the *earth mover's distance* (EMD). This is a bipartite network flow problem which can be formalized as follows: let I be a set of suppliers, J a set of consumers and c_{ij} the cost to ship a unit of supply from $i \in I$ to $j \in J$. We want to find a set of flows f_{ij} that minimize the overall cost:

$$\sum_{i \in I} \sum_{j \in J} c_{ij} f_{ij}$$

subject to the following constraints:

$$(1) f_{ij} \geq 0 \quad i \in I, j \in J \qquad (2) \sum_{i \in I} f_{ij} = y_j \quad j \in J \qquad (3) \sum_{j \in J} f_{ij} \leq x_i \quad i \in I$$

where x_i is the total supply of supplier i and y_j is the total capacity of consumer j. A feasibility condition is that the total demand does not exceed the total supply:

$$\sum_{j \in J} y_j \ \leq \ \sum_{i \in I} x_i$$

Once this problem is solved (using linear programming), i.e. we get an optimal set of flows $\{f_{ij}\}$ which satisfies all the constraints, EMD is defined as:

$$D(I, J) \ = \ \frac{\sum_{i \in I} \sum_{j \in J} c_{ij} f_{ij}}{\sum_{j \in J} y_j}$$

Intuitively, one can imagine that each supplier i has some earth x_i to be transported to the consumers where each consumer j has a hole of size y_j. Then EMD measures the least amount of work needed to fill the holes with earth where a unit of cost corresponds to moving a unit of earth by a unit of ground distance.

a. Explain how EMD can be used to measure the color similarity distance between two images using the *color cluster* feature. You basically need to map the elements of the color cluster feature to the terms in the EMD formulation.

b. Does this EMD distance take perceptual similarity into account? Explain.

4. The *histogram refinement* feature for color-based image retrieval can be further improved by using the notion of successive refinements in which two (or more) refinements can be applied to the initial color histogram.

a. Develop the method for doing successive refinement twice – first by using the 50% centering refinement and the second time by using the coherence refinement assuming 4-connectedness. Provide the exact feature and similarity measure expressions.

b. Assuming the value of threshold $\tau = 4$, compute the successive refinement feature that you have developed for this image with three colors:

3	1	2	3	1	3	3	1	3	2	3	1	3	3	1	3
2	2	1	3	3	1	3	3	1	1	3	3	1	3	3	1
1	3	2	3	1	2	3	1	1	3	3	3	3	1	1	3
3	1	2	3	3	3	1	1	3	2	3	3	3	1	1	3
2	2	3	3	3	3	1	1	3	2	3	1	3	3	1	3
3	3	2	3	3	1	1	1	3	2	3	1	3	3	1	3
3	1	3	2	1	3	2	3	1	3	3	3	3	1	1	3
2	2	3	3	3	3	1	1	3	1	3	3	1	3	2	3
1	3	2	3	1	2	3	1	1	1	1	1	3	2	3	1
3	1	2	3	1	3	3	1	3	3	1	1	3	1	3	3
2	2	1	3	3	1	3	3	1	1	1	3	1	3	3	1
1	2	3	3	3	3	1	1	3	1	3	3	1	3	2	3

c. Does the order of applying the two refinements (i.e. centering followed by coherence versus coherence followed by centering) matter in the feature vector computed? Explain.