CoE 703 Course Project 1

September 15, 2014

When displaying a digital image on a monitor, the gray level x of a pixel is mapped to an output intensity level y on the screen. This mapping is carried out by a transfer function $y = T(x)$. Let N_x be the number of input pixel gray levels and N_y the number of output device intensity levels. The transfer function performs an integer-to-integer mapping

$$T : \{0, 1, \cdots, N_x - 1\} \to \{0, 1, \cdots, N_y - 1\} \tag{1}$$

The nature of the physical problem stipulates that the transfer function T be monotonically non-decreasing, because T should never reverse the order of intensities. In other words, we must have

$$T(x_j) \geq T(x_i) \quad \text{if } x_j > x_i \tag{2}$$

Therefore, any transfer function satisfying the required monotonicity has the form

$$\begin{aligned} T(i) &= \sum_{0 \leq j \leq i} s_j, \ 0 \leq i < N_x \\ s_j &\in \{0, 1, 2, \cdots, N_y - 1\} \\ &\sum_{0 \leq j < N_x} s_j < N_y \end{aligned} \tag{3}$$

In (3), s_j is the increment in output intensity versus a unit step up in input level j. Therefore, s_j can be interpreted as contrast at level j, which is the rate of change in output intensity without considering the pixel context. Note that a transfer function is completely determined by the integer-valued vector $\mathbf{s} = (s_0, s_1, \cdots, s_{N_x - 1})$. Having associated the transfer function T with contrasts s_j's at different levels, we induce from (3) a natural definition of expected contrast of T for an image I:

$$C(\mathbf{s}) = \sum_{0 \leq j < N_x} p_j s_j \tag{4}$$

where p_j is the probability that a pixel in I has input gray level j.

a Formulate optimal contrast-tone mapping for contrast enhancement as a linear programming problem of maximizing the expected contrast $C(\mathbf{s})$ while satisfying the monotonicity condition (2) and the range of the mapping function T in (1).

b Solve the above formulated linear programming problem by MatLab, and run your program on test images provided by your TAs. Are the results good? Explain your observations.

c Improve your results by using additional constraints (hints: get some ideas from Xiaolin Wu' paper "A linear programming approach to optimal contrast-tone mapping", IEEE Transactions on Image Processing, vol. 20 (5), pp. 1262-1272).

d Design and implement a dynamic programming algorithm for the above stated problem of optimal contrast-tone mapping.

e Write a project report to detail: the algorithm development; comparison between the linear programming algorithm and dynamic programming algorithm; the roles of different constraints and their impacts on visual effects of the processed image. Your conclusions and claims have to be backed up by experimental results, such as output images and plots of the input histograms and optimized transfer functions.

Notes:

- Submit your project report together with your codes.
- This project is individual work.

Due: Sunday, October 19, 2014.