BIL 415 - Image Processing Practicum

Giving Artistic Effects to Colorful Images

Due Date: 23:00pm on Thursday, November 26th, 2015

a) Input   b) Artistic smoothing   c) Kuwahara filter result

Figure 1: Input image and painting-like results of it

Background

Image filtering is one of the most fundamental tasks in Image Processing. It has been used for very different purposes such as image smoothing and edge detection. The main aim of image smoothing is to remove the high frequency component of the given image and to obtain the low frequency component. Basically, smoothing is carried out by convolving an image with a low-pass filter like the Gaussian filter kernel. The goal of edge detection is to determine the pixels where the brightness values are changed abruptly. Sobel and Prewitt filters are some of the examples to edge detection filters.

Many image editing tools like Photoshop let the user to perform some special filters on the images for various artistic effects. For example, one can obtain cartoon like images, pencil drawing images, etc. Artistic Edge and Corner Enhancing Smoothing by Papari et al.[2] is one such study where the painting-like outputs are obtained by preserving edges and corners. You may refer to the article for the details and to understand how those processes are performed.

Overview

The goal of this assignment is to implement Kuwahara filter[1] and Artistic Edge and Corner Enhancing Smoothing[2] by using formulas given below. A sample image showing a possible result is given above.

Details

Your program will take a color image as input and produce a filtered version of the input image as output by performing Kuwahara filter and artistic filter on it. The formulation of each step is given below for grayscale images. Specifically, you should implement the following steps for color images:

1. **Formulation For Kuwahara Filter**

Let I is a grayscale image and a square of length 2a centered around a point (x,y) which is partitioned into four identical square subregions Q_1, Q_2, Q_3, Q_4 like in below.
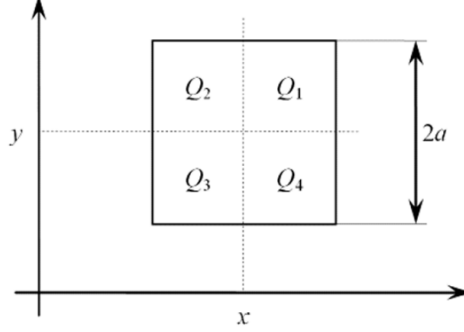
To calculate Kuwahara filter, we have to calculate local average($m_i(x,y)$) and the local standard deviation($s_i(x,y)$) for each subregion $Q_i(x,y)$ where i represents subregion id($i = 1..4$). Kuwahara filter can be calculated by using

$$\Phi(x,y) = \sum_i m_i(x,y) f_i(x,y)$$

where

$$f_i(x,y) = \begin{cases} 1, & s_i(x,y) = \min_k\{s_k(x,y)\} \\ 0, & \text{otherwise.} \end{cases}$$

2. **Formulation For Artistic Smoothing**

You should divide a circular region around each pixel in equal sectors , over which you'll compute weighted local averages and local standard deviations. The sectors S_i are defined by the following cutting functions $V_i(r,v)$, expressed in polar coordinates:

$$V_i = U_i * g_{\sigma/4},$$
$$U_i(r,\vartheta) = \begin{cases} N, & i - \frac{1}{2} < \frac{N}{2\pi}\vartheta < i + \frac{1}{2} \\ 0, & \text{otherwise.} \end{cases}$$

For example, if you determine 8 sectors for your filter your region should look like in Fig.2 (a). You have to generate a 2-D Gaussian kernel that you'll use to compute weighted local averages and local standard deviations like above(symbolized with g). Let be the following 2-D Gaussian kernel:

$$g_\sigma(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

The weighting functions are defined as products between the Gaussian mask and the cutting functions V_i:

$$w_i = g_\sigma \cdot V_i$$

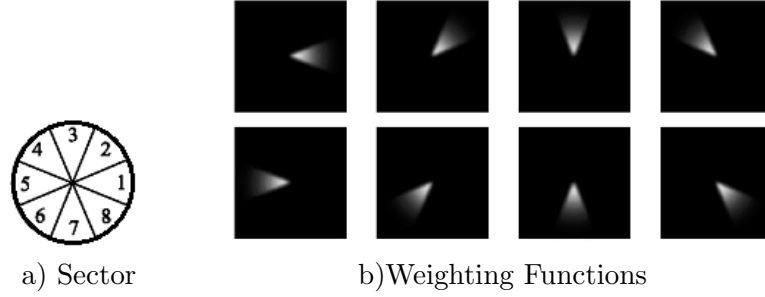Fig. 2(b) shows the weighting functions for the case N=8 sectors.

a) Sector   b)Weighting Functions

Figure 2: Sectors and weights

Note that,

$$\frac{1}{N}\sum_{i=1}^{N} V_i(x,y) = 1, \quad \frac{1}{N}\sum_{i=1}^{N} w_i(x,y) = g_\sigma(x,y)$$

After that you'll compute weighted local averages(m_i) and local standard deviations(s_i) which are defined by convolutions of the input image with weighting functions,

$$m_i = I * w_i$$
$$s_i^2 = I^2 * w_i - m_i^2, \quad \iint_{\mathbb{R}^2} w_i(x,y)\mathrm{d}x\mathrm{d}y = 1$$

where I is the input image.

Once s_i and m_i are computed according to the formula above, the output can be computed by using this formulation

$$\Phi_q = \frac{\sum_i m_i s_i^{-q}}{\sum_i s_i^{-q}}$$

where q is a parameter.

3. **Details for Implementation**

For artistic smoothing: There are three main parameters that affect the results of artistic filter; σ, N and q. These parameters should not be determined automatically in your implementation. Instead of it, you should handle them as function parameters. Your function definition should be like;

function y = artisticsmoothing(image, sigma, N, q)

where image is image name and others are mentioned parameters.

For Kuwahara filter: There is one main parameter, which is window size, that affects the result. Your function definition should be like;

function y = kuwahara(image,windowSize)

where windowSize determines the size of square window.

Details for Report

Your report should contain a brief overview of the problem, the details of your approach, and the results of your algorithm on at least 5 different images with your comments. Your should contain the items listed below:

- comment about parameters and their effects(generate results with different parameters, add to the report and examine the results).

- explanation of behaviour of the filtering methods.

- comment about difference between kuwahara filter and artistic smoothing filter(advantages and disadvantages compared to each other)

- comment about difference with the median filter, advantages and disadvantages compared to median filtering.

- Is there another way for implementation? Explain.

If your algorithm failed to give a satisfactory result on a particular image, provide a brief explanation of the reason(s).

Notes

- You can implement this assignment individually or as a group (at most 2 student in a group). Only one of the group members should submit the assignment(write down your partner's information in the report).

- **Late submission only exists for November 27th, 23:00pm and it will be evaluated over 80 points.**

- Do not send your assignment via e-mail. There will be no extension.

What to Hand In

You are required to submit all your report along with a short webpage in *PDF*. For that purpose, prepare a folder containing

- `README.txt` *(text file containing details about your project)*
- `code/` *(directory containing all your code)*
- `pset3.pdf` *(PDF report)*

Archive this folder as `studentid.zip` and submit to dersler.cs.hacettepe.edu.tr BBM415 group.

References

[1] M. Kuwahara, K. Hachimura, S. Eiho, and M. Kinoshita. Processing of ri-angiocardiographic images. In Jr. Preston, K. and M. Onoe, editors, *Digital Processing of Biomedical Images*, pages 187–202. Springer US, 1976.

[2] Giuseppe Papari, Nicolai Petkov, and Patrizio Campisi. Artistic edge and corner preserving smoothing. *IEEE Transactions on Image Processing*, 29, 2007.