EE3206/EE3206E INTRODUCTION TO COMPUTER VISION AND IMAGE PROCESSING

Semester 1, 2013/2014

Experiment 1

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1 INTRODUCTION

The experiment is based on a Windows image processing application, Image Processing Lab, or IPL. It consists of several routines that are used for the display, processing and analysis of digital images. This laboratory session introduces the basic concepts of digital image processing and provides hands-on experimentation in the topics of noise reduction and the 2-D discrete Fourier transform (DFT). The ideas covered in the lectures are revised and extended so as to reinforce comprehension of the material. The open-ended nature of some of the experiments and questions will enhance your understanding and perhaps provide valuable insight.

To derive maximum benefit, you should go through the lab sheet before you come for the experiment. If there are topics that you are not familiar with, you should read up the notes or the reference books. Please note the following:

- The experimental work is to be done in the **Vision and Machine Learning Lab** (E4-08-25)**.**
- Bring along a thumb drive for storing the images.
- Use only the **Temp** folder for storing your results, and delete all your files before you leave. Do not try to overwrite the image files that are already in Temp; the system may hang.
- Save results in c:\temp, zip the images and then transfer to your thumb drive. You need not save the test images as they can be downloaded from IVLE.

2 PROCEDURE

2.1 Familiarization

2.1.1 Run ***IPL.exe*** and open some images. Spend 5~10 minutes exploring the functions, including the following:

- **Zoom** function
- Defined **area of interest (AOI)** for processing
- **Gray level profile** to facilitate detailed examination

2.1.2 The brightness and contrast settings on the monitor have a significant effect on the appearance of the image being viewed. Load ***lena.jpg*** and adjust the brightness and contrast to obtain a good quality, high-contrast image.

2.1.3 Load ***couple.jpg*** and answer the following questions.

Q1. Consider the two scalar operations: $a+I$ *and* $b\times I$ *, where* $a,b>1$*. Explain the effect of each operation on an image and its histogram.*

Q2. Use the scalar addition and multiplication operations (Edit > Image Operation) to enhance ***couple*** *so that the details of the image may be seen clearly. Your enhancement procedure may involve one or more functions used sequentially. Describe and explain the steps in your enhancement procedure.*

2.2 Image Quality

2.2.1 Image quality is a subjective issue and depends on a variety of image attributes, e.g., overall brightness, contrast, noise, colour balance and sharpness.

Q3. How is a digital image different in appearance from an analogue image (e.g., a photograph)?

Q4. Consider these images: ***woman.jpg, flower.jpg****,* ***lake.jpg*** *and* ***cells.jpg****. Classify the quality of each image as good, medium or poor, giving the reasons for your decisions.*

2.2.2 Image compression is used to store an image using a smaller number of bytes, but this may be at the expense of image quality. Load ***eagle.bmp***. Compress the image with **Save as JPEG**. Compress using various quality factors, from 50 down to 5. Note the file size of the compressed image. Obtain a plot of SNR versus compression ratio (CR), defined as

CR = size of original image/size of compressed image.

- For determining the SNR, the original image should be used as the reference image
- Image file size is listed under **Image Statistics**.

Q5. Describe the image artifacts that appear as the image quality decreases. At which CR (based on your subjective assessment) does the image become unacceptably degraded? Discuss the factors you have considered in arriving at your answer.

2.3 Noise Reduction

2.3.1 Load ***test1.bmp***. Use the ***Display Histogram*** function to observe the histogram.

2.3.2 Various noise types can be added. Try adding salt-and-pepper, uniform and Rayleigh noise, and observe their effects on the image and the resulting histograms.

2.3.3 Add Gaussian noise of mean 0 and s.d. 15 to ***test1.*** Save the resulting image as ***test1a.bmp***. Compare the histograms of ***test1*** and ***test1a*** and explain your observations.

2.3.4 Apply mean and median filtering to ***test1a*** using neighbourhood sizes of 3×3 and 7×7. Compare the performance of the two filters in terms of SNR, visual quality, and other pertinent parameters. (Use the original image, ***test1***, as the reference image when computing the SNR.)

2.3.5 Add salt-and-pepper noise (probability 0.05) to ***test1***. Apply median and mean filtering separately to the noisy image and comment on the results.

2.3.6 Add salt-and-pepper noise (probability 0.5) to ***test1***. Apply median filtering and obtain the absolute difference between the ***test1*** and the filtered image. Do this for window sizes 3 × 3 and 7 × 7. Compare and explain the results.

Q6. Comment on the effects of repeatedly applying the median filter to reduce salt-and-pepper noise.

2.3.7 We now investigate image averaging (under the **Edit** menu). Generate several noisy images, each obtained by adding Gaussian noise of mean 0 and s.d. 15 to ***test1***, and use these for image averaging. Obtain the SNR after each image averaging operation. Obtain a plot of SNR against n_f, the number of images (frames) averaged, for $1 \le n_f \le 10$. Comment on the results. (Use the original image, ***test1***, as the reference image when computing the SNR.)

2.3.8 Anisotropic diffusion (Filters > Edge preserving smoothing filters) is a noise reduction technique that aims to preserve edges. Compare anisotropic diffusion with mean filtering and median filtering for ***ctslice.bmp*** and ***test1a.bmp.*** A visual comparison would be sufficient.

2.4 Discrete Fourier Transform

2.4.1 Using the FFT (not the DFT) function in IPL, obtain the Fourier spectrum (DFT magnitude) of ***test1*** and ***test1a***, respectively. Compare and explain the main visual features. (The gray-level profile may be helpful in examining the Fourier spectrum.)

2.4.2 Consider the mask

$$M = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 1 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

What is the general effect of applying this mask to an image? Apply mask M to ***test1*** (Filter > Linear Filter > User defined). Save the resulting image as ***test1b.bmp***. Obtain the Fourier spectrum of ***test1b.*** Explain its main features and compare it with the Fourier spectrum of ***test1***.

2.4.3 Study carefully the images ***pots1.bmp***, ***pots2.bmp*** and ***pots3.bmp*** and their respective histograms. ***pots2*** and ***pots3*** are obtained by re-quantizing ***pots1*** to 16 gray levels using two different methods. Examine their respective gray-level histograms. Compare the three images in terms of visual quality and explain how their different visual quality may be explained in terms of their quantization.

2.4.4 Obtain the Fourier spectrum of ***pots1***, ***pots2*** and ***pots3***. Explain their differences (if any).

3 REPORT

3.1 Submit the formal report within two weeks of the lab session to the Vision and Machine Learning Lab (E4-08-27). The focus of the report should be on answering the questions and discussing and explaining your observations.

3.2 **Reminder:** ***The results and report must be your own work. Plagiarism is a serious offence.***

Notes on Using IPL

(a) The **active image** is identified by the blue title bar of the image window. Image operations are performed on the active image. The result may be displayed in the same window or a new window, depending on the operation. Clicking the LMB (left mouse button) on the title bar or anywhere in the image window will make this image the active image.

(b) Image operations are generally performed on the pixels within the **area of interest** (AOI). The default area of interest is the entire image. Defining an area of interest is achieved by clicking and dragging with the LMB. If the AOI is very small (e.g., 8×8), it is still shown but the AOI will still be the full image. Clicking the LMB alone will set the AOI to the entire image. The AOI may be defined by using the toolbar box of the IPL window or the Edit menu.

(c) The **image origin** (0, 0) is the top left corner. The *x* axis points across and the *y* axis points down.

(d) The **cursor position** and the gray level are displayed at the bottom status bar.

(e) An **Undo** function (under Edit) will help you recover from errors, but it can only recover one previous operation.

(f) **Clone** (under Edit menu) replicates the image – it is useful, e.g., when you wish to try out different operations on one image.

(g) Gaussian noise is defined by the standard deviation while uniform and Rayleigh noise are defined by the variance.

(h) Do not use the DFT function as it is very slow.

(i) The image histogram and a gray-level profile can be saved as image files.

(j) $$\mathrm{SNR} = 10\log_{10}\left(\frac{\sum\sum f_{\mathrm{ref}}^2(x,y)}{\sum\sum\left[f_{\mathrm{ref}}^2(x,y) - f_t^2(x,y)\right]}\right)$$

where f_{ref} = reference image and f_t = test image.