CHAPERT III

EXPERIMENT

3.1 Apparatus

3.1.1 LCD Monitor

Model: EIZO Height Adjustable Stand for FlexScan L767

Size: 19 inch

Resolution: 1024 x 768 pixel True color

DPI setting: Normal Size 96 DPI

Color: Color quality Highest 32 bit

3.1.2 Power PC: Intel (R) Celeron (R) CPU 1.70 GHz

3.1.3 Spectrophotometer: Gretag Macbeth Spectrolino scan

3.1.4 Software

Matlab Version 7.0

Image Processing Toolbox Version 4.2

Adobe Photoshop Version 7.0

Profile Maker Professional Version 5.0

3.2 Experimental Procedure

In this study, an experimental procedure can be divided into three steps (Figure 3-1). The first step is the preparation of original images, followed by a process of image enhancement. The last step deals with a method of image comparison. The detailed descriptions for each step are given in the following sections.
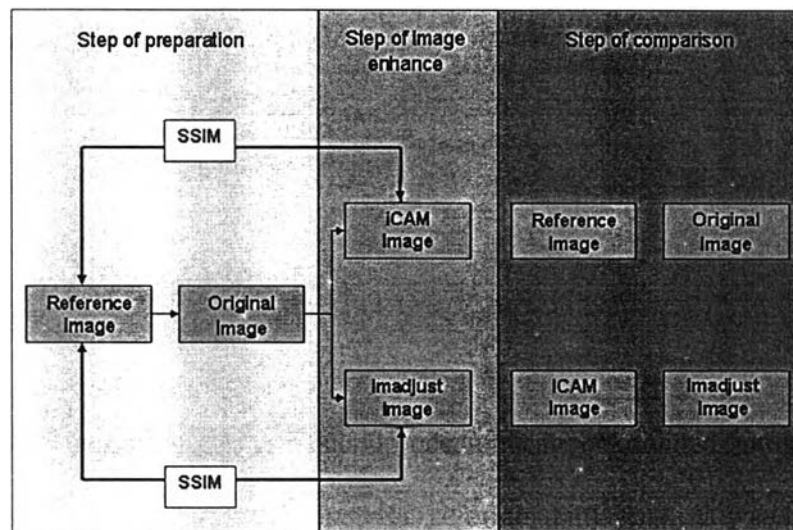
Figure 3-1: A flow chart of experimental procedure.

### 3.2.1 Experimental preparation.

3.2.1.1 Test images

Three different images were selected to use in this study. Two images, i.e. Boat and Japan, were selected from the SHIPP standard [29]. The dynamic ranges of both images were moderate. Boat was an outdoor scene with fine details in either highlight, or midtone, or shadow areas (see Figure 3-2). Japan was a low-key image, i.e. a low brightness image, containing colorful man-made objects. The other image was Party which was selected from a set of test images available from

http://www.colour.org/tc8-04/test_images/Sony/party_4s.tif. Party was a picture of a

lady shot indoors. Various objects were included in the image, including the standard

color chart, fruits, silverware, etc. All three images were of good quality and therefore

were taken as reference images. In addition, they were in the same size of 600 x 450

pixels.
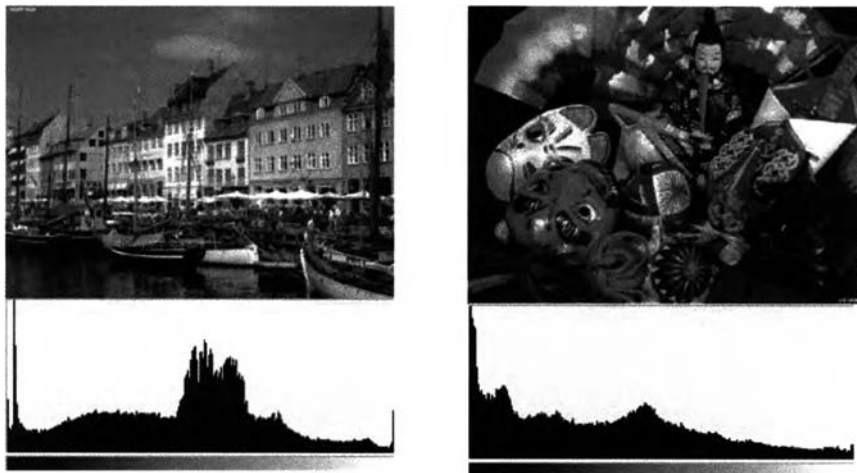
Boat   *Japan*
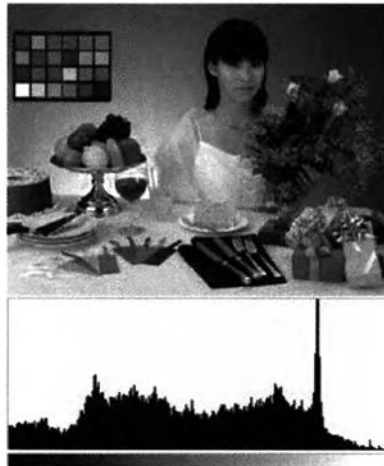
Party

Figure 3-2: Reference images and their lightness histograms.

To generate original images that had poor quality with respect to poor image rendering, the histograms of the reference images were adjusted such that the image data were not well spaced through the entire dynamic range. As a result, some details in the images were lost and the overall appearance darkened. Figure 3-3 shows the resulting images. These images referred to as original images were used as input images to be enhanced by iCAM or other methods of image enhancement in the next step of this study.

Boat   *Japan*

Party
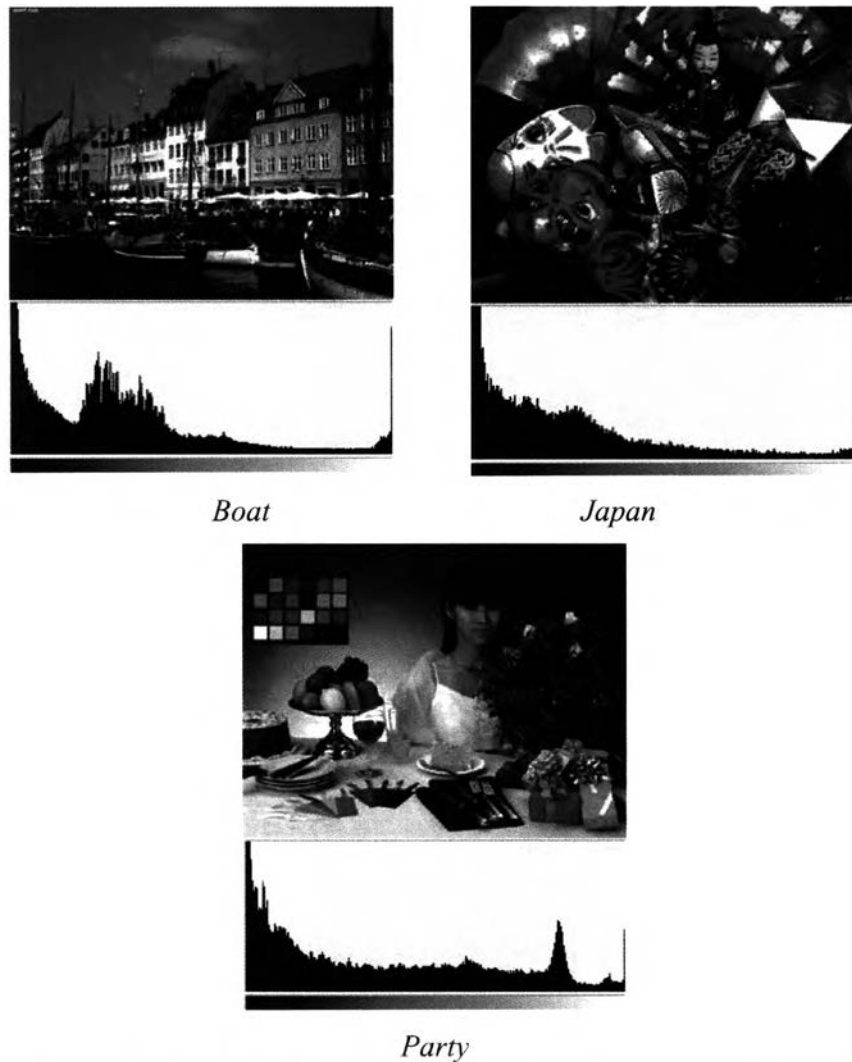
Figure 3-3: Original images (or input images to be enhanced) and their lightness

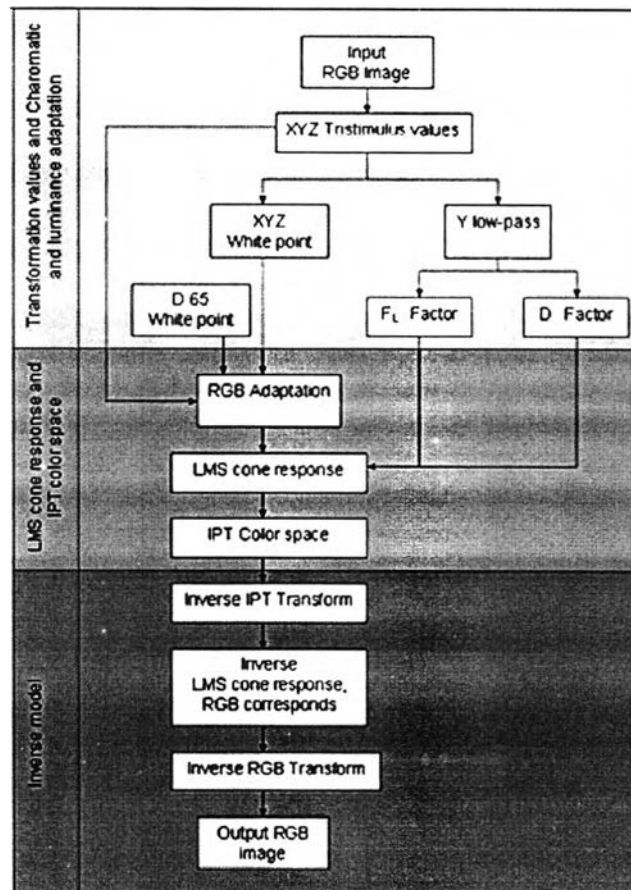*histograms.*

3.2.1.2 Implementation of iCAM.

Figure 3-4: A flow chart of iCAM process.

Figure 3-4 illustrates a process of implementing iCAM for image rendering. Firstly, the image data in RGB space were transformed to XYZ tristimulus values. The next step accounts for chromatic and luminance adaptation of the image. This was done by calculating RGB responses from the given XYZ values and then converting to LMS cone responses. The LMS cone responses were further computed to obtain the IPT appearance space. To view the resulting images, the IPT color appearance data were transformed back to XYZ and RGB, respectively, using inverse equations of the relevant steps.

Detailed descriptions for each step of are given below.

(a) The input image data were in sRGB space. Thus, the RGB image data were transformed into CIE1931 XYZ tristimulus values based on a pixel-by-pixel basis using the Equations 2-2 to 2-5 given in Chapter 2.

(b) The step of chromatic and luminance adaptation serves two purposes: local adaptation of scenes and a global white point shift toward CIE D65. This white point shift is necessary, as the IPT color space used in iCAM is defined only for D65. The chromatic adaptation trandform is identical to that of CIECAM02, as shown in Equations 2-10 to 2-12. A degree of adaptation factor, D, was calculated according to the equation provided in the CIECAM02 formulation, as shown in Equation 2-15.

(c) A Gaussian blur in the frequency domain, the amount of blurring in the low-pass image, was utilized. Two free parameters of Gaussian filter is width of the filter and σ, proportional to the amount of blur. The degree of adaptation depends upon the choice of the blurring function.

(d) The adapting chromatic information is obtained from the XYZ tristimulus values of the image. The Gaussian filter was applied to the image to yield a low-pass image. The XYZ values of the low-pass image were taken as adapting white points for calculating the corresponding RGB responses.

(e) The corresponding RGB responses were converted to LMS cone responses according to Equation 2-17.

(f) The modulation of the absolute luminance image and surround luminance image uses the F_L factor from CIECAM02. The adapting luminance, L_A, is a low-pass version of the absolute Y tristimulus image, which using a different Gaussian filter from the one described in Step (d).

(g) The surround exponents calculated in the previous step were used in the transform from XYZ tristimulus values into the IPT appearance space.

(h) The output image data were then transformed into XYZ values and converted to RGB display.

3.2.1.3 Set-up of LCD

An EIZO LCD monitor was used to display test images in this experiment. The monitor was first calibrated by setting brightness contrast at 0-255 and its white point to D65. It was then characterized using a CMS software Profile Maker Professional with color measurements made by a spectrophotometer. The LCD monitor profile was then obtained and was named k.icc profile. Figure 3-5 shows the color gamut of the monitor profile.
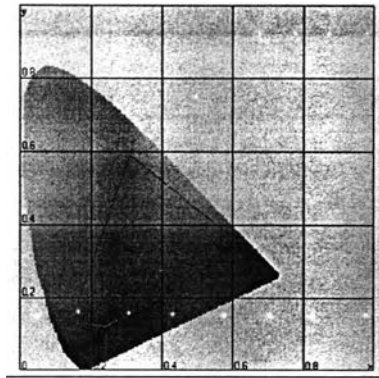
Figure 3-5: The xy chromatic diagram showing the gamut of the k.icc profile.

3.2.2. Image enhancement

After obtaining original images that were of poor quality in a sense of image detail and color appearance, the next step was to enhance these images by means of iCAM, which was implemented earlier, and the function Imadjust in Image Processing Toolbox, Matlab. The explanation of how to do image enhancement using each method is given below.

3.2.2.1 iCAM

The important parameters affecting the performance of iCAM in image enhancement are obtained from low-pass images. These low-pass images are generated as a result of applying Gaussian filters to the original image. Different filters yield different low-pass images, thus different parameters. In this experiment, two parameters that affect the characteristics of a Gaussian filter: size and sigma (σ), were varied to obtain different types of Gaussian filters. The size of filter was varied with two sizes, i.e. a filter size equal to image size and a filter size of half the image size. The amount of blurring in the image depends on a sigma value of Gaussian filter.

The values between 1- 500 were varied for sigma in this study. In iCAM, two low-pass images are required, as described in Step (d) and (f) in the previous section. The filters used in both steps were varied as such. The iCAM applied with appropriate types of Gaussian filters, i.e. a suitable combination of size and sigma of the two filters, would result in pleasing image appearance when applied to render images. To determine the appropriate types of filters, the SSIM index indicating similarity in quality between two images under investigation was employed. The SSIM index has a value between 0-1, where 0 indicates no similarity, 1 indicates that two images are identical. The numbers in between in an ascending order represent the increasing degree of similarity. Each of resulting images enhanced by iCAM with different types of filters was quantitatively compared with the reference images, considered to have perfect quality, using the SSIM index. The resulting images that yielded the highest SSIM index were selected to use in visual experiments to be described in Section 3.2.3.

3.2.2.2 Imadjust

The Imadjust function available in Image Processing Toolbox in Matlab adjusts image intensity values or colormap. The function requires variables low_in, low_out, high_in, and high_out. Its simplest syntax is as follows:

$$J = Imadjust \ (I, \ [low\_in \ high\_in], \ [low\_out \ high\_out])$$

The values in intensity image I are mapped to new values in image J such that values between low_in and high_in linearly map to values between low_out and high_out. In this experiment, an empty matrix ([]) specifying the default of [0 1] was used for [low_in high_in]. The values of low_out and high_out were varied between 0 and 1.

A series of resulting images was therefore obtained. In a selection of best resulting images, the SSIM index was calculated and images enhanced with appropriate low_out and high_out values that gave the highest SSIM index among images tested were selected to use in visual assessments.

3.2.3. Visual assessment

A comparison of four images including a reference image, original image (lost detail), and an image enhanced using iCAM, and using Imadjust was carried out by means of a rank order technique. All images were displayed on the LCD monitor at 72 dpi with Adobe Photoshop. As a result, the physical size of images displayed on the monitor was 8.33 x 6.25 inches. Observers were instructed to rank the images from 1 for most preferred, 4 for least preferred and 2, 3 for an intermediate preference follow. Observers were required to use the ranks 1, 2, 3, 4 once for each of the images. The observers were explicitly told that there were no constraints and that their preferences could be based on color and detail aspects of the image. First, they were asked to rank the images based on the appearance of color. Having done so, they were then asked to rank the same set of images based on image detail. They were clearly informed that the two ranks for different aspects needed not be the same. Each observer conducted the same experiment for all three images, i.e. Boat, Japan and Party. The observers sat approximately 22 inches away from the monitor. This distance was comfortable for observers to make judgments, while keeping it far enough not to resolve the mosaic of images. Twenty observers with normal color vision took part in the visual experiment.