CHAPTER 5

CONVERSION OF GRAY-SCALE IMAGE TO COLOR IMAGE WITH AND WITHOUT SYNTHESIS

5.1 INTRODUCTION

The color fundamental process followed by the human brain in perceiving color is a physiopsychological phenomenon that is not yet fully understood, the physical nature of color can be expressed on a formal basis supported by experimental and theoretical results. Basically, the colors can perceive in an object are determined by the nature of the light reflected from the object. Due to the structure of human eye, all colors are seen as variable combinations of the three so-called Primary colors Red, Green and Blue (RGB).

The characteristics generally used to distinguish one color from another are brightness, hue and saturation. Brightness refers to intensity. Hue is an attribute associated with the dominant wavelength in a mixture of light waves. Saturation refers to relative purity or the amount of white light mixed with a hue. The Hue and saturation taken together are called chromaticity, and therefore a color may be characterized by its brightness and chromaticity. The amounts of RGB needed to form any given color are called the tri-stimulus value. The chromaticity is useful for color mixing because a straight line segment joining any two points, and define all the different color variations that can be obtained by combining these two colors additively. The Luminance is the intensity of light per unit area of its source.

Color can be added to gray-scale images in order to increase the visual appeal of images such as black and white photos, classic movies and scientific illustrations. In addition, the information content of some scientific images can be perceptually enhanced with color by exploiting variations in chromaticity as well as luminance.

The task of coloring a gray-scale image involves assigning RGB values to an image which varies along only the luminance value. Since different colors may have the same luminance value but vary in hue or saturation, the problem of coloring gray-scale images has no correct solution. Due to these ambiguities, human interaction usually plays
a large role in the coloring process.

Here, the gray-scale image is represented by only the luminance values that can be matched between the two images. Because a single luminance value could represent entirely different parts of an image, the remaining values within the pixel's neighborhood are used to guide the matching process. Once a pixel is matched, the color information is transferred but the original luminance value is retained. In difficult cases, a few sample blocks can be used to aid the matching process between the source (color) and the target (gray-scale) image. After the color is transferred between the source and the target blocks, the final colors are assigned to each pixel in the gray-scale image by matching each gray-scale image pixel to a pixel in the sample blocks using the distance metric. Thus, each pixel match is determined by matching it, only to other pixels within the same image. We have found that this simple procedure works well for a wide range of images.

It is possible to specify other types of transformations that are more general and thus are capable of achieving a wider range of pseudo-color enhancement results. Basically, the idea underlying this approach is to perform three independent transformations on the gray levels of any input pixel. The results are then fed separately into the Luminance and Chrominance. This produces a composite image whose color content is modulated by the nature of the transformation function. It should be kept in mind that these are transformations on the gray-level values of an image and that they are not functions of position.

Gonzalez et al [1], the mapping of luminance values to color values is automatic, the choice of the color map is commonly determined by human decision for pseudo coloring. Colorization technique is to exploits textural information. The work of Welsh et al [32], which is inspired by the color transfer [30] and by image analogies [31], examines the luminance values in the neighborhood of each pixel in the target image and adds to its luminance, the chromatic information of a pixel from a source image with best neighborhoods matching.

Even in the case of pseudocoloring, [1] where the mapping of luminance values to color values is automatic, the choice of the color is commonly determined by human decision. However, a few web articles describe software in which humans must
meticulously hand-color each of the individual image regions. Then the system tracks polygons between frames and transfers colors in order to reduce the number of frames that the user must color manually [39]. Alternatively, photographs can be colorized using photo-editing software to manually or automatically select components of a scene. The area is then painted over with a color selected from a palette.

There also exist a number of applications for the use of color in information visualization. For example, [1] describe a simple approach for pseudocoloring gray-scale images of luggage acquired by X-ray equipment at an airport. The method uses separate transformations for each color channel which results in coloring objects with the density of explosives in bright orange and other objects with a blue tone. Further, color can be added to a range of scientific images for illustrative and educational purposes.

Color using in a printing press has been around for slightly over 100 years using a variety of techniques from stones and grease pencils to films and plates to more recently using “digital” processes for page design, imaging and plate making [96]. We see color because of the RGB sensitive cones in our eyes and sophisticated processing in our brains. To observe color there must be a light source, an object that the light source is illuminating and an observer that is viewing the object. The color of light is defined in terms such as wavelengths and radiation whereby different wavelengths produce different colors within the human visual spectrum.

A methodology for adding color to grayscale images [99] is completely automatic. Towards this goal, a technique that was recently developed to transfer colors from a user-selected source image to a target grayscale image. More specifically, it eliminates the need for human intervention in the selection of the source color images, which can be a first step towards real-time video colorization. To assess the merit of our methodology, they performed a survey where volunteers were asked to rate the plausibility of the colorings generated automatically for individual images. In most cases automatically-colored images were rated either as totally plausible or as mostly plausible.

The thesis focuses on converting the gray scale image to color image without synthesis and with synthesis. From the research survey, the color conversion for textile industry is not done so far. From this method, color can be converted to any gray scale.
image to the color image of same input and the output size or for the different output size (i.e., after synthesis). The pattern has been designed by the synthesis, the gray scale image may be converted to the color image.

An image enhancement technique can be used to enhance the detectability of detail within the image. In its most basic form, pseudocoloring is a transformation $T$, such that, $c(x,y) = T(f(x,y))$ where $f(x,y)$ is the original gray-scale image and $c(x,y)$ is the resulting color vector for the RGB. A simplified example of this method is the application of an arbitrary color to the data where a single, global color vector is assigned to each gray-scale value. The strength is that it does not alter the information content of the original data since no extra information is introduced. However, by using a color which does not increase monotonically in luminance, pseudo colored images may introduce perceptual distortions.

The concept of converting the color from one image to another is inspired by work [30] in which color is transferred between two color images. In their work, colors from a source image are transferred to a second colored image using a simple but surprisingly successful procedure. The basic method matches the distribution of color values between the images and then converting the gray-scale image to color image. Further, sample blocks can be employed to match similar areas between the two images.

5.2 ALGORITHM

The general algorithm for transferring color, the basic idea is then extended to use sample blocks. The general procedure for converting the gray-scale image to color image requires a few simple steps.

Step 1: Each image is converted into the $lxy$ color space. Select a small subset of pixels in the color image as sample.

Step 2: Go through each pixel in the gray-scale image in scan-line order and select the best matching sample in the color image using neighborhood statistics.

Step 3: The best match is determined by using a weighted average of pixel luminance and the neighborhood statistics.

Step 4: The chromaticity values $(x,y)$ of the best matching pixel are then transferred to the gray-scale image to form the final image.

Step 5: Color transfer using sample blocks involves the same for the whole image.
matching procedure but only between the source and target sample blocks.

The colored pixels in the target sample block regions are then used as the source pixels for conversion of color to the remaining non-colored pixels using a texture synthesis approach explained in chapter 3.

5.2.1 MATCHING PROCEDURE

Both color (source) and gray-scale (target) images are converted to the decorrelated \( lxy \) space for subsequent analysis. \( lxy \) space was developed to minimize correlation between the coordinate of the color space[38]. The color space provides the decorrelation, corresponding to an achromatic luminance, \( l \) and two chromatic values \( x \) and \( y \), which roughly correspond to yellow-blue and red-green opponent channels. Thus, changes made in one color should minimally affect values in the other. The reason for \( lxy \) color space is selected in the current procedure is, it provides a decorrelated achromatic value for color images. This allows to selectively transferring the chromatic \( x \) and \( y \) values from the color image to the gray-scale image without cross-channel artifacts. The transformation procedure follows directly from [30].

In order to transfer chromaticity values from the source to the target, each pixel in the gray-scale image must be matched to a pixel in the color image. The comparison is based on the luminance value and neighborhood values of that pixel. The luminance value is determined by the \( l \) in \( lxy \) space. In order to account for whole differences in luminance between the two images the performance luminance remapping [2] use the linearly shift and scale the luminance of the source image to fit it with the target image. This helps to create a better correspondence in the luminance range between the two images but does not alter the luminance values of the target image.

The neighborhood values are precomputed over the image and consist of the standard deviation of the luminance values of the pixel neighborhood. The neighborhood size 5x5 of pixels works well for most images. For some problematic images larger neighborhood size may be used.

Since most of the visually significant variation between pixel values is attributed to luminance differences, limit the number of samples for source color pixels and still obtain a significant range of color variation in the image. It allows reducing the number of
comparisons made for each pixel in the gray-scale image and decrease computation time. Then for each pixel, in the gray-scale image in scan-line order the best matching color sample is selected based on the weighted average of luminance and standard deviation. Once the best matching pixel is found, the \( x \) and \( y \) chromaticity values are transferred to the target pixel while the original luminance value is retained. This automatic, matching procedure works reasonably well on images when corresponding color regions between the two images also correspond in luminance values.

### 5.2.2 SAMPLE BLOCKS

In order to allow more user interaction in the color conversion procedure and to improve results, sample blocks are used between corresponding regions in the two images.

- The first step is to use the general procedure described above to convert color, but now only between the corresponding sample blocks. This allows the user to selectively convert colors between the source and target sample blocks. Expectation result is good for individual sample blocks because there should be less overlap of luminance levels between different color regions within the same block. Luminance remapping is done for the whole image block procedure but only between corresponding sample blocks. Again, the random sampling is applied for some samples per block.

- The second step is similar to texture synthesis algorithm in which the distance is used to find texture matches. The Error distance \( E \) is calculated by using the distance metric between neighborhood \( N_g \) in the gray-scale image and \( N_c \) in the colored block neighborhood as:

\[
E(N_g, N_c) = \sum (G(p) - L(p))^2, \ p \in N
\]  

(5.1)

where \( G \) is the gray-scale image, \( L \) is the luminance channel of the colored block and \( p \) are the neighborhood pixels.

At this stage no longer search is made for color image for texture matches but only search for matches within the colored sample blocks in the target image. The advantage of the approach is that in the first stage the color has been converted to the
selected sample blocks, which prevents pixels with similar neighborhood but from the wrong part of the image from corrupting the target block colors. It also allows the user to transfer colors from any part of image to a select region even if the two corresponding regions vary largely from one another in texture and luminance levels. Secondly, there may be more texture coherence within an image than between two different images, the expected pixels which are similar in texture to the colored target sample blocks to be colored similarly.

5.3 RESULTS AND DISCUSSIONS

The technique works well on scenes where the image is divided into distinct luminance or where each of the regions has distinct textures. The algorithm works well in a number of image domains. It should be clear that when one considers only a small neighborhood size around a pixel it is often impossible to determine whether that neighborhood belongs to one texture or another. However, by using high resolution images and larger neighborhoods improved results may obtain. The computation time is very less.

5.3.1 GRAY SCALE TO COLOR IMAGE WITHOUT SYNTHESIS

Fig. 5.1 shows the sample input gray scale image, Fig. 5.2 is the color image from which the color is going to extract and the colored output is shown in the Fig. 5.3.

![Fig. 5.1 Input Gray Image](image1)
![Fig. 5.2 Input Color Image](image2)
![Fig. 5.3 Colored Output Image](image3)

Some more examples for Gray scale to Color image without Synthesis. It is shown in the Fig. 5.4 and in Fig. 5.5.
5.3.2 GRAY SCALE TO COLOR IMAGE WITH SYNTHESIS

The sample input is a gray scale image shown in the Fig. 5.6. Synthesis is made on the input image by using the concept of chapter 3. Color is applied to the synthesized resultant image. The synthesized result is shown in the Fig. 5.7.
Fig. 5.6 Input Gray-scale Image  
Fig. 5.7 Output Synthesized Gray-scale Image

Fig. 5.8 shows the color image (for color extraction) and the Fig. 5.9 is the colored result of the synthesized image. Another colored output is shown in the Fig. 5.10.
The running time of the algorithm for one image can range from 15 seconds to 60 seconds on a Pentium III, 1.0 Ghz CPU, 256 MB RAM. For implementation MATLAB 7.1 is used. Running time will vary depending on the number of samples used for comparison, the number of sample blocks, neighborhood size and the size of the images. Most images can be colored reasonably well in under a 60 seconds.

5.4 CONCLUSION

Considering the gray scale and the color image as an input, the color can be extracted from the input color image and applied to the input gray scale image. The output image may be the colored image. Only the luminance and the chrominance are considered. Color conversion can be done for the synthesized image also. Concept of synthesis may be taken from chapter 3. This is more useful for Textile industry.