CHAPTER VI
COLOR TRANSFORMATION

6.1 Introduction:

This chapter deals with the study and analysis of various color models and their vital role. It discusses gray scale and color images with its formation. It also deals with the color transformation of gray scale X-Ray images to a color image. The characteristics and performance of various color models are studied and analyzed and their boundaries are given here. This process enables the researcher to understand the important research contributions in the area of color image processing. The main research contributions on color image processing applied to gray scale X-Ray images can be classified into two algorithms namely:

- Method 1: Gray scale conversion using reference image alone
- Method 2: Gray scale conversion using chrominance checking

These two algorithms are discussed in detail in the subsections 6.4 and 6.5. These are two existing algorithms used in the color transformation from gray scale to color images. They are used in the field of colorizing old black and white photos, colorizing satellite images and in many applications. These algorithms are analyzed and used in the process of colorizing gray scale X-Ray images in this research work. Method using chrominance checking yields a better result than the method using reference image alone.
The subsection 6.2 discusses the gray scale images with their limitations. Subsection 6.3 analyses the various color models and importance of adding color to gray scale images.

**6.2 Gray Scale Images:**

Gray scale is a range of monochromatic shades from black to white. So a grayscale image contains only shades of gray and no color. They are different from black and white images. Their pixel value ranges from 0 to 255. They have only intensity values [61] [70]. Gray scale images are made up of only one bit value. They lack the chromatic information. They are also called monochromatic images. It shows only the luminance information [73].

The gray-scale image contains all the details of information; it is easier to understand. Moreover, it is free from ambiguities typical of black-and-white images. On the other hand, gray scale image may accelerate vectorizing significantly applying semiautomatic tracers. These tools view black lines placed on top of the grey-scale image. The lines are imperfect of course, and the tracer often asks for help, but is not difficult to lead it through a dirty zone manually looking at the gray scale image.

![Fig. 6.1 Sample Gray Scale X-Ray Images](image-url)
A pixel at \((x,y)\) is a vector in the gray scale image is,

\[
f(x,y) = I(x,y)
\]

Fig 6.2 Pixel at \((x, y)\)

### 6.3 Color Images:

The human visual system can distinguish hundreds of thousands of different color shades and intensities, but only around 100 shades of grey. Therefore, in an image, a great deal of extra information may be contained in the color, and this extra information can then be used to simplify image analysis. It is used in object identification and extraction based on color [14].

![The Visible Spectrum](image)

Fig 6.3 The Visible Spectrum
The hue is determined by the dominant wavelength. Visible colors occur between about 400nm (violet) and 700nm (red) on the electromagnetic spectrum. The saturation is determined by the excitation purity, and depends on the amount of white light mixed with the hue. A pure hue is fully saturated and no white light mixed in. Hue and saturation together determine the chromaticity for a given color. Finally, the intensity is determined by the actual amount of light, with more light corresponding to more intense colors. Color depends primarily on the reflectance properties of an object.

The human eyes can see those rays that are reflected, while others are absorbed. However, it is necessary to consider the color of the light source, and the nature of human visual system.

6.3.1 Tristimulus theory of color perception:

The human retina has 3 kinds of cones. The response of each type of cone as a function of the wavelength of the incident light. The peaks for each curve are at 440nm (blue), 545nm (green) and 580nm (red).

![Spectral response curves for each cone type](image)
6.3.2 CIE primaries:

In 1931, the Commission Internationale de l’Éclairage (CIE) defined three standard primaries, called X, Y and Z, that can be added to form all visible colors [14]. The primary Y was chosen so that its color matching function exactly matches the luminous-efficiency function for the human eye, given by the sum of the three curves. Tri-chromatic coefficient:

\[
x = \frac{X}{X + Y + Z} \quad y = \frac{Y}{X + Y + Z} \quad z = \frac{Z}{X + Y + Z}
\]

\[x + y + z = 1\]

Fig. 6.5 CIE Chromaticity Diagram

The CIE Chromaticity Diagram shows all visible colors. The x and y axis give the normalized amounts of the X and Y primaries for a particular color, and hence:

\[z = 1 - x - y\]

It gives the amount of the Z primary required. Chromaticity depends on dominant wavelength and saturation, and is independent of luminous energy. Colors with the same chromaticity, but different luminance all map to the same point within this region.
6.4 Color Models:

A color image is a digital image that has color information for each pixel. Each pixel is a combination of three band values of Red, Green and Blue. Each pixel has 24 bits value. A color model provides a coordinate system and a subspace in it where each color is represented by a single point. Color models describe how colors are represented. There are different types of color models in image processing. They are RGB, CMYK, HSV, LAB, and HSL.

6.4.1 RGB:

This is very common type of color model for which the processing is done very easily. The RGB color model is composed of three color components. They are Red, Green, and Blue [56] [70]. The RGB color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. The RGB is made up of 24 bit per pixel and is specified by three 8-bit unsigned integers to represent the three color models [60] [12]. It allows more than 16 million different color combinations and it is also called truecolor.

Fig. 6.6 RGB Color Image
This is an additive model, which says the colors present in the light add to form new colors, and is appropriate for the mixing of colored light [50] [23] [70]. The RGB model is used for color monitors and most video cameras.

RGB color space:

\[
C(x,y) = \begin{bmatrix}
R(x,y) \\
G(x,y) \\
B(x,y)
\end{bmatrix}
\]  

\[(6.3)\]
6.4.2 CMY Model:

The CMY (cyan-magenta-yellow) model is a subtractive model appropriate to absorption of colors, due to pigments in paints. In RGB model what is added to black to get a particular color is specified, in CMY model what is subtracted from white is specified [61]. In this case, the primaries are cyan, magenta and yellow, with red, green and blue as secondary colors.

![Fig. 6.9 CMY Model](image)

6.4.3 HSI Model:

This model is known as Hue, Saturation and Intensity Model. Hue is measured from red, and saturation is given by distance from the axis [8] [10] [60]. Colors on the surface of the solid are fully saturated and has pure colors, and the grayscale spectrum is on the axis of the solid [62].

![Fig. 6.10 HSI Model](image)
6.4.4 HSL and HSV:

HSL and HSV are the two most common cylindrical-coordinate representations of points in an RGB color model [60]. The two representations rearrange the geometry of RGB in an attempt to be more intuitive and perceptually relevant than the cartesian representation [8]. HSL stands for hue, saturation, and lightness, and is often also called HLS. HSV stands for hue, saturation, and value, and is also often called HSB where B represents brightness.

![HSL Cylinder](image1.png) ![HSV Cylinder](image2.png)

Fig. 6.11 (a) HSL Cylinder (b) HSV Cylinder

6.5 Color Transformation:

After preprocessing the gray scale images, they are converted into color images by adding up color. This process gives more details to the X-Ray image. This adding up colors is done by two algorithms:

- Method 1: Gray Scale Conversion using Reference image alone
- Method 2: Gray Scale conversion using Chrominance Checking

Gray scale image colorization is a useful application in the world of image processing [22] [33].
Color can increase the visual appeal of grayscale images such as old black and white photos, classic movies or scientific outcomes, image modalities in medicine, which only acquire grayscale images such as Magnetic Resonance Imaging (MRI), X-Ray and Computerized Tomography (CT) images.

These type of images can be enhanced with color for presentations and demonstrations. In addition, the information content of some scientific images can be perceptually enhanced with color by exploiting texture, chromaticity as well as luminance variations [76] [82]. Adding colors to a grayscale image actually involves assigning three-dimensional (RGB) pixel values to an image which varies along only one dimension (luminance or intensity).

Different colors may have the same luminance value but may vary in hue or saturation, hence, the problem of colorizing grayscale images has no inherently “correct” solution. Due to these reasons, human interaction usually plays a large role in the colorization process. The term "Colorization" was introduced in 1970 and was later patented by Wilson Markle.

Colorization trends have been classified into three categories;

- Hand coloring
- Semi automatic coloring
- Automatic coloring

Hand coloring has been long used by artists as a way of showing their talent. Usually image editing software's like Adobe Photoshop or Paint shop Pro are used similarly to convert gray images to color images.
Semiautomatic coloring refers to mapping luminance values to color values, which is done by converting the gray image to an indexed image. Pseudo coloring is a common example. Automatic coloring can be classified into three categories according to the source of colors to be transferred to the gray image pixels, which are transformational coloring, known as Image Matching and User Selection.

6.5.1 Method 1: Gray Scale Conversion using Reference image:

This process of color conversion includes adding color to the gray scale images using Reference image alone. Depending on the Reference image taken, the output image is colorized [49]. Following is the algorithm for adding color to the gray scale images:

Step 1: Check whether the Original image is a gray scale image or not. If it is a color image, then it should be converted into a gray scale image.

Step 2: The Source image which is taken for reference should be a color image.

Step 3: The size of the original image and the source image should be taken.

Step 4: Convert the original image and the source image to \textit{ycbcr} color space.

Step 5: Normalization process is done.

Step 6: Finally luminance is compared.

Step 7: After comparing the luminance the color mood is taken from the source image and added accordingly to the original image to form the destination image.
The gray scale image is converted into **ycbcr** image. Y is the *luma* component and CB and CR are the blue-difference and red-difference chroma components. After this algorithm is processed the gray scale image is modified into a color image by the luminance effect of the Source image.

![CBR Planes with different Y Planes](image)

Fig. 6.12 CBR Planes with different Y Planes

![Results of conversion of gray scale to RGB Images using the Source image](image)

Fig. 6.13 Results of conversion of gray scale to RGB Images using the Source image
These images are processed and their running time is calculated. The running time of the algorithm for one image can range from 10 seconds to 2 minutes on a Pentium IV CPU using MATLAB code. Execution time will vary from one image to another, depending on the size of the image. This X-Ray image which is taken as an source image in fig. 6.13, took a running time of 22.546743, 23.342643, 24.983431 seconds for Red, Green and Blue colored reference images.

6.5.2 Method 2: Gray Scale conversion using Chrominance Checking:

In this method, the chrominance value of the reference image is compared with that of the original gray scale image. Depending on the chrominance value of the referenced color image, the gray scale image is colorized [56]. The algorithm for adding color to the gray scale images,

Step 1: Check whether the original image is a gray scale image or not. If it is a color image, then convert it to a gray scale image.

Step 2: The source image which is taken for reference should be a color image.

Step 3: The size of the original image and the source image should be taken.

Step 4: The original image is converted into XYZ space.

Step 5: Then it is converted into lalphabeta.

Step 6: Finally, the luminance of the original image is compared with the lalphabeta image.

Step 7: When the value is found out, that particular pixel’s alpha and beta value is taken.
Step 8: The chosen value is added with corresponding luminance values alpha and beta.

Step 9: The steps from 6 to 8 is done to all pixel’s value in the original image.

![Fig. 6.14 (a) Original Image (b) Reference Image (c) Color Transferred Image](image)

The image is processed and their running time is calculated. The running time of the algorithm for one image can range from 10 seconds to 2 minutes on a Pentium IV CPU using MATLAB code. The execution time for this image is calculated as 17.273303 seconds. Execution time will vary from one image to another, depending on the size of the image.

### 6.6 Comparison:

Comparison of both these methods is done by two parameters;

- Execution Time
- PSNR, MSE and RMSE values

Data Set:

The Reference Image chosen is of Size 125 * 125,
The Source Images used for the method 1 and method 2 are:

![Source Images](image1) ![Source Images](image2) ![Source Images](image3) ![Source Images](image4)

Fig. 6.16 Sample Source Images

### 6.6.1 Execution Time:

Execution time for both these algorithms is calculated in MATLAB.

<table>
<thead>
<tr>
<th>Source Images</th>
<th>Source Image Size</th>
<th>Time Taken for Method 1 (SEC)</th>
<th>Time Taken for Method 2 (SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image 1</td>
<td>114 * 119</td>
<td>22.546743</td>
<td>17.273303</td>
</tr>
<tr>
<td>Image 2</td>
<td>111 * 118</td>
<td>22.234113</td>
<td>17.209648</td>
</tr>
<tr>
<td>Image 3</td>
<td>112 * 120</td>
<td>22.864336</td>
<td>17.342657</td>
</tr>
<tr>
<td>Image 4</td>
<td>123 * 127</td>
<td>22.987456</td>
<td>17.718234</td>
</tr>
</tbody>
</table>

Table 6.1: Execution Time for Method 1 and Method 2
6.6.2 Mean Square Error:

Mean Square Error can be estimated in one of many ways to quantify the difference between values implied by an estimate and the true quality being certificated. MSE is a risk function corresponding to the expected value of squared error [2] [48]. The MSE is the second moment of error and thus incorporates both the variance of the estimate and its bias.

The equation for calculating the MSE value is,

$$MSE = \frac{1}{MN} \sum_{j=1}^{M} \sum_{k=1}^{N} (x_{j,k} - x'_{j,k})^2 \quad (6.4)$$

$X$ and $X'$ are two arrays of size $N \times M$, respectively. The more $X'$ is similar to $X$, the more MSE is small. The greatest similarity is achieved when MSE equal to 0.
6.6.3 Peak Signal to Noise Ratio:

The Peak Signal to Noise Ratio (PSNR) is the ratio between maximum possible power and corrupting noise that affect representation of image. PSNR is usually expressed as decibel scale [43]. The PSNR is commonly used as measure of quality reconstruction of image [2] [3].

The signal in this case is original data and the noise is the error introduced. High value of PSNR indicates the high quality of image. It is defined via the Mean Square Error (MSE) [48]. The equation for calculating the PSNR value is;

$$\text{PSNR} = 10 \log \left( \frac{(2^n - 1)^2}{\text{MSE}} \right) \quad \text{(6.5)}$$

Where 'n' is the depth of the intensity value.

The equation for calculating the RMSE (Root MSE) value is [2],

$$\text{RMSE} = \sqrt{\text{MSE}} \quad \text{(6.6)}$$

6.7 Results for Colorization Algorithms:

Colorization is done by two methods,

Method 1: Gray Scale Conversion using Reference image alone

Method 2: Gray Scale conversion using Chrominance Checking

The results are as follows;
Fig. 6.18 Colorization of Images 1 - 4 by Method 1
Fig. 6.19 Colorization of Images 1 - 4 by Method 2
6.7.1 Calculation of PSNR Value in Color Images:

Color Images have three band values R, G and B [12]. To calculate PSNR value for colored image, the following equation is used;

\[ \text{Color Image} = R + G + B \]

\[ \text{PSNR Value} = \frac{\text{PSNR (R)} + \text{PSNR (G)} + \text{PSNR (B)}}{3} \]

The value of PSNR for each band is calculated separately and average is calculated to get the PSNR value for the color image. In the example, Image 4 is considered and it is colorized using method 2. The Red, Green and Blue components are separated and their PSNR Values are computed. This procedure is computed for all the colorized images.

![Colorized Image 4](image1)

![Red Component](image2)

![Green Component](image3)

![Blue Component](image4)

Fig. 6.20 Colorization of Images 4 to calculate PSNR Value

<table>
<thead>
<tr>
<th>Images</th>
<th>MSE</th>
<th>PSNR</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image 1</td>
<td>25.97dB</td>
<td>63.18dB</td>
<td>5.10dB</td>
</tr>
<tr>
<td>Image 2</td>
<td>43.71dB</td>
<td>46.64dB</td>
<td>6.61dB</td>
</tr>
<tr>
<td>Image 3</td>
<td>31.24dB</td>
<td>55.63dB</td>
<td>5.59dB</td>
</tr>
<tr>
<td>Image 4</td>
<td>32.20dB</td>
<td>54.36dB</td>
<td>5.67dB</td>
</tr>
</tbody>
</table>

Table 6.2: MSE, PSNR and RMSE Values of Sample Images 1 - 4
This table shows that the images colorized by:

* Method 1: Reference image alone = A
* Method 2: Luminance Checking = B

From the colorized images (A and B), the MSE, PSNR and RMSE values are calculated. The colorization of these images differs a lot due to the high MSE value. The process of colorization differs in these methods.

![MSE, PSNR, RMSE Values for Images 1 - 4](image)

From Fig. 6.21, it shows that colorizing an image with luminance checking is better than colorizing an image with reference image alone. It will yield better result in the segmentation process and pneumonia affected region is extracted more exactly in the image colorized by the luminance checking process.
6.8 Experimental Results:

The results are evaluated using MATLAB and displayed in GUI environment. From the main module the sub modules are;

- Color X-Ray image processing
- Gray scale X-Ray image processing

An gray scale X-Ray image is of size (114 * 119) as source image and Reference image of size (125 * 125) are taken. This source image is colorized in the sub modules section using the Reference Image. The source and reference images are,
6.8.1 Color X-Ray Image Processing:

The X-Ray image is first colorized. The remaining four steps are performed in the following chapters. The first push button is selected in the modules group.

![Modules]

Fig. 6.24 Steps in Severity Findings

Step : 1

Gray scale X-Ray image is chosen and with the help of reference image which is considered as destination image, converted into color X-Ray image by following two methods,

- Method 1: Gray Scale Conversion using Reference image alone
- Method 2: Gray Scale conversion using Chrominance Checking
Method 1:

Fig. 6.25 (a) Choosing the Gray Scale X-Ray Image  
(b) Colorized X-Ray Image

Method 2:

Fig. 6.26 (a) Choosing the Gray Scale X-Ray Image  
(b) Destination Image is selected
From the two colorization process, the second method of Luminance checking yields the better results. With this colorized X-Ray image, the next chapter is the segmentation process.