Contrast Image Enhancement Using Luminance Component Based On Wavelet Transform

Ravi Kumar Gupta, Santosh Kumar Upadhyay, Ajay Kumar Yadav
1 M.Tech, CSE Department, Mewar University Chittorgarh, Rajasthan, INDIA
2 Asst. Professor in Galgotia Engineering College Gr. Noida
3 Asst. Professor in College of Engineering & Rural Technology Meerut

Abstract
The goal of Contrast image enhancement is to improve the image quality so that the resultant image is better than the original image for a specific application or set of objectives. Image enhancement refers to accentuation or sharpening of image features such as edges, boundaries or contrast to make a graphic display more useful for display and analysis. The enhancement process does not increase the inherent information content in the data. But it does increase the dynamic range of the chosen features so that they can be detected easily. There are many image enhancement techniques to obtain satisfactory result, but here I use color image enhancement and I got good results.

1. Introduction
The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide ‘better’ input for other automated image processing techniques.[1] Image enhancement techniques can be divided into two broad categories:

1. Spatial domain methods, which operate directly on pixels, and
2. Frequency domain methods, which operate on the Fourier transform of an image.

Unfortunately, there is no general theory for determining what is ‘good’ image enhancement when it comes to human perception. If it looks good, it is good! However, when image enhancement techniques are used as pre-processing tools for other image processing techniques, then quantitative measures can determine which techniques are most appropriate.

2. Spatial domain methods
The value of a pixel with coordinates (x; y) in the enhanced image ^ F is the result of performing some operation on the pixels in the neighborhood of (x; y) in the input image, F.[2] Neighborhoods can be any shape, but usually they are rectangular.

3. Grey scale manipulation
The simplest form of operation is when the operator T acts only on a 1 x 1 pixel neighborhood in the input image, that is ^ F(x; y) depends on the value of F only at (x; y). This is a grey scale transformation or mapping. The simplest case is thresholding where the intensity profile is replaced by a step function, active at a chosen threshold value. In this case any pixel with a grey level below the threshold in the input image gets mapped to 0 in the output image. Other pixels are mapped to 255.[3] Other grey scale transformations are outlined in Figure 1 below.

4. Histogram Equalization
Histogram equalization is a common technique for enhancing the appearance of images. Suppose we have an image which is predominantly dark. Then its histogram would be skewed towards the lower end of the grey scale and all the image detail is compressed into the dark end of the histogram. If we could ‘stretch out’ the grey levels at the dark end to produce a more uniformly distributed histogram then the image (see Figure would become much clearer.[4]
5. Contrast Perception and Enhancement
The information collected here identifies contrast as a fundamental aspect of visual perception and builds a basic groundwork for measuring contrast in images, which is needed to understand the methods presented in short overview on how imagery is processed by the human visual system,[5] the role played by contrast and the effects of apparent contrast. Various measures of contrast are defined, including a multi-scale contrast representation of images. A detailed description of color contrast and color brightness perception is provided. This is included because it is necessary for understanding how contrast is measured in color images. Additionally, provides an introduction to chromatic lightness, which is an integral aspect of the grayscale conversion method. In photography and publishing, higher contrast images have a stronger visual impact and appreciation. Due to this preference for higher contrast, many image processing techniques increase contrast to enhance or otherwise improve the original image. The methods by explaining contrast enhancement techniques, findings that people not only perceive enhanced images as having a higher quality, but have been shown to prefer photos whose contrast has been increased.[6]

6. Seeing Contrast
Conceptually, contrast is the spatial variation of a visual stimulus. In cognitive respects, Contrast as a perceptual quality arising from differences in brightness is a key to visual understanding: how we distinguish one visual element from another, the shape of an object, its texture and details. The term contrast is intentionally vague, since it has both physical and perceptual definitions, and depends on whether the stimulus is a real scene, a photograph or a simplified test image. Contrast can be defined objectively as a difference between the luminance reflected by two regions or surfaces. Perceptually,[7], it is the difference in perceived brightness, which makes it dependent on attributes such as surround, chroma, local spatial structures and environmental aspects. The following four sections show how and why vision is heavily based on local contrast, and how human sensitivity to contrast is a factor of average illumination and spatial frequency. The theories and science are presented to give a general context to terminology, and so the reader may understand the motivation behind the novel contributions detailed in following articles[8]

7. Lightness constancy
There are several terms to describe different aspects of seeing light. To begin, light is reflected off a surface to an eye. The amount of physical light is termed luminance. Luminance the physical amount of light reflected off a surface or emitted from a light source in a particular direction, measured in cd/m² and denoted as Y. Through various levels of physiological and neurological processing, luminance is perceived by a viewer as lightness: Lightness The perceptual response of a human viewer to luminance and is defined by Hunt as “the brightness of objects relative to that of a similarly illuminated white”. Denoted L* (“L-star”), it is defined in terms of luminance Y and reference white luminance Yn.[9]

8. Methodology
Image enhancement is a technology to improve the quality of an image in terms of visual perception of human beings. With the growing quality in image acquisition, image enhancement technologies are more and more needed for many applications. Images are categorized into grey-level images and color images. Each pixel of the grey-level image has only one grey-level value as opposed to color images’ pixels; therefore, there have been many algorithms for contrast enhancement for grey-level images. The main techniques for image enhancement such as contrast stretching, slicing, histogram equalization,[10] for grey-level images are discussed in many articles and books. On the other hand, since each pixel of color images consists of color information as well as grey-level information, these typical techniques for grey-level images cannot be applied to color images. Thus, compared with grey-level images, the enhancement of color images is more difficult, and there are much more points to be
researched. Some color enhancement methods were proposed. Based on histogram equalization, as the well-known contrast enhancement methods, Buzuloiu proposed an adaptive neighborhood histogram equalization method, and Trahanias proposed a 3D histogram equalization method in RGB cube. Thomas proposed an enhancement method by considering the correlation between the luminance and saturation components of the image locally. A method for enhancing the color contrast in xy-chromaticity diagram was proposed by Lucchese. Shyu suggested a genetic algorithm approach in which the enhancement problem is formulated as an optimization problem. In recent years, multi-scale technologies have been widely used in image processing[11].

9. Color Space
If the visible portion of the light spectrum is divided into three components, the predominant colors are red, green and blue. These three colors are considered the primary colors of the visible light spectrum. The RGB color space, in which color is specified by the amount of Red, Green and Blue present in the color, is known as the most popular color space. RGB is an additive and subtractive model, respectively, defining color in terms of the combination of primaries, whereas HSV color space encapsulates information about a color in terms that are more familiar to humans. In HSV color space,[12] the color is decomposed into hue; saturation and luminance value similar to the way humans tend to perceive color. Ledley’s research shows that the performance of HSV color space is good in color improving. Among the three components of HSV color space, hue is the attribute of a color, which decides which color it is. For the purpose of enhancing a color image, it is to be seen that hue should not change for any pixel. If hue is changed then the color gets changed, thereby distorting the image. Compared with other perceptually uniform such as CIE LUV color space and CIE Lab color space, it is easier to control the Hue component of color and avoid color shifting in the HSV color space. In our approach, we exploit the characteristic that wavelet transform can decompose the signals into approximate components and detail components, and the approximate component is enhanced by increasing the contrast. According to the human visual theory, receptive fields on the retina receive light stimuli. Rod cells and cone cells process them. Receptive fields are very common in the retina of many species, and the same arrangement is found in second and higher order neurons. Kobayashi analyzed the feature of human visual system and proposed a Reverse-S-Shape transform to enhance the grey-level image. To obtain the result, we generalize the method to color image processing and applied the transform to the luminance component of the color image.[15]

11. Algorithm
Color Space Conversion
As mentioned before, we apply our enhancement method in HSV color space. In general, color images are represented by RGB color space. Therefore the first step is to convert RGB color space to HSV color space[16].

10. Luminance Enhancement
We apply wavelet transform and Reverse-S-Shape transform obtained from human visual system to enhance the luminance component. The wavelet transform, or wavelet expansion is to express a signal or function as a linear decomposition based on a group of certain functions. Wavelet analysis, a new mathematics branch developed in recent years, is a perfect combination of harmonic analysis, function analysis, Fourier analysis and numerical analysis. Wavelet analysis has been applied to various research areas. Xu developed a noise filtration method based on the spatial correlation between wavelet coefficients over adjacent scales. Pan proposed an improved schema. In our approach, we exploit the characteristic that wavelet transform can decompose the signals into approximate components and detail components, and the approximate component is enhanced by increasing the contrast. According to the human visual theory, receptive fields on the retina receive light stimuli. Rod cells and cone cells process them. Receptive fields are very common in the retina of many species, and the same arrangement is found in second and higher order neurons. Kobayashi analyzed the feature of human visual system and proposed a Reverse-S-Shape transform to enhance the grey-level image. To obtain the result, we generalize the method to color image processing and applied the transform to the luminance component of the color image.
12. Luminance Contrast Enhancement

The luminance value, V component in the HSV color space, is enhanced. The wavelet transform can decompose the luminance into approximate component and detail component. We apply a contrast enhancement method for grey-level images to the approximate component and then reconstruct the brightness information by applying inverse Wavelet transform. Thus, the above mentioned process consists of three steps: Wavelet Transform, contrast enhancement and Inverse Wavelet Transform[17]

$$S = \begin{cases} 0, & \text{if MAX} = 0 \\ 1 - \frac{MIN}{MAX}, & \text{otherwise} \end{cases}$$

![Coefficient Conversion Mapping Diagram](Fig.png)

To assign the threshold m and M, we tried two ways. One is “Manual Assignment”, the other is “Automatic Adaptation”. The manual assignment is to simply assign the parameters as certain constants. The manual assignment is simple but there is a problem. From the wavelet decomposition equation, we get a set of approximate coefficients. If most of the coefficients are near the maximal value, we need to set a larger threshold otherwise most coefficients are not changed which leads to an ineffective enhancement. The situation is similar when most of the coefficients are near the minimal value. To solve the problem, we use Automatic Adaptation. Automatic Adaptation is to compute the parameters according to the information of the input image. So we compute the threshold m and M to assure: [18]

1. Most of the coefficients are between m and M. The coefficients out of the range [m, M] are not converted.
2. The range [m, M] should not be too small. Otherwise, even if most coefficients are in the range and converted, the effect of the contrast enhancement is not significant, because the results are also in [m, M]. The computing algorithm includes the following three steps:
   1. Assign two constants m0 and M0, which satisfy 0≤ m0 < M0 ≤ 255, and M0- m0 > 150. For instance, m0= 30, M0 = 200.
   2. Compute m1 and M1 satisfy that there are just 5% of approximate coefficients ($A_j^f$) are less than m1 and 5% of $A_j^f$ larger than M1.
   3. Set m = min (m0, m1), M = max (M0, M1). The algorithm assures that at least 90% coefficients are converted and the conversion range is large enough.[19] It may be considered that it is simpler to manually assign m = 0 and M = 255 to meet with the two requirements. However, if most coefficients are near 128, and few are near maximal or minimal value, the contrast efficiency is low. In this situation, Automatic Adaptation algorithm shows its advantage.[20]

13. Processing Flow

Our method is represented by the following steps:
1. Load a color image
2. Read (r, g, b) values for each pixel
3. Convert RGB color space to HSV color space
4. Apply the wavelet transform to V component
5. Apply the Reverse-S-Shape transform to the approximate coefficient of Eq. (1)
6. Reconstruct V by inverse wavelet transform
7. Apply the saturation enhancement
8. Convert HSV color space to RGB color space
9. Store the color image

14. RESULT

To test the performance of our method, we apply our method to a low contrast color image and a dark color image and compare the results, the experimental result of the low contrast image. (a) is the original image, (b) is the result obtained by our proposed method. The experimental result of different images shown blow, respectively.
15. Conclusion and applications

The motivation is to enhance local contrast so that the resulting imagery communicates the utmost of the represented scene. This thesis has proposed a color contrast enhancement method that uses a luminance component enhancement based on wavelet transform: more specifically, Reverse- S-Shaped enhancement based on human visual system for the approximate component coefficients obtained by the Wavelet transform. It turns out that the proposed wavelet based color contrast enhancement method can achieve a successful enhancement of color images which are dark or with low contrast. However, there are still some remaining issues. The transformation algorithm for the approximate coefficients is to be improved and the enhancement of detail coefficients may also be effective. The relationship between luminance value and saturation is not considered in the method. The method is a global transformation of a certain image but the performance might be better if we divide the image into some certain areas according to some certain rules and apply a different algorithm or different parameters to different areas. Another topic is that sometimes the color contrast enhancement requires changing color; that is, the hue component should also be adjusted. The overall performance of this method is good.

Applications

Image enhancement is a process of improving the quality of a digitally stored image, image enhancement techniques have been widely applied to geological images and use to make it easier for visual interpretation and geological understanding. Image enhancement techniques widely using medical science and microscopy image processing and many image analysis applications

References


