# Image Enhancement using Thresholding Techniques and Histogram Equalization

Charles Lam

72364146

Dr. Jack Xin

Wenye Ma

University of Calfornia, Irvine

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## Abstract

The human eye can perceive a vast array of colors. Whether light or dark, the colors that our eyes can see are supposedly unlimited. However, this is not the case. In reality, every image has two aspects or descriptors to it, a reflectance and an illumination. While the reflectance essentially shows an image's "true color," the illumination is what causes the colors to seem different to the human eye. This effect, originally discovered by Helmholtz, is known as Color Constancy. Color Constancy ensures that the color the Human Visual System (HVS) receives is the true color of the image, regardless of illumination. As a result of this effect, in 1971, Land and McCann created the Retinex theory. Using the pixels in the image, Land tried to estimate the value of the reflectances and thus reveal the true color of the image. This theory was basically a color constancy algorithm that tried to explain why colors look different when exposed to lighting. By calculating the pixels, Land was able to depict the sameness in a gradient of colors in an image. However, the algorithm is both inefficient and complicated. Following their footsteps, many other people have tried to formulate new algorithms around the Land's original Retinex algorithm. In this paper, different methods such as least squares and discrete cosine transform are explained as well as how to enhance images using both Land's idea and histogram equalization.

# Contents

# 1 Introduction

In addition to being a feature of the Human Color Perception System, Color Constancy is also the ability to determine an images "true color" regardless of lighting and illumination conditions. While a computer is able to tell compute what an image's color really is disregarding the multiple gradients, the Human Visual System cannot. The HVS is only able to compute what it sees and the result is a variety of independently defined colors effected by illumination and also surrounding colors. Instead of the HVS, we want to be like a computer: seeing color in an image regardless of illumination or surrounding color. Thus, the goal of Color Constancy research is to take these two descriptors, illumination and reflectance and alter them: discounting the illumination, while simultaneously enhancing the reflectance in order to produce a smoother and more constant image.

The original algorithm proposed by Land and McCann was a foundation for many other algorithms. While the techniques and methods of these algorithms vary, the goal still remains the same. These experiments try to show that an image has three different color receptors (red, green, and blue) and that the illumination or "lightness" of the image is independent from the color of the image itself. Land's Retinex theory is one of many that tries to describe Color Constancy. Although flawed, the algorithm is a good foundation and many have tried to improve it instead of creating a entirely different algorithm. Following their path, this paper tries to devise a new way of defining color constancy and using it to enhance images.

Land's original Retinex algorithm is essentially a partial differential equation, which can be solved by different methods. In this paper, a variety of methods are explained, such as least squares, discrete cosine transform, and from that, thresholding techniques. The next section details Land's original algorithm and following this are some previous methods to solve the original algorithm. Section 3 introduces the two previous methods of least squares reduction and discrete cosine transform (DCT). While the least squares method works, there are flaws and DCT is a better alternative in solving Land's algorithm. Section 4 deals with image enhancement and thresholding techniques as well as histogram equalization. Section 5 details results of my work. Section 6 is the conclusion, including both the strength and weaknesses of my proposed method.

## 2 Land's Original Algorithm

The word Retinex is derived from the words Retina and Cortex. This is because the effect of perceiving color is believed to effect both the eyes and the brain. Originally, in Land's algorithm, its function was to achieve a consistent color constancy. In addition to this, Land also discovered that the Retinex theory also heavily involves edges and edge descriptors. By assuming a pixel is at max reflectance in comparison with the surrounding pixels, Land was able to discover the reflectance of the surrounding pixels and simultaneously remove illumination and detect edges of an image.[2] Since there are three color channels for every image, this process is done three times over all three color channels.

# 3 Previous Methods

The flaws in Land's original algorithm have led to many attempts in simplifying or accelerating the Retinex theory. As a result of this, there are a variety of Retinex algorithms all aimed at achieving one goal: Color Constancy. Many people have suggested different ideas such as using piecewise linear functions, taking logarithms, and other methods that are more complicated. The original problem still remains: the computation is inefficient and too complicated. A simple solution still needs to be found. Although inefficient, the methods still work and two of these methods are least squares minimization and discrete cosine transform optimization.

## 3.1 Least Squares Minimization

The least squares method, created by Carl Friedrich Gauss, is one way to solve Land's partial differential equation. This aim of this method is to minimize and solve overdetermined systems, which are sets of equations that have more equations than unknowns. By minimizing the sum of squares of the errors made in each of the equations, this method allows for the simplification of the PDE and the result is a Poisson equation. Although this sufficient method takes a sufficient amount of time to compute, it is still accurate.

$$\Delta R = \delta(\Delta I) \tag{1}$$

Where R is the reflectance of the Image and I is the original information. The problem with this function is that it is overdetermined. However, by using least squares, we can solve for R.

## 3.2 Discrete Cosine Transform Optimization

A better alternative to least squares minimization is discrete cosine transfomation optimization or DCT. This method involves summing cosine functions at different frequences. Instead of trying to find the minimum of the sum of squares which is what least squares minimization achieves, DCT diagonalizes the image and thresholds the frequencies. This results in a faster computation.

$$\Delta r = div(\delta_t(\Delta i) \tag{2}$$

The aim of this equation is to solve for r, which is the reflectance. We do this by implementing a diagonalizing matrix $\lambda$ and taking the DCT of the equation which results in:

$$\lambda DCT(r) = F \tag{3}$$

From this, we can isolate the reflectance by taking the inverse DCT and dividing b the diagonalizing matrix $\lambda$.

$$r = iDCT(F/\lambda) \tag{4}$$

This results in the reflectance of an image.

# 4 RETINEX IMAGE ENHANCEMENT

This section of the paper introduces the use of Land's Retinex algorithm in Image Enhancement. This is made possible by modifying the Retinex algorithm and adding thresholds to the function $f(x) = \delta(\log(x))$. The addition of thresholds allow for better image contrast and thus better image quality. Also, by applying thresholds, color constancy is achieved.

Addition of the two thresholds, $T$, and $t$, are essential in adjusting color contrast and achieving color constancy. This threshold implementation was originally created by Morel. In Morel's original threshold function, the upper threshold, $T$, is used to reduce large impulses and makes contrast adjustment possible. This function, also known as Contrast Retinex, is defined as

$$f(x) = \begin{cases} 0 & \text{if } |x| < t \\ \text{x} & \text{if } t < |x| < T \\ \text{sign(x)T} & \text{if } |x| > T \end{cases}$$

The upper threshold $T$ is used for reducing very large impulses. The lower threshold, t, is used to remove minor variations of intensity.[1]. According to

Morel, the sound thresholds are $t = 3$ and $T = 20$.

## 4.1 Alternating the Threshold Function

While DCT and Contrast Retinex is an effective way to enhance certain images, other images are not so successful.

Original

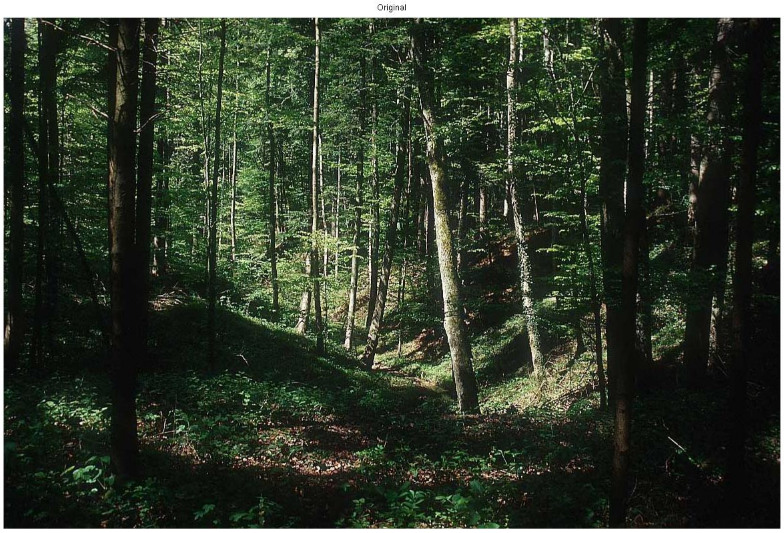

Figure 1: Original Image

Notice the original image in Figure 1. Now we apply discrete cosine transform optimization at the optimal thresholds and our result is:

As this image shows, although Figure 2 achieves a certain amount of color constancy which is the aim of DCT, this image is clearly not enhanced. However, even though most of the detail in the image is gone, Figure 2 succeeds in "lightening" this image, which leads to a new method and technique of

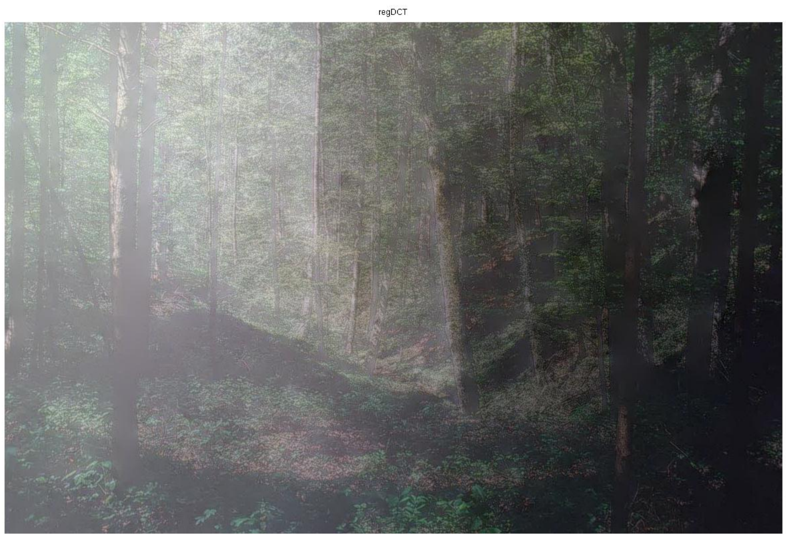


Figure 2: Result after DCT

image enhancement: the average of the resulting DCT image and the original image to create a newly enchanced image.

Essentially the final result is an alteration of Morel's original function. We redefine the boundaries as:

$$f(x) = \begin{cases} \text{(x/2)+(T/2)} & \text{if } x > T \\ \text{(x/2)} & \text{if } |x| < t \\ \text{-x} & \text{if } -T < x < -t \\ \text{x} & \text{if } t < |x| < T \\ \text{(x/2)+(T/2)} & \text{if } |x| > T \end{cases}$$

## 4.2 Results of New Method

By implementing the result of the DCT and the original image and modifying morel's threshold function, the final result is a better enhancement technique. If this method is applied to Figure 1, the new image is:

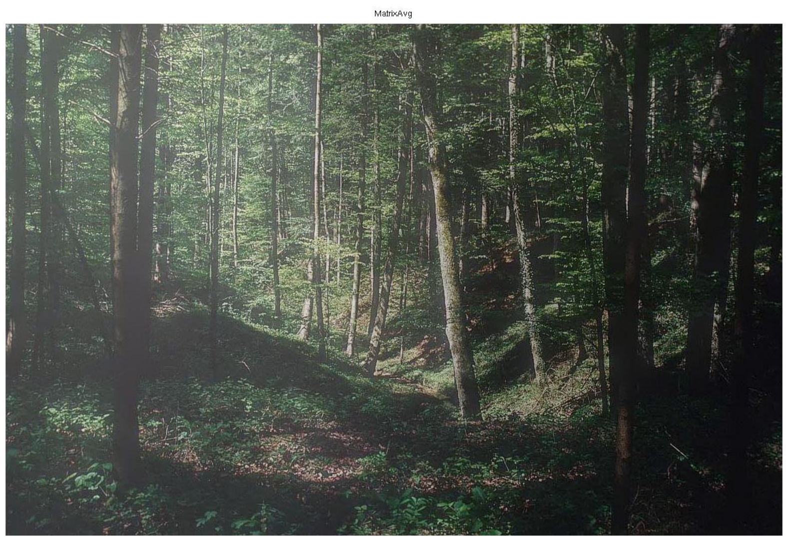


Figure 3: New Result

This image retains the details of the original image while also enhancing the darker parts of the image by using the DCT method.

## 4.3 Problems

Although the new thresholding technique works better than the DCT method, there are still some flaws. If it is applied to a darker image, it enhances the image by lightening the image. However, given an already bright image, it is not as effective.

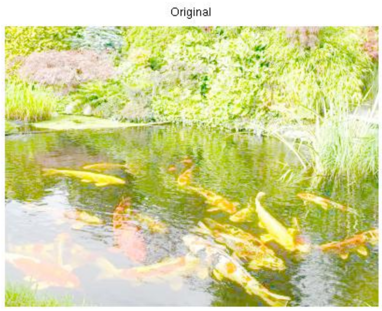


Figure 4: Original Image


Figure 5: New Image

From Figure 5, the illumination is reduced but some detail in the image is lost.

## 4.4 Solution: Histogram Equalization

Histogram Equalization is a technique used in image processing that involves contrast adjustment by using an image's histogram and normalizing it. This finishing touch yields a crisper image. However, histogram equalization can only be applied to grayscale images. Fortunately, I converted my new image to its luminosity, which is a grayscale image, and took the histogram equalization of the luminosity.

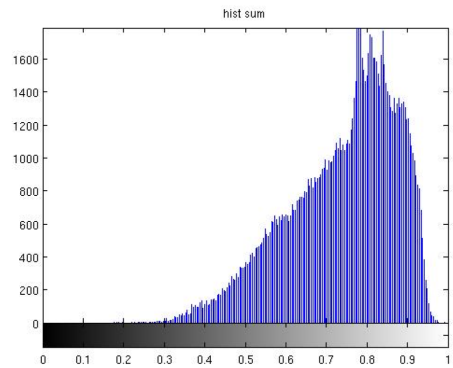


Figure 6: Original Image

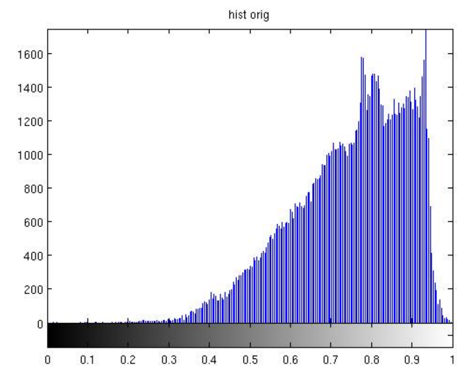


Figure 7: New Image

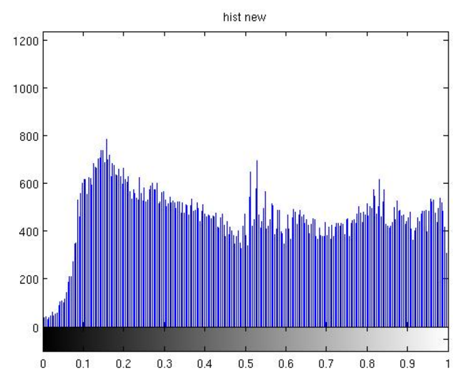


Figure 8: Histogram Equalization


Figure 9: Histeq Image

## 4.5 Results from Applying Histogram Equalization

Figure 6 plots the histogram of the original image. The next Figure, Figure 7 plots the histogram for the image produced by the addition of the summation of the DCT and original image matrix. Figure 8 displays the histogram with the Histogram Equalization applied. In Figure 9, it shows the combination image enhanced by Histogram Equalization.

# 5 CONCLUSION

By taking the result of the DCT image and adding it to the original image, and then further implementing Histogram Equalization, we achieve a greater enhanced image than the original threshold function could achieve. However, this method can be improved. Possible further research could include modifying the Contrast Retinex parameters, applying a weighted average, or modifying the threshold function to an even greater degree. I believe that I have discovered a simple and less complex method than applying least squares or other complex mathematics. I have, by combination of the techniques of discrete cosine transform optimization and histogram equalization, created threshold function and a better image enhancement technique.

## References


[1] J. Morel, A. B. Petro, and C. Sbert, *Fast Implementation of Color Constancy Algorithms*, Image Processing Online, pp. 1-10.

[2] E. H. Land, J. McCann, *Lightness and Retinex Theory*, Polaroid Corporation, Cambridge, Massachusetts, September 1970, pp. 1-11.