*Project Report on*

**Satellite Image Contrast Enhancement Using Sensitivity Model-based Sigmoid function**


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**Department of Electronics and Communication Engineering**

## CERTIFICATE

This is to certify that the thesis entitled **'Satellite Image Contrast Enhancement Using Sensitivity Model-based Sigmoid function',** submitted by **Anitha Pappu(202SP002), Kranti Kumari(202SP011)** is a record of bonafide work carried out by them, in the partial fulfillment of the requirement for the award of Degree of M.Tech in Electronics and Communication Engineering at National Institute of Technology Karnataka, Surathkal.

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## ABSTRACT

For indirect contrast enhancement, researchers have proposed various transformation functions based on histogram equalization and gamma correction. However, these transformation functions tend to result in over-enhancement artifacts such as noise amplification, mean brightness change, and detail loss. To overcome the limitations of conventional transformation functions, this paper introduces a novel sigmoid function based on the contrast sensitivity of human brightness perception. In the method, the contrast sensitivity of the human retina is modeled as an exponential function of the log-intensity, and a transformation function is derived using the sensitivity model as the exponent of Steven's power law. Experimental results demonstrate that the method has low computational complexity and outperforms the state-of-the-art methods in terms of contrast enhancement performance, mean brightness preservation, and detail preservation.



**Keywords:** Contrast enhancement, sensitivity model-based sigmoid function, Steven's power law

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## 1. Introduction

Digital images often have low contrast owing to inadequate image capture devices or undesirable lighting conditions. Since low contrast images may have a washed-out appearance or do not reveal all the scene details, researchers have proposed various enhancement methods to improve the visual quality of these images.

Contrast enhancement techniques are broadly classified into two groups: direct and indirect methods. In direct methods, image contrast is measured based on the human visual system (HVS), such as the Weber–Fechner law or Retinex theory, and is improved by applying various nonlinear functions or solving optimization problems. Direct methods have some advantages of image detail enhancement as well as dynamic range compression, however, they require high computational complexity and introduce ‘‘halo’’ artifacts particularly around strong edges. Although recent direct methods have been proposed to alleviate these problems, it is still challenging to provide both high image contrast and real-time processing without causing noticeable distortion. For these reasons, indirect methods utilizing a global transformation function are more widely employed in practical applications than direct methods.

In this implementation, a novel sigmoid function based on the contrast sensitivity of human brightness perception is used. Motivated by the observation that the contrast sensitivity of the human retina decreases exponentially as the log-luminance increases, the contrast sensitivity is modeled as an exponential function of the log-intensity level. Using the contrast sensitivity model, the sigmoid function is derived by modifying the exponent of Steven’s power law. We also present a parameter optimization method that maintains the mean brightness of the input image and stretches the image histogram while minimizing information loss. This process requires low computational complexity and exhibits high enhancement performance while preserving the mean brightness and details of the input image.
More recently, deep learning-based methods, especially Convolutional Neural Networks (CNNs), have been extensively researched for image enhancement. In our best knowledge, however, most deep learning-based methods have been developed for medical images, low-light images or hazed images rather than natural image enhancement.

## 2. HUMAN BRIGHTNESS PERCEPTION

The photoreceptors in the human retina, which are called rods and cones, operate as the sensors for the HVS. Rods are very sensitive to light and provide achromatic vision named scotopic vision at low luminance levels (10−6 to 10cd/m2 ). At luminance levels higher than 10−2 cd/m2 , rods begin to saturate and cones provide chromatic vision named photopic vision. At luminance levels between 10−2 and 10 cd/m2 , both rods and cones are active and the human retina operates in a transition mode called mesopic vision. Since neurons can only transfer a signal with a dynamic range of approximately 1 :103 , the human retina compresses the dynamic range of the real-scene luminance by adapting to a certain luminance level called the adaptation level and then perceiving images in a rather small dynamic range around the adaptation level. To describe the retinal response of human brightness perception, various response models based on neuroscience experiments have been proposed. One of the representative response models—the Naka-Rushton equation, describes the relationship between the retinal response R and the luminance level L, which is given by

$$R(L) = \frac{L^n}{L^n + \sigma^n}$$

where n is a parameter determining the steepness of the retinal response function and σ is the adaptation level. The above equation indicates that the HVS transforms the luminance level into the retinal response by employing a sigmoid curve centered on the adaptation level

## 3. Method

Stevens' power law is a well-known stimulus-response model that covers a wider range of sensations compared with the Weber-Fechner law.
In Steven's power law, the perceived brightness R (L) is given by

$$R\,(L) = L^k$$

Here, k works as a sensitivity parameter determining how fast the sensation grows as the stimulus intensity increases. For various types of sensations, k is assumed as a constant, resulting in the conventional GC curve. However, because the contrast sensitivity of the human retina is adaptively determined by the background luminance, k is modeled according to human brightness perception.

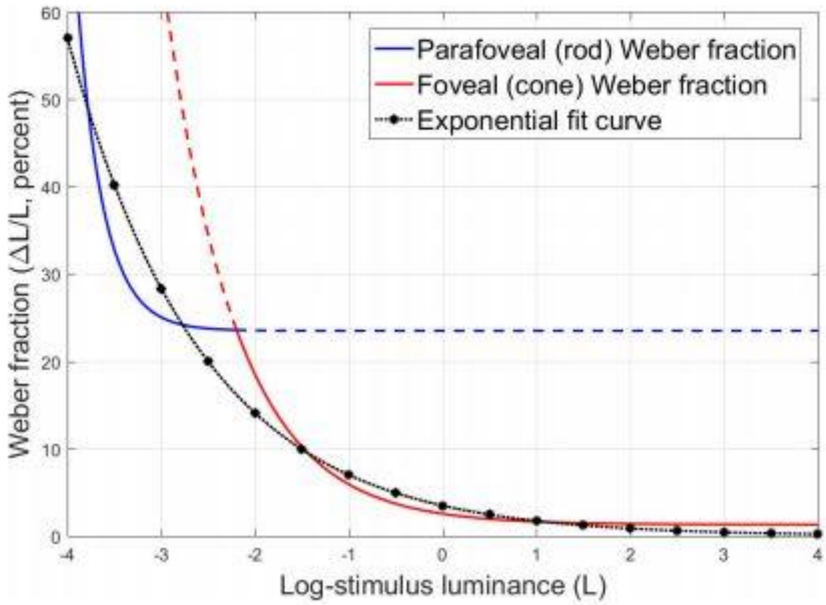



Figure 2: Weber fraction for different luminance levels. The left (blue line) and right (red line) parts correspond to scotopic and mesopic vision, respectively. The fitting curve (dark line) shows that the Weber fraction can be approximated using an exponential function of the log-luminance.

As illustrated in Fig. 2, Wyszecki and Stiles [] showed experimentally that the contrast sensitivity of human brightness perception, i.e., the Weber fraction, decreases exponentially as the log-luminance increases. The fitting curve in Fig. 2 indicates that the Weber fraction can be approximated as an exponential function of the log-luminance. Based on these observations, k is modeled as the following exponential function:

$$k(L) = \alpha\beta^{-\log_e(L)},$$

where α and β are parameters determining the maximum value and steepness of k(L) respectively and hence the transformation function R (L) is given as

$$R\,(L) = 255 \times \tilde{L}^{\alpha\beta^{-\log_e(\tilde{L})}}$$

Where L is the original pixel intensity in the range of [0, 255]

L˜ is the pixel intensity normalized to [0, 1] which is obtained by

$$\tilde{L} = \frac{L - L_{\min}}{L_{\max} - L_{\min}},$$

where Lmin and Lmax are the minimum and maximum intensity levels of the input image.

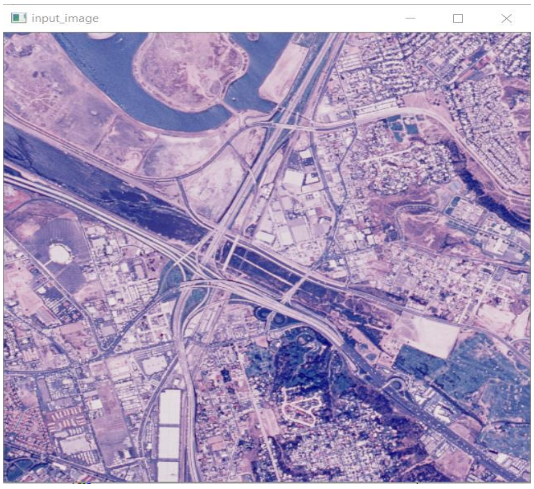
R ( L˜ ) for L˜ = 0 as zero to avoid the singularity problem. The transformation function covers the full dynamic range [R (Lmin) = 0, R (Lmax) = 255] of a digital image.
optimal α for mean-brightness preservation is as follows:

$$\alpha = \frac{\log_e(L_{\text{mean}}/255)}{\log_e(\tilde{L}_{\text{mean}})} \times \beta^{\log_e(\tilde{L}_{\text{mean}})}.$$

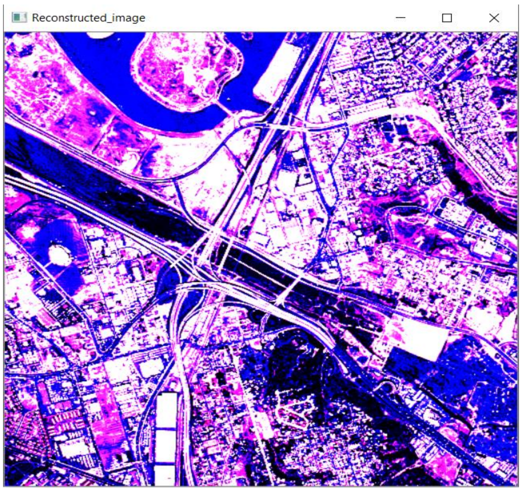
## 5. Results and discussion

The main goal of this system is to enhance the contrast of the images which lacks the fine details Using Sensitivity Model-Based Sigmoid Function.

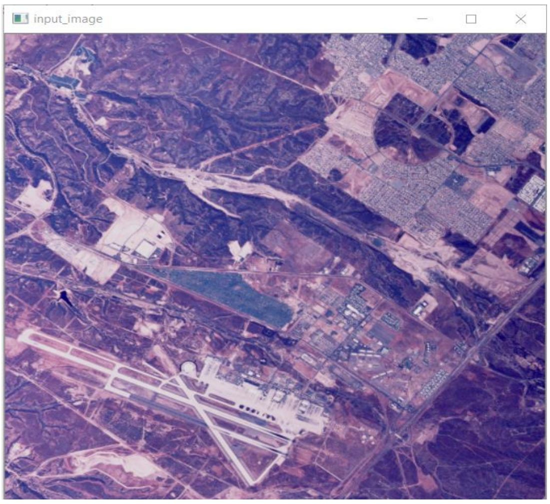
Figure below depicts the result obtained using our method:




(a) Original Image




(b) Enhanced Image



(c) Original Image

(d) Enhanced Image

Figure 3: Results obtained using our method

## 6. Conclusion

The contrast enhancement method using a sigmoid function is based on the contrast sensitivity of the human retinal-photoreceptor. In our method, we have modelled the contrast sensitivity as an exponential function of the log-intensity and derived a sigmoid function using the contrast sensitivity model. The optimal parameters for the proposed contrast enhancement method were estimated by employing a cost function that maximized the image contrast while preventing information loss. The proposed method not only had low computational complexity but also exhibited superior performance to state-of-the-art methods with regard to the contrast enhancement degree and mean-brightness/detail preservation

## 7. References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