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# Improved knee transfer function and gamma correction based method for contrast and brightness enhancement of satellite image

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ABSTRACT

In this paper, a novel contrast enhancement approach based on knee transfer function and gamma correction using discrete wavelet transform (DWT) has been proposed for quality enhancement of the especially low contrast satellite images. The proposed algorithm computes the knee transfer function using gamma correction scheme in wavelet domain, and then transforms intensity values according to the transfer function. More specifically, discrete wavelet transform is performed first on the input images to get LL, LH, HL and HH frequency components. Intensity transfer functions are adaptively estimated by using the knee transfer function and gamma adjustment function. The conventional knee curve is used to stretch the intensity level, i.e., contrast of the input image. After intensity transformation, the resultant enhanced image is obtained by using inverse DWT. The experimental results demonstrate that the proposed algorithm enhances the overall contrast and visibility of local details better than the existing conventional techniques. The proposed method can efficiently enhance any low-contrast images acquired by a satellite camera, and are also suitable for other different imaging system.



## 1. Introduction

The goal of image enhancement techniques is to improve a characteristic, feature or quality of an image, such that the resulting image is better than the original one, when compared against specific application or set of objectives [1]. Many image enhancement algorithms have been proposed, in which most frequently used technique is global histogram equalization or general histogram equalization [2]. It adjusts the intensity histogram to approximate a uniform distribution. The main shortcoming of global histogram equalization is the problem of covering global image properties that may not be appropriately applied in a local context [3]. In fact, global histogram modification deals with all regions of the image equally, and as a result, often yields degraded local realization in terms of detail conservation. Accordingly, numerous local image enhancement algorithms have been anticipated to get better and quality enhancement [3–6]. Enhancement is an important and elementary step in the field satellite image processing. The miscellaneous kinds of noise and artifact in imaging modalities degrade the image quality.

In practice, most general degradation is due to corruption by additive noise (Gaussian), multiplicative noise (speckle), etc. Such degradation can have a critical impression on the image quality and as a consequence, it affects the human interpretation as well as accuracy of the computer assisted methods in satellite imaging or usual imaging. Furthermore, feature extraction, analysis, recognition and quantitative measurements become challenging and unpredictable due to reduced quality of images. Therefore, enhancement of the images becomes major requirements for many realistic applications [7]. Initial efforts in this area started with the idea based on statistical filtering in spatial domain. The image enhancement research can be broadly divided into two domains named spatial and transform domain [2]. A survey of the spatial domain enhancement techniques can be found in [8–10], and transform-based image enhancement techniques can be found in [2,8,11–15]. The basic idea behind the use of transform domain is to enhance image by manipulating the transform coefficients.

In spatial domain techniques, it directly deals with the image pixels. The pixel values are manipulated to accomplish desired enhancement. In frequency domain methods, the image is first transformed into frequency domain for processing of input image, and then the inverse transformation is performed to get the resultant image. These enhancement operations are performed in order to modify the image brightness, contrast or distribution of gray levels. The pixel value (intensities) of the output image will be

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modified according to transformation function applied on input values [16].

Among these two areas, in last two decades, more research has been conducted, and now a day's current research is going on in wavelet transform (WT) domain. Owing to the property of wavelet coefficients like sparsity and decomposition [11], effective and simplified implementation of enhancement ideas have become easy. During the image acquisition process, bad visual effects arise from many factors such as illumination, equipments and noise, etc. So, it is necessary to employ image detail enhancement algorithm to highlight the image details, which are very important in expressing the captured sight or covered details [12]. For all intents and purposes, the process involved to enhance the image detail is decomposing the input image into a base image which reflects the low frequency information and several detail layers that reflect multi-scale high frequency information, and then enlarging the details to obtain improved detail layers. Finally, the better-quality image is obtained by synthesizing the base image and the enhanced detail layers.

For several decades, satellite images have played an important role in numerous areas. Therefore, it is essential to have high resolution satellite images with effective quality. To meet the rising demand for high-quality satellite images, contrast enhancement techniques are required for better visual perception and color reproduction. In general, raw satellite images have a relatively narrow range of brightness values; hence, contrast enhancement is frequently used to enhance the multiband satellite images for better interpretation and visualization [13,14]. Resolution of these images is very low and it is affected by various factors such as absorption, scattering, etc. Satellite image resolution enhancement has always been a foremost subject to extract more information from them [15]. There are numerous techniques that can be used to increase resolution and contrast of the remote sensing images. Wavelet domain based approaches have demonstrated themselves as most powerful method serving for the required purpose. Even though different histogram equalization approaches have been considered in the literature, they tend to degrade the overall image quality by exhibiting saturation artifacts in both low and high intensity area. In order to overcome such kind of problem, many image enhancement methods have been exploited to increase image contrast and brightness. A wide variety of image enhancement approaches using different concepts have appeared in literature [16–21]. The proposed algorithm overcomes this problem by using adaptive intensity transfer function (also called adaptive intensity transfer function).

Histogram equalization (HE) [2] has been the most admired approach for enhancing the contrast in various application areas such as medical image processing, satellite image processing, pattern recognition field, etc. Although HE based approaches cannot be extremely effective to maintain average brightness level, which may possibly result in either under or over saturation in the resultant image. There have been several techniques to overcome these issues [22–28], such as GHE [23] and local histogram equalization (LHE) [29]. In numerous image processing applications, GHE method is one of the simplest and most effective primitives for contrast improvement [30]. One of the drawbacks of GHE is that the information laid on histogram or probability distribution function (PDF) of the image will be lost. Therefore, enhancement of the images becomes necessary for many practical applications.

Demirel and Anbarjafari [31] have explored the DWT based technique in which interpolated high frequency subband images and input low resolution image is used, and IDWT is applied to get better resolution image. Demirel et al. have also proposed a modified HE method [32], which is based on the LL subband of DWT [32,33]. Yusuke Monobe et al. [34] have proposed the dynamic range compression preserving local image contrast for digital video camera using approximate knee curve that guarantees the continuities in the output level and first order differential coefficients at any luminance level keeping the feature close to conventional knee curve. Eunsung Lee et al. [35] have proposed a contrast enhancement approach based on dominant brightness level analysis and adaptive intensity transformation for remote sensing images. The proposed algorithm computes the brightness-adaptive intensity transfer functions using low-frequency luminance component in wavelet domain, and transforms intensity values according to transfer function.

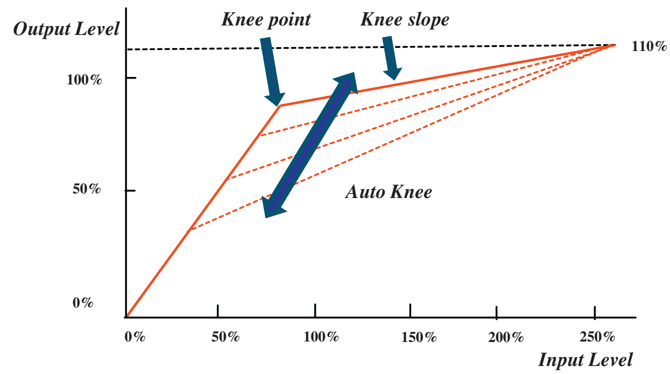


**Fig. 1.** Conventional knee curve and auto knee curve [34,39].

In satellite images, the typical artifacts affected by existing contrast improvement method, such as drifting brightness, saturation, and distorted details, need to be minimized since amounts of essential facts are widespread throughout the image in sense of both spatial locations and intensity levels [36,37]. Due to this, enhancement algorithms for remote sensing images not only enhance the contrast but also reduce the pixel distortion in low and high intensity regions [35,38]. To achieve this goal, this paper presents a novel contrast enhancement approach based on knee transfer function and gamma correction using DWT for satellite images.

Fig. 1 shows the input-to-output mapping of conventional knee curve. The knee function powerfully compresses the emphasized range above knee point maintaining the shadow to center range luminance which consists of the facial regions. The demerit of this method is to formulate the highlight contrast firmly lower. As a more sophisticated method, an auto knee function has been used in this paper to get better result. The auto knee function automatically adjusts the knee point. This method is intended to allocate more tonal levels to highlight range adaptively by adjusting the knee point on the basis of maximum luminance level or the number of pixels in highlight sections. As an improved technique, an auto knee curve has been used to improve the highlight contrast, but middle range luminance is lowered because only a single knee curve is applied to each image [34,39].

The adaptive intensity transfer function is computed in two decomposed layers using knee transfer function [35,39], and gamma adjustment function [40–42]. Subsequently, the adaptive transfer function is applied to get color-preserving high quality contrast enhancement. The momentous enhanced image is achieved by taking inverse DWT (IDWT). Results show that the performance of proposed technique is better as compared to conventional methods of image resolution enhancement. The necessary visual and quantitative results are given in the results and discussions section.

Section 2 gives an overview of DWT. Section 3 presents the proposed approach with brief introduction to enhancement methodologies, which have been used in the proposed approach, viz. methodology based on knee transfer function and gamma correction using wavelet transform. The results and their related