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Remote sensing image enhancement using hazy image model

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ABSTRACT

In this paper, an effective and simple enhancement method for remotely sensed images is proposed to improve the visual quality of the image. Proposed method uses the hazy image model for image enhancement. Hazy image model consist of two unknown parameters, the global airlight and the transmission map. The proposed method determines the global airlight and the transmission map, by using simple statistical values (the standard deviation and the mean value) of the original image. The proposed method enhances the images better than the former methods, as well as keeps the original reflectance values of the input image better compared to the traditional remote sensing enhancement methods.

1. Introduction

Remotely sensed images have a wide area of use, such as meteorology, agriculture. The images obtained by satellites have to be in higher quality. To obtain higher quality images, the image contrast and the edge information should be improved in order to meet the increasing need of higher quality images for both human perception and advanced remote sensing applications. However, for advanced and automated remote sensing applications, the original reflectance information of the input image should be preserved [1,2]. Therefore, remote sensing image enhancement methods have to preserve the original information of the image as possible as they can, while they improve the visuality of the image.

Recently, several methods have been developed to increase the image quality for remote sensing image enhancement. The simplest method is Histogram Equalization (HE) [3], which is still popular especially for object tracking. However, the enhanced images based on HE, generally suffer from oversaturation or undersaturation, where the enhanced images have very poor quality especially for human perception. In order to reduce the oversaturation and undersaturation problems, bi-histogram equalization (BHE) based [4] and Recursive Mean-Separate histogram equalization (RMSHE) [5] based enhancement methods have been proposed. BHE and RMSHE methods, firstly divides the original histogram to obtain sub histograms. Secondly, the methods applies separate histogram equalization to the sub histograms. Finally, the enhanced image is reconstructed from these equalized sub histograms [4,5]. The enhanced image obtained by BHE and RMSHE methods have higher quality than HE method, however, oversaturation and undersaturation problems are still present. In addition to these methods mentioned above, other methods using 2D histograms are proposed recently [6,7]. These methods are not suitable for some applications due to their high computational cost for 2-D histogram creation [1].

Recently, an enhancement method is proposed, which is called “adaptive gamma correction with weighting distribution“ (AGCWD) [8]. This method preserves original reflectance values quite well and can produce effective results, but it also suffers from saturation artifacts and loss of details especially in brighter regions [1]. Another method recently proposed is an algorithm that uses “discrete wavelet transform and singular value decomposition” (DWT-SVD) [2]. In this method, the image

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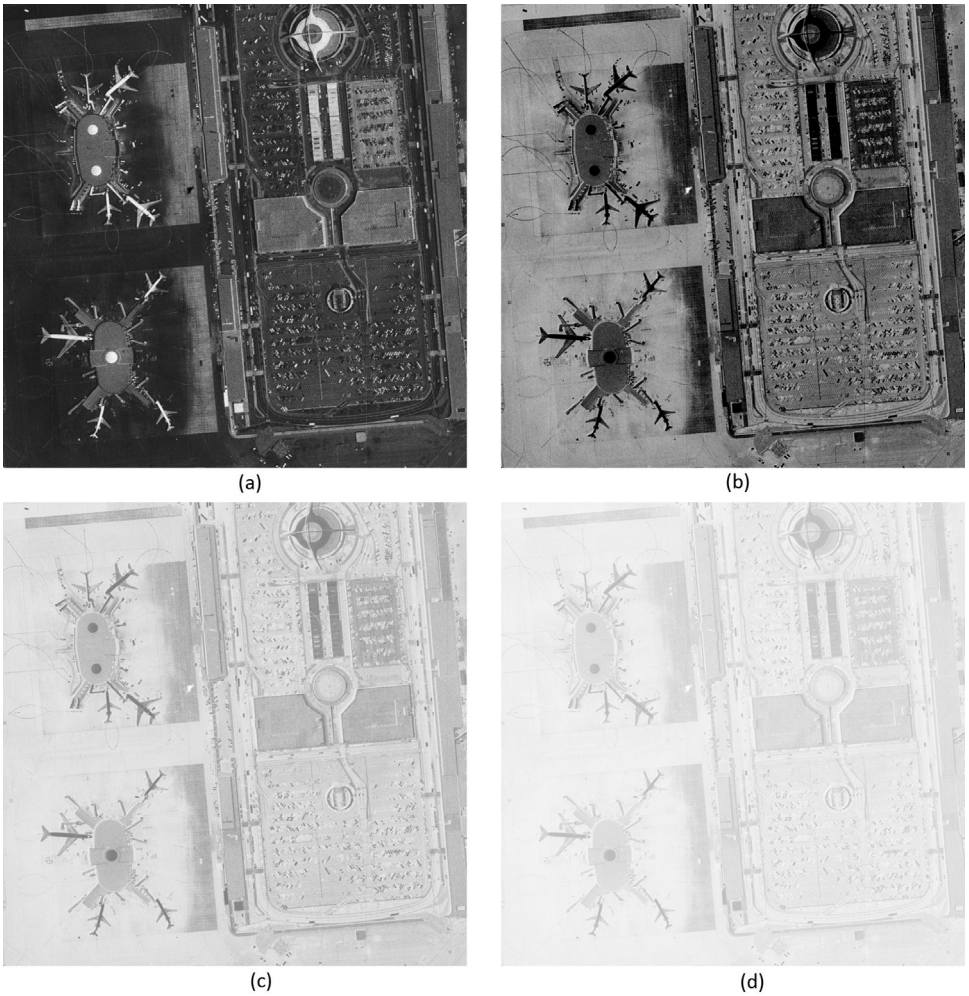

Fig. 1. (a) Original image, transmission maps obtained when, (b) $A = 0.1$, (c) A = mean of the image = 0.35, (d) $A = 0.7$.

is first decomposed into its approximation and detail subbands using DWT. Then the SVD is applied to the approximation subbands. Finally, the resulting enhanced image is obtained by inverse SVD and inverse DWT. Another algorithm based on SVD and DWT is proposed in [9], uses the knee transfer function and gamma correction (KTSVD). A more recent method for remote sensing image enhancement uses the regularized histogram equalization and discrete cosine transform (RHE-DCT) [1]. In this method, a local contrast enhancement in DCT domain is proposed, after a regularized histogram equalization is applied to the input image. Also, a visibility enhancement method for intelligent transportation systems which uses the hazy image model with a hybrid dark channel prior (HDCP) is proposed [10].

In this paper, a simple and effective image enhancement technique for remotely sensed images is proposed. The method models the remotely sensed image with the hazy image model [11]. The hazy image model is generally used for constructing haze free images [11–13]. The dehazing methods determine two unknown parameters of the hazy image model; the global airlight and the transmission map [11–13]. For dehazing purposes, the global airlight is generally estimated by the use of the brightest pixels, then transmission map is determined by the calculated airlight and the original image itself [11–13]. Since the proposed method aims to enhance haze free remotely sensed images, the airlight is obtained by the mean value of the original image instead of the brightest pixels, and the transmission map is estimated by simply using the standard deviation and the mean of the input image. Finally, resulting enhanced image is obtained by using the estimated airlight and transmission map.

Rest of the paper is organized as follows. Hazy image model is explained in Section 2. Proposed enhancement method is explained in Section 3 and experimental results are presented for various remote sensing images to demonstrate the performance of the proposed technique, in Section 4. Finally, the paper is concluded in Section 5.