Computers and Electronics in Agriculture 151 (2018) 196–206

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Image dehazing based on dark channel prior and brightness enhancement for agricultural remote sensing images from consumer-grade cameras

Jiawei Zhang[a,b], Xiuyuan Wang[a,b], Chenghai Yang[c], Jian Zhang[c,d], Dongjian He[a,b], Huaibo Song[a,b,c,*]

[a] Northwest A&F University, College of Mechanical and Electronic Engineering, 22 Xinong Road, Yangling, Shaanxi 712100, China
[b] China Key Laboratory of Agricultural Internet of Things, Ministry of Agriculture, Yangling, Shaanxi 712100, China
[c] USDA-ARS Southern Plains Agricultural Research Center, 3103 F and B Road, College Station, TX 77845, United States
[d] Huazhong Agricultural University, College of Resource and Environment, 1 Shizishan Street, Wuhan, Hubei 430070, China

ARTICLE INFO

Keywords:
Dehazing
Remote sensing image
Image enhancement
Dark channel prior

ABSTRACT

Remote sensing technology has been widely used for monitoring crop fields and other agricultural applications. However, the clarity of remote sensing images is often affected by clouds and chaotic media in the atmosphere. Image dehazing can be achieved through the dark channel prior method (DCP), but there is always a brightness distortion problem after image dehazing. To address the problem, this study proposed an improved image dehazing approach based on the DCP method and determined optimal enhancement parameters. Four evaluation indices, including mean square error (MSE), peak signal to noise ratio (PSNR), average gradient and program running time, were first calculated to evaluate the quality of enhanced images. An example image was dehazed by the DCP method initially using the four indices to determine optimal dehazing parameters. Results showed that image enhancement achieved the best effect when the dark channel window size $\Omega(x)$ is 5, atmospheric light A is 215/255, and the lower limit t_0 of transmission factor $t(x)$ is 0.1. Next, these indices were applied to evaluate the enhancement methods used in this research. The logarithmic enhancement method was finally selected as the optimal method with the base number $(1 + r) = 11$ and enhancement parameter $m = 0.5$. To verify the effectiveness of the selected method, 50 airborne images from a consumer-grade camera flown by an agricultural aircraft were used to evaluate the improved method. Both the original and the enhanced images after dehazing were mosaicked by Adobe Photoshop software. The mosaicked images before and after image dehazing were compared. Results showed that the mosaicked image without dehazing had an entropy of 6.359 and an average gradient of 6.513. In comparison, the mosaicked image with dehazing had an entropy of 6.668 and an average gradient of 11.305, which were 4.86% and 73.58% higher than the respective values for the mosaicked image without dehazing. These results indicate that the proposed method in this study is effective and can be applied to dehaze remote sensing images.

1. Introduction

Remote sensing technology has been widely used in agriculture, forestry, geology, environmental protection as well as many other areas. However, remote sensing images are always affected by adverse weather conditions. The clouds in the atmosphere are one of the main influencing factors (Riaz et al., 2016). As visible remote sensing images are mainly affected by clouds and atmospheric turbid media such as molecules and water droplets, the images are always degraded (Shi et al., 2014). In addition, the images captured even in sunny weather conditions will also be affected because of the atmospheric scattering. Image contrast and color fidelity of the degraded images will also be compromised to some extent (Ansia and Aswathy, 2015). As atmospheric scattering is related to distance from the target to cameras, the degree of image degradation changes with space (Iqbal et al., 2016). Therefore, in order to reduce influences of these factors on images and to improve the reliability of remote sensing data, image dehazing technology has become a practical and valuable research topic and has attracted increasing attention (Ni et al., 2016).

Fog image enhancement methods can be divided into two categories: globalized and localized. Globalized fog image enhancement refers to adjusting the gray values determined by statistical information of the whole image, regardless of the area where the adjusted point is located (Luan et al., 2017; Xiao and Gan, 2012; Ge et al., 2015). For

* Corresponding author at: Northwest A&F University, College of Mechanical and Electronic Engineering, 22 Xinong Road, Yangling, Shaanxi 712100, China.
E-mail address: songhuaibo@nwsuaf.edu.cn (H. Song).

https://doi.org/10.1016/j.compag.2018.06.010
Received 25 October 2017; Received in revised form 1 June 2018; Accepted 4 June 2018
0168-1699/

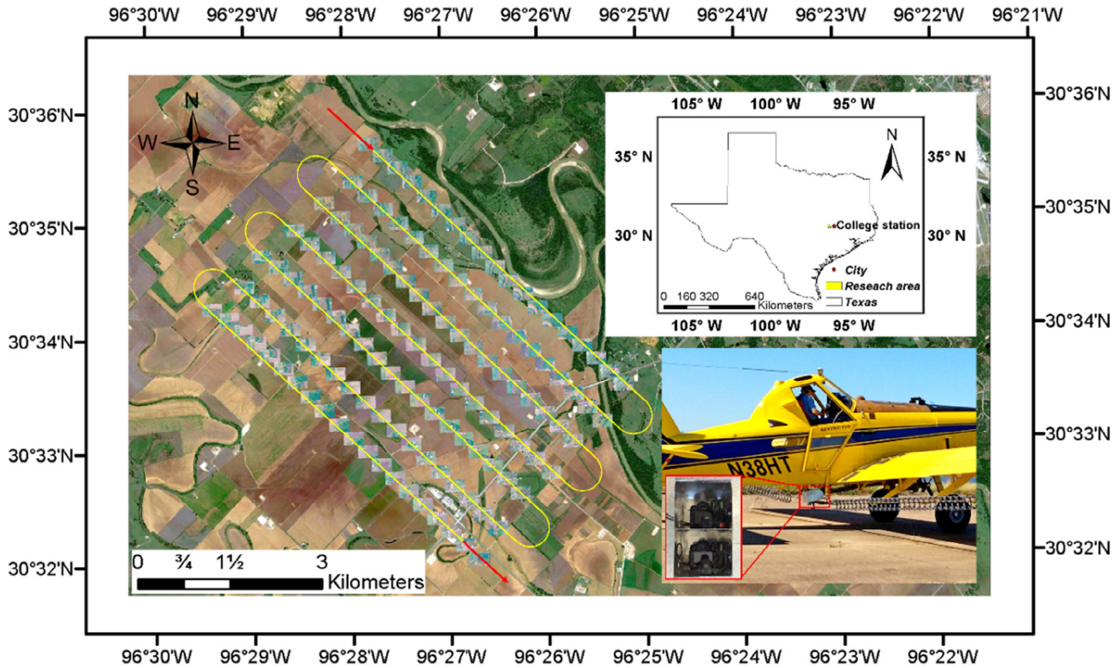

Fig. 1. Research site and flight route map.

example, image brightness preserving ability was improved by the modification of traditional histogram equalization (Dhal and Das, 2017). Homomorphic filtration was used as a preliminary data processing method for upgrading the flaw images obtained during coherent echo-signal processing (Badalyan and Bazulin, 2003). A wavelet-based algorithm for image enhancement was proposed to solve the problem of noise over-enhancement efficiently (Wu et al., 2004). Qureshi and Deriche (2016) proposed a wavelet algorithm for image compression based on compressive sensing. A low-light image restoration method based on the variational Retinex model was put forward by Park et al. (2017). However, the degree of degradation in fog scenes is related to its depth, and images often contain complex depth information. As a result, globalized image enhancement is often not the ideal method. Localized fog image enhancement operates on a portion of the entire image. The transformation or transfer function is determined based on the statistics of the region. For example, the Kuwahara edge corner keeping filter was used to estimate atmospheric scatter light and the filter was further improved to achieve a more accurate dielectric transmittance (Wang et al., 2013). He et al. (2011) put forth the dark channel prior (DCP) method and used image statistical methods to obtain general law of fog images. Then the results were combined with known fog imaging models and interpolation methods to obtain high-quality dehazing images. Verdenet et al. (1981) applied local area histogram equalization to images with differences in intensity. Choi and Yun (2011) presented a contrast enhancement method using an advanced image formation model in which an image was divided into three components.

Dehazing based on DCP theory could increase the depth of field effect to make the image more realistic. However, the brightness of the dehazed image is always distorted (Guo et al., 2017). The objectives of this research were to dehaze remote sensing images using an improved DCP method, to determine the optimal dehazing parameters through objective evaluation indices, and to compare the dehazed images with original images using selected evaluation indices.

2. Materials and methods

2.1. Materials

2.1.1. Study sites

This study was conducted at a cropping area of approximately 38.9 km^2 near College Station, Texas, on July 14, 2015. The geographical location for the center of the area is 30°31′34.97″ N and 96°24′30.44″W. The study site is adjacent to the Brazos River near College Station, Texas and has an abundant vegetation distribution, making it suitable for this study. Due to extensive cloudy and humid weather in May to July, aerial imagery acquired during this period is always affected by haze, making it difficult for crop monitoring.

2.1.2. Airborne image acquisition

A low-cost, dual-camera imaging system consisting of two Nikon D90 digital cameras was used in this study. One camera equipped with AF Nikkor 24 mm f/2.8D lens was used to capture three-band RGB images and the other was modified to capture near-infrared (NIR) images. To obtain consistent images, the cameras were set to the manual mode and the lens focus set to infinity. In order to obtain high quality images, exposure time, aperture opening, and ISO speed were set to 1/1000 s, f/6.3 and 200, respectively. All other parameters were set to defaults. The captured image had an array of 4288 × 2848 pixels. The imaging system was mounted on the right step of an Air Tractor AT-402B. A wireless remote control was attached to the GPS receiver to automatically trigger the camera for image acquisition. To achieve an overlap of at least 50% along and between flight lines, images were acquired at 10-s intervals with a flight speed of 240 km/h along eleven flight lines spaced at 1066-m intervals. Images were stored in 12-bit RAW (NEF format) and 8-bit JPEG files in a SD memory card. A set of 50 continuously captured RGB images belonging to the first six adjacent flight lines was selected for this study. The study site and the imaging system are shown in Fig. 1. The yellow[1] line is the flight route and the red arrows are the starting and ending directions. Detailed descriptions can be found in Yang and Hoffmann (2015).

[1] For interpretation of color in Fig. 1, the reader is referred to the web version of this article.