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Coffee plantation area recognition in satellite images using Fourier transform

Du-Ming Tsai *, Wan-Ling Chen

Department of Industrial Engineering and Management, Yuan-Ze University, Taiwan, ROC

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A B S T R A C T

In this study, a machine vision scheme is proposed for coffee plantation area recognition in satellite images. It automatically segments the row-planted coffee field from forest trees and irrelevant areas in the image. The result can be used for coffee yield estimation to improve the supply and demand of coffee commodity in the market. Commercial coffee plantation grows coffee trees in rows along a specific direction to increase the production yield and management efficiency. The coffee plants and forest trees present the same color tone in the image and, thus, color cannot be used for the discrimination. The row-planting pattern of coffee trees shows structural texture in the satellite image. This study presents a Fourier transform-based method to extract structural features in the spectral domain for image segmentation. Row-planted coffee fields generate high-energy frequency components in a single direction, while naturally-growing plants present omnidirectional frequency components in the spectral domain image. The main frequency in the power spectrum indicates the number of parallel lines in a small patch window and, thus, gives the density feature. The density feature for the row-planted coffee filed is equivalent to the number of rows in a unit square area, whereas it is only one for the randomly-growing plants. This study analyzes the satellite images of coffee plantation regions in different times with varying illuminations and growing stages in Brazil, Africa, Vietnam and Hawaii. The experimental results have shown that the Fourier-based structural and density features can provide correct segmentation to distinguish the row-planted coffee field from irrelevant vegetation areas in the satellite image.

1. Introduction

Coffee is among the most important agricultural commodities in the world market (Pohlan and Janssens, 2010). It is the second most exported commodity after oil (Gole, 2015). Its popularity and volume of consumption keep growing every year. According FAO (Food and Agriculture Organization of the United Nations) statistics (www.faostat3.fao.org), global coffee production area covered more than 10 million hectares (Pohlan and Janssens, 2010; Gole, 2015) in the world. In order to increase the production yield and improve farming management, coffee plantation has been popularly adopted for widespread commercial sale in the main coffee production countries.

Coffee trees are generally planted in row or line pattern along a specific direction to achieve maximum production yields. In this paper, we present a machine vision scheme to identify row-planted coffee fields in satellite images. Fig. 1(a) shows a satellite image in Kauai, Hawaii. It contains the coffee field, tree forest, buildings and roads in the image. The enlarged image patches of these four categories are presented in Fig. 1(b1)–(e1). The coffee trees display green color and are planted in rows. The forest trees are also green-colored, but grow randomly without any structural arrangement. Due to the variations of terrain, slop and shape of the land, the row patterns of coffee planting could be quite different from region to region. Different growing stages of coffee trees present also complicated texture patterns in satellite images. The satellite images captured in different weather and lighting conditions also cause high variations of coffee plantation regions. The spatial domain-based methods cannot reliably handle the diversity of coffee fields in the satellite image. We thus present a spectral domain method to extract structural features of row-planted coffee fields using the Fourier transform. The Fourier transform allows the extraction of global features of a structural pattern with minimal affection of irregular planting changes and environmental noise.

The row planting of coffee trees shows a line pattern along some specific direction in a region, and the forest trees grow in arbitrary directions without distinct structural arrangement. We

* Corresponding author at: Department of Industrial Engineering & Management, Yuan-Ze University, 135 Yuan-Tung Road, Nei-Li, Tao-Yuan, Taiwan, ROC.
E-mail address: iedmtsai@saturn.yzu.edu.tw (D.-M. Tsai).

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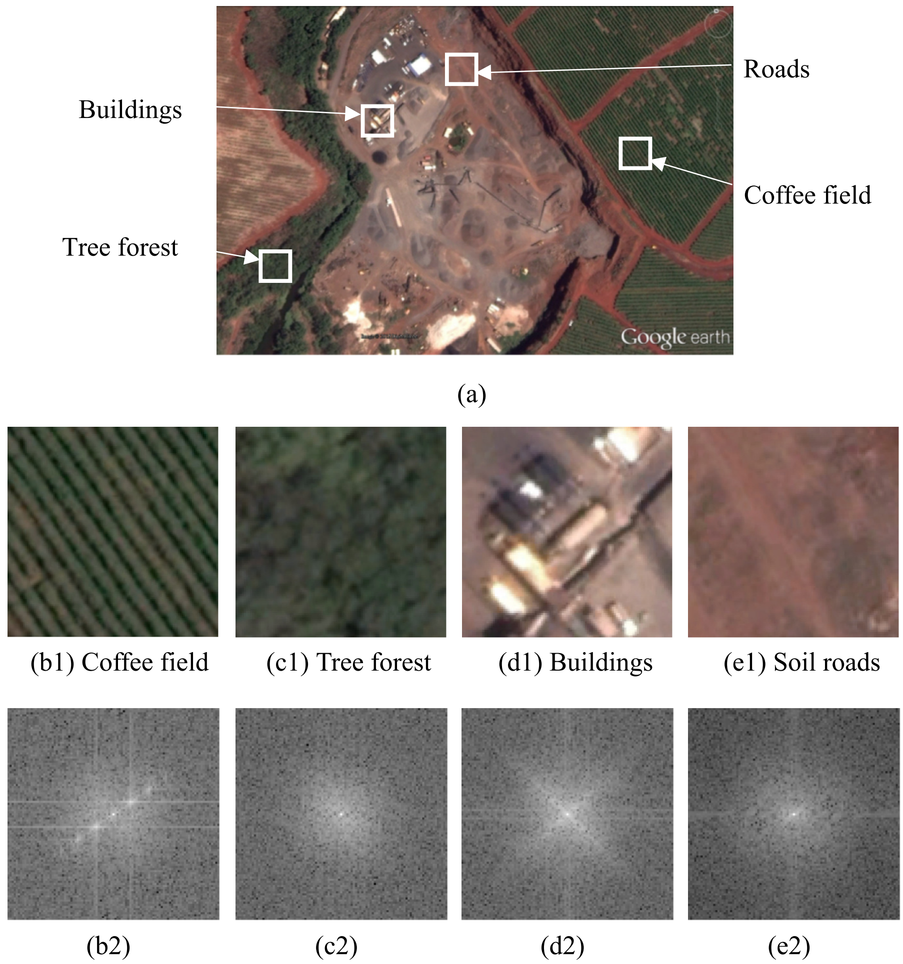

Fig. 1. Image structures of various surface categories: (a) satellite image of Kauai, Hawaii (dated 2011/09/11); (b1)–(e1) enlarged image patches of coffee field, tree forest, buildings and roads, respectively; (b2)–(e2) corresponding Fourier power spectra of (b1)–(e1).

thus propose two discriminant features, linear structural ratio and number of rows (density) obtained from the power spectrum of the Fourier transform. Row-planted coffee fields generate high-energy frequency components in a single direction, while naturally-grown forest trees present omnidirectional frequency components in the spectral domain image. The main frequency in the power spectrum indicates the number of parallel lines in a small patch window and, thus, gives the density feature. The density feature for the row-planted coffee filed is equivalent to the number of planting rows in a unit square area, whereas it is only one for the naturally-growing plants. Because the two proposed Fourier features are highly distinctive to separate the row-planted coffee field and irrelevant vegetation area, simple thresholding is robust enough to segment the satellite image. No complicated supervised classification (such as Support Vector Machine, SVM) or unsupervised clustering (such as Fuzzy C-means) is involved for image segmentation. The total coffee planting area and density for mass commercial use can be accurately evaluated from the segmented region and the number of rows in the satellite image. The result can be potentially used for the estimation of the production volume, and eventually the coffee price in the market.

This paper is organized as follows: Section 2 reviews the previous work. Section 3 describes first the material of satellite images used in this study. It then discusses the Fourier transform properties of row-planting patterns in the power spectrum. The structural feature and density feature used for coffee field segmentation are finally defined and described. Section 4 presents the experimental results on a variety of coffee production regions in the world. The effect of changes in the parameter values is also discussed. The paper is concluded in Section 5.

2. Previous work

Image processing techniques have been used widely for agriculture applications and satellite image analysis. Brosnan and Sun (2002) and Chen et al. (2002) reviewed computer vision for inspection and grading of agricultural and food products. Thorp and Tian (2004) reviewed weed detection techniques in remote sensing images. Meyer and Neto (2008) verified color vegetation indices for crop imaging applications. Ozdogan et al. (2010) reviewed remote sensing of irrigated agriculture. It discussed various vegetation indices and classification techniques in identifying irrigated lands. Mountrakis et al. (2011) surveyed the support vector machines for land cover and land use tasks in remote sensing images. dos Santos et al. (2010) evaluated 20 color descriptors and 7 texture descriptors extracted from spatial domain images and used the K-NN for remote sensing image retrieval and classification.

The color image processing techniques are popularly used for fruit grading and inspection in agriculture. Xu and Zhao (2010) studied the strawberry grading based on shape, size and color of the fruit. Zhou et al. (2012) used color differences (R-B and G-B) for apple recognitions, and evaluated two color models to segment ripening apple images for yield prediction. Camargo and Smith (2009) used image processing to identify the visual symptoms of