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Feature-location analyses for identification of urban tree species from very high resolution remote sensing data

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ABSTRACT

The interference from background noises and the weak spectral separability between species have negative impacts on the identification of urban tree species from remote sensing images. The density of neighbouring members (members mean both pixels and patches) similar to the centre pixel in some image features may offer an opportunity to improve the separability. This paper focuses on the density-involved feature-location analyses (refer to as F-L analyses) developed from the framework of integrated analysis of feature and space. We expressed the density of feature-carried members in two elaborated models: using the density dimension and adding the density descriptors to a feature space to conduct the F-L analyses during a procedure of classifying urban tree species. Experimental results indicate that the two models cannot only increase the number of available independent components for constructing an input vector therefore making the feature space richer, but also provide the reference of spatial dependence among the feature-carried members thus finally making the identification less difficult. The method with the density-involved F-L analyses obviously outperforms that with only conventional spectral features analyses in the classification. The average overall accuracy (OA) derived from the former is 23% higher than that from the latter.

1. Background

Plant species is indispensible data for getting some important variables such as flora biomass, plant net productivity (Heinzel and Koch, 2012) and associated biodiversity (Ferrier, 2002), quality of animal and insect habitat (Kukkala and Moilanen, 2013), carbon storage (Graf Pannatier et al., 2010), etc. Therefore, developing techniques and enhancing ability for identification tree species from recently applied data (e.g. remote sensing image) are important for ecological modelling.

In situ spectroscopy tests revealed that there were certain statistical correlations between spectral reflectance and plant species (Milton et al., 2009). The correlations were used to guide classification of plant species from remote sensing data (Yu et al., 1999; Pu, 2009; Prospere et al., 2014). Over the last decade multi-spectral (Ingram et al., 2005) and hyper-spectral (Clark et al., 2005; Peerbhay et al., 2013; Alonzo et al., 2014) data have proved effective for discrimination of plant species found in various ecosystems (Zhou et al., 2011; Heinzel and Koch, 2012). The accuracy of classification might sometimes be improved by integrating crown structural information from LiDAR data (Jones et al., 2010; Colgan et al., 2012; Dalponte et al., 2012).

However, conventional classification techniques, especially those excessively depending on the relationship between remote sensing bands, are often untenable for discriminating tree species (Pu, 2009; Li et al., 2012; Ghiyamat et al., 2013; Prospere et al., 2014). The band-based classification is usually based on the assumption that each species has a unique spectral signature. However, intra-species variations due to age differences (Gausman and Allen, 1973), micro-climate (Asner et al., 2000), topography (Turner et al., 2003), phenology, illumination differences, precipitation and other environmental factors (Asner, 1998) have sure influences on the biophysical and biochemical constituents of a leaf (Asner, 1998; Schmidt and Skidmore, 2003) thus ruining the assumption. In addition, assemblage of tree crowns with little to no inter-crown distance leads inter-species signatures interfered with each other (Ehlers et al., 2003; Korpela et al., 2011; Ghosh et al., 2014) therefore further weakening the spectral separability and sometimes deviating the classification results from reality (Foody, 2002).

In other hand, many studies indicated that image object's location was a kind of important information to inform spatial dependency between objects thus offering an opportunity to improve the separability. Many “geographically weighted” methods developed from the framework of integrated feature-space analyses were reported such as the geographically weighted regression (Foody, 2005), the geographically weighted difference measure (Comber et al., 2012), etc. Behaving like them, member's density function field might provide meaningful

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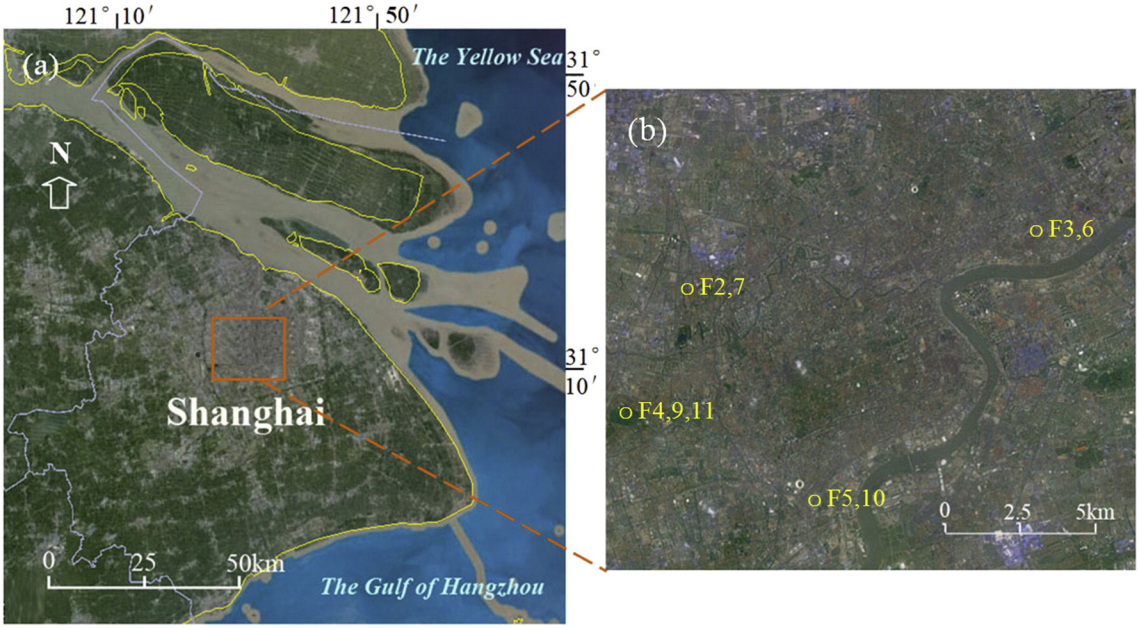

Fig. 1. The study site is in the downtown area of Shanghai, locating on the eastern coast of mainland China. b provides a more detail image of the site. The yellow circles in it show several test sites in following figures and the strings starting with "F" notate figure numbers. Both the back images were downloaded from the website of Google Earth. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

reference for image analyses. It is not rare that two species may be separable from their density values derived from a spectral feature even though they are spectrally confused from the feature. Therefore, the basic assumption underlying the proposed method is that a properly designed density variable may transmit spatial dependency information among members and the F-L analyses associated with such density variables may help to make the identification of urban tree species less difficult.

More specific objectives for this study include (1) designing and testing density descriptions, and (2) comparing the performance between the density-involved F-L analyses and conventional band analyses with no density description for classification of urban tree species from very high resolution remote sensing images.

2. Study site and experimental data

The Shanghai City was chosen as the study area (Fig. 1). Trees in this area are often surrounded by buildings and other urban facilities leading to locally random radiation noise. Therefore, it is a severe challenge to identify tree species in this area from remote sensing images.

In rainy southern cities in China, such as Shanghai, aerial digital NIR images have been commonly used for city surveying and mapping because it was difficult to gain satellite images of all seasons with less cloud cover. In order to prove the proposed approach effective, two dozen test images with decimetre or finer spatial resolution were randomly selected from stock images. Inquired from the image description, the image colours of red, green and blue indicated NIR (near-infrared, 760–900 nm), R (red, 630–690 nm), and G (green, 520–600 nm) bands respectively. Experimental results indicate that the NIR band with 0.1 m spatial resolution is helpful for classifying urban tree species.

3. Methods

3.1. Overview

The density-involved F-L analyses and associated formulas, algorithms and testes will be introduced below.

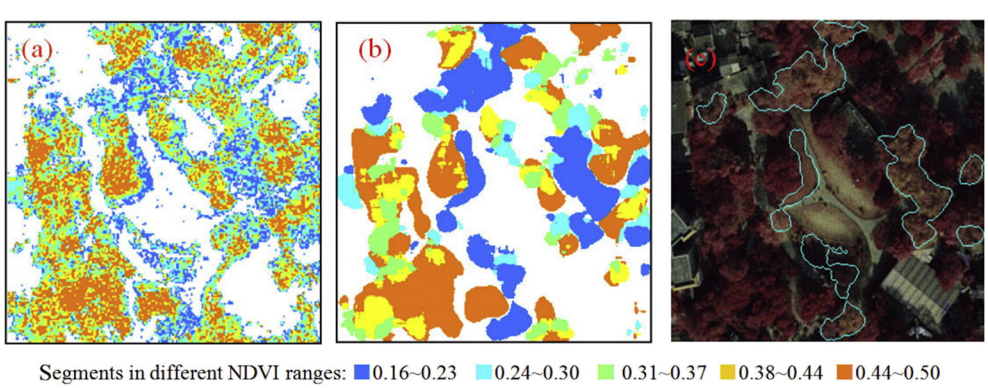

Fig. 2. A comparison of segmentation between with and without density descriptions. (a) Segments in five ranges of NDVI. (b) Segments in a case density of higher than 25% with 11-by-11 window in accordance with these NDVI ranges. (c) *Platanus acerifolia* crowns (cyan-sketched) derived from b. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)