Extending the Pairwise Separability Index for Multicrop Identification Using Time-Series MODIS Images

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***Abstract*—The pairwise separability index (SI) has been demonstrated as an effective indicator for capturing crucial phenological differences between two plant species. However, its application to crop types, which have more obvious phenological characteristics than natural vegetation, has received less attention, and extending the pairwise SI to multiple crops for feature selection still remains a challenge. This paper presented two SI extension approaches (SI_{ave} and SI_{min}) to select the optimal spectro-temporal features for multiple crops, and investigated their classification performance using Heilongjiang Province, China, as a study area. Feature interpretability and classification accuracy of different crops were evaluated for the two approaches. The results showed that the SI_{ave} approach generally has relatively high feature interpretability due to its better description of crucial phenological characteristics of different crops. Those crops with high separability are insensitive to the extension approach and have similar classification accuracy for the two approaches, whereas those crops with poor separability show good performance with the SI_{min} method. Due to the higher temporal autocorrelation, the optimal features for crop classification that are selected by the SI_{ave} approach exhibit greater information redundancy across the time domain than those that are selected by the SI_{min} approach, which largely explains the relatively low classification accuracy achieved using the SI_{ave} approach. These comparison results between SI_{min} and SI_{ave} approaches also indicate that time-series images with high temporal resolution do not necessarily produce high classification accuracy, regardless of their ability to describe the seasonal characteristics of crops.**

***Index Terms*—Crop identification, extension approaches, feature interpretability, moderate resolution imaging spectroradiometer (MODIS), separability index (SI).**

I. Introduction

TIMELY and accurate large-scale information about the spatial distributions of crops is important for crop growth monitoring, acreage surveys, yield estimation, and water management [1]–[4]. In addition to being time-consuming and labor intensive, ground observations or visits may generate errors and discrepancies in declarations because of their subjective nature [5], [6]. Newly emerging remote sensing technology has proved to be a more efficient and reliable method to quickly derive large-scale crop distribution information with good temporal consistency [7], [8].

The remote sensing approach for crop identification largely depends on the spectral discrimination capability. However, the intensive management of croplands, together with the frequent modification of farming strategies, increases the variability of the spectral signatures of crops [9], [10]. Moreover, the spectral reflectance of crops is strongly correlated with leaf pigment, nutrients, and structural properties and varies with the growing season [11], [12]. Consequently, different crops in the same region may share similar spectral characteristics, whereas the same crop in different locations may exhibit substantially different spectral signatures, which is challenging for crop identification using remotely sensed images [1], [5]. It is thus critical to better understand the spectral separability of different crop types and how it varies over time to facilitate determining the optimal time period and appropriate spectral features for crop identification [10], [13], [14].

Many studies have investigated the spectral characteristics of vegetation. Somers and Asner [13] proposed the separability index (SI) based on hyperspectral Hyperion data and defined it as the ratio of the interclass endmember variability to the intraclass endmember variability, which was already used to evaluate the spectro-temporal separability of plant species and to select the optimal features for plant species classification. Their SI-based separability analysis determined the optimal features and eventually yielded high classification accuracy with a relatively low cost and low time investment. The successful tests of SI-based feature selection for plant species classification [13], [15], [16] inspired our interest in applying the SI for crop identification, which is currently rare. Furthermore, similarly to the well-known Jeffries–Matusita (JM) distance, the SI is a pairwise measure that is naturally suitable for two-class classification (i.e., native and invasive species). However, how to extend the pairwise SI measure to a global measure of multiple crops (such as rice, corn, soybeans and wheat) remains a key issue. In general, there are two extension strategies that have been widely used for extending JM measure to determine the optimal feature subsets when multiple classes must be considered [17], [18]. The first method is to calculate the average distance and choose the features with the largest average distance as the optimal features [17], [19]. The second is to choose the feature subsets that allow the largest separation between the

Manuscript received February 3, 2016; revised April 21, 2016; accepted May 12, 2016. Date of publication July 28, 2016; date of current version September 27, 2016. This work was supported by the National Administration of Surveying, Mapping and Geoinformation of China under Grant 201512028.

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Digital Object Identifier 10.1109/TGRS.2016.2581210