Lecture Notes on Data Engineering and Communications Technologies 88

Hongying Meng · Tao Lei · Maozhen Li · Kenli Li · Ning Xiong · Lipo Wang *Editors*

Advances in Natural Computation, Fuzzy Systems and Knowledge Discovery

Springer

Lecture Notes on Data Engineering and Communications Technologies

Volume 88

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ISSN 2367-4512 ISSN 2367-4520 (electronic)
Lecture Notes on Data Engineering and Communications Technologies
ISBN 978-3-030-70664-7 ISBN 978-3-030-70665-4 (eBook)
https://doi.org/10.1007/978-3-030-70665-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The 2020 16th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD 2020) was held from December 19 to 21, 2020, in Xi'an, China.

ICNC-FSKD is a premier international forum for scientists and researchers to present the state of the art of machine learning, data mining and intelligent methods inspired from nature, particularly biological, linguistic and physical systems, with applications to computers, systems, control, communications and more. We are delighted to receive many submissions from around the globe. After a rigorous review process, the accepted papers are included in this proceeding.

Xi'an is the capital and largest city of Shaanxi Province in west China. As an ancient imperial capital of 13 dynasties and eastern departure point of the Silk Road, Xi'an has long been an important historical city in China. Famous attractions in Xi'an include terracotta warriors in the Mausoleum of the First Qin Emperor (a UNESCO World Heritage Site), Giant Wild Goose Pagoda, Fortifications of Xi'an (Ancient City Wall), Huaqing Palace and Stele Forest. In modern times, Xi'an is an important cultural, industrial and educational center in central and western China, well known for its universities, R&D facilities, as well as China's space exploration.

We would like to sincerely thank all organizing committee members, program committee members and reviewers for their hard work and valuable contribution. Without your help, this conference would not have been possible. Special thanks go to Shaanxi University of Science and Technology for hosting this event. We thank Springer for publishing the proceedings. We are very grateful to the keynote and

invited speakers for their authoritative speeches. We thank all authors and conference participants for using this platform to communicate their excellent work.

December 2020

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The original version of the book was revised: book series changed from Advances in Intelligent Systems and Computing to Lecture Notes on Data Engineering and Communications Technologies. The correction to the book is available at https://doi.org/10.1007/978-3-030-70665-4_207

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Contents

Derivation of Multitemporal Kauth-Thoms Transformation for GF-2 mIHS Pansharpening Digital Number Data

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Abstract. Gaofen 2 (GF-2) high spatial resolution imagery has been recognized as an important data source for mapping vegetation pattern dynamics. The Kauth-Thomas (KT) indices of brightness, greenness, and wetness derived from single-date imagery has also been proved to be better than the common vegetation indices in monitoring the vegetation, mapping land desertification, and classifying land covers. However, for change detection of vegetation status, multitemporal Kauth-Thomas (MKT) transformation is found to be a more effective approach. In this paper, the parameters defining the KT dimensions for single-date mIHS pan-sharpeniing GF-2 data (acquired on April 30, 2016) were derived. Then, the MKT transformation matrix was proposed using a linear transformation process, which could be applied to GF-2 digital number image data for detecting vegetation pattern dynamics in the future.

Keywords: Gaofen 2 · Multitemporal Kauth-Thomas transformation · Digital number

1 Introduction

It has been widely accepted that remote sensing imagery can be used to detect changes in land use and land cover. A lot of approaches of change detection have been developed and applied, many of which have been done based on the spectral appearance of land cover changes [1]. Classification of the Kauth-Thomas (KT) transformation components was found to yield slightly higher classification accuracy of land cover than the common vegetation indices derived from any single band-pair difference or ratio [2–6]. Much research indicate that linear change detection techniques can be used to monitor land cover changes based on multidate satellite data. Multitemporal Kauth-Thomas (MKT) transformation is found to be one of the best effective linear change detection techniques [1, 7–9].

It is well known that the KT coefficients must be derived again for a new sensor or a different data from a different level of image preprocessing, such as the fused or not fused digital number (DN), at-satellite reflectance, surface reflectance [10–12]. Over the

H. Meng et al. (Eds.): ICNC-FSKD 2020, LNDECT 88, pp. 1–7, 2021.
https://doi.org/10.1007/978-3-030-70665-4_1

last four decades or so, a large variety of the KT coefficients for the different sensors and different image data have been proposed [13, 14]. The MKT is a multitemporal generalization of the KT transformation of multispectral data in nature. According to Collins and Woodcock (1996) [1], the MKT transformation matrix can be defined as follows:

$$M = \frac{\sqrt{2}}{2}\begin{bmatrix} K & -K \\ K & K \end{bmatrix} \quad (1)$$

M is a matrix in which the first part of even column vectors is multidate resemblances of the corresponding single-date KT indices, and the last part indicates changes in the corresponding KT components. The $\sqrt{2}/2$ is the normalized factor. K is a coefficient matrix for single-date KT transformation.

Gaofen 2 (GF-2) has two multispectral scanners imaging the earth with one panchromatic band with 1 m spatial resolution and four multispectral bands with 4 m spatial resolution (showed in Table 1). The previous studies discussed in the literature demonstrate that image with a spatial resolution of 2 m is suitable for mapping decametric-scale vegetation pattern dynamics [15, 16]. Thus, it is necessary to merge high spatial panchromatic band with low spatial resolution multispectral bands to create a single high spatial and spectral resolution image for the effective change detection of vegetation. The details of some state-of-the-art remote sensing fusion methods have been reviewed and explained by Ghassemian (2016) [17]. The modified intensity-hue-saturation (mIHS) method is one of very commonly applied pansharpening approaches in the literature, embedded in commercial remote sensing processing system-ERDAS imagine v9.2 software, and has a strong ability to meet the demands of improving the spatial resolution of the original multispectral bands with preserving the color fidelity [18–20]. Thus, in this paper the mIHS pansharpening method is applied to fuse the GF-2 multispectral data. Collins and Woodcock (1996) found that a full radiometric correction and matching could not result in any improvement of change detection over a much simpler method, and recommended the use of simple DN matching for change detection studies [1]. Thus, in this paper the single-date KT and MKT coefficients are derived for the DN image.

Table 1. Spectral ranges and resolution of Gaofen-2 image.

Band	Spectral range (nm)	Spectral resolution (m)
1	450–900	1
2	450–520	4
3	520–590	4
4	630–690	4
5	770–890	4

Therefore, our goal is to derive the single-date KT coefficients based on the mIHS pansharpened GF-2 DN image. Then, the MKT transformation matrix is proposed for the mIHS pansharpened GF-2 DN image using a linear transformation process, which will be useful for applying GF-2 digital number image data to detect vegetation pattern dynamics in the future.

2 Data and Methods

2.1 Data

One GF-2 scene of Xianhe town, Dongying City, Shandong Province, China was acquired on April 30, 2016 (spring season), and download from China Center for Resources Satellite Data and Application (CRESDA, http://www.cresda.com), and was registered to a UTM projection (UTM, zone 50N, WGS84). The subset of the mIHS pansharpened GF-2 image was showed in Fig. 1.

Fig. 1. The subset image of Gaofen 2 satellite data acquired on April 30, 2016

2.2 Kauth-Thomas Transformation

According to the processes used by the previous literatures [5, 12, 21], the single-date KT coefficients were derived. Because the GF-2 satellite data has no shortwave infrared band, the KT wetness component coefficients were not calculated in this paper.

Firstly, the representative samples of dense green vegetation (23028 pixels, from *Robinia pseudoacacia* forest), bright soil (10676 pixels), and dark soil (10522 pixels) was selected by visual inspection of the image.

Secondly, the differences between the average values of bright and dark soil sample pixels were calculated for every band. Then, the normalization factor was obtained by the square root of the sum of the squares of the differences of every band. The KT brightness component (KTB) coefficients were derived by dividing the differences between the average values of bright and dark soil pixels of every band by normalization factor.

Thirdly, to derive the KT greenness (KTG) component coefficients, the differences between the average values of bright and dense vegetation sample pixels were calculated for every band. Then, a Gram-Schmidt orthogonalisation process was carried out to obtain the green vector components. Finally, the KTG coefficients was derived by dividing the green vector components of every band by the normalization factor, which was the square root of the sum of the squares of the green vector components of every band. The detailed procedures can be found in the literatures [12, 21].

Finally, the MKT transformation matrix was derived using the Eq. 1, which is a 8×4 matrix in which the first two column vectors were multidate resemblances of the corresponding single-date KT indices (KTB, KTG), and the last two column vectors indicated changes in the corresponding KT components (ΔKTB, ΔKTG).

3 Results and Discussions

The following Table 2 presents the coefficients for calculating the KTB and KTG from the DN data of four mIHS pansharpened bands of GF-2 image.

Table 2. The single-date Kauth-Thomas coefficients for the DN data of Gaofen-2 mIHS pansharpened imagery.

The Kauth-Thomas transformation component	Band 2	Band 3	Band 4	Band 5
The brightness	0.4352	0.4503	0.6041	0.4929
The greenness	0.0483	−0.2365	−0.5246	0.8164

All four multispectral bands (Band 2 to Band 5) had positive loadings on the KTB component (see Table 2). This finding was consistent with the previous research on the different sensors with the similar spectral bands from IKONOS, Quickbird 2, CBERS-02, and HJ-1B satellite [22–25]. The red band (Band 4) contributed the most to the KTB. This finding was not consistent with the results of the previous studies. It may be due to the pansharpening performance, which needs to be studied in the future. Two multispectral bands (Band 3, Band 4) had negative loadings on the KTG component, and the near infrared band (Band 5) contributed the most positive loadings to the KTG. This finding was consistent with the previous studies [22–25]. The Band 2 had the slightly small positive loadings on the KTG, which was inconsistent with the previous studies [22–25]. It may be due to the pansharpening performance or the representative sample selection.

Table 3 gives the MKT transformation matrix. The first four bands (Band 2 to Band 5 in the first column of Table 3) were from the first date GF-2 image, and the last four bands (Band 2 to Band 5) were from the last date GF-2 image. The change in the KT brightness (ΔKTB), and the change in the KT greenness (ΔKTG) calculate increases in the KTB, and KTG, respectively. Component scores on the different bands were closely related to simple inter-date differences of the KTB, and KTG. It should be noted that before using the MKT transformation matrix (see Table 3), according to the research from Collins