Urban House Detection Using SAM and SIFT on Hyperspectral Remote Sensing Images

Cailing Wang¹, Fan Yang¹, Hongwei Wang², Pu Guo¹, Jiale Hou¹

¹Xi’an Shiyou University, Xi’an 710065, China
²Engineering University of CAPF, Xi’an 710086, China
azering@163.com

Abstract: The detection and identification of urban object targets have always been a research hotspot. In recent years, the spectral, spatial and temporal resolution of remote sensing images have been continuously increased, making hyperspectral remote sensing images widely used in urban object recognition. We proposed a new method for urban house detection by combining the spectral mapping results and spatial features. Firstly, the target spectral information is used to distinguish the targets in spectral domain. Then, the spatial SIFT feature algorithm is used on the results of spectral mapping, which can improve the accuracy of urban housing target recognition.

1. Introduction

Hyperspectral remote sensing is a new type of Earth observation technology developed in the 1980s and listed as one of the most significant advances in remote sensing technology in the 21st century [1]. Hyperspectral image (HSI) captures reflectance values from visible to infrared spectrum which cover the wide spectral range with hundreds of bands for each pixel in the image [2]. The hyperspectral imager covers the ground in dozens or even hundreds of channels, and the detailed spectral information of the ground object can be obtained, which is a powerful complement to the inherent defects of the traditional urban remote sensing data source. Using the rich spectral information of hyperspectral remote sensing data, from the spectral analysis and spectral mapping technology, the city features and artificial targets are finely classified, providing information on urban change planning, environmental monitoring and evaluation, and related social and economic aspects [3].

Many scholars have used advanced aerospace data to research a variety of techniques for extracting information on urban construction land using remote sensing information. Ridd [4] proposed a VIS (vegetation-impermeable surface-soil model) for studying urban ecology. In this paper, the spectrum in each pixel in the city image is seen as a linear combination of the three representative land cover types, and then the improved VIS model is mainly manifested in a small increase in the end-members of the object. Xu Han-qi [5] extracted the urban construction land information by compressing the data dimension and using the three exponential bands derived from ETM+ data. All of the above cases are carried out for multi-spectral data with higher spatial resolution. The extracted urban surface features are too general, and multi-spectral data has certain difficulties for accurate extraction of pure end elements.

The data used for the recognition of traditional urban object targets are mostly RGB three-channel images or multi-spectral images, both of which can provide spatial two-dimensional information with higher resolution. In the detection of urban object targets, it is only possible to identify and classify the objects by manual visual interpretation, which requires a lot of manpower and material resources. At the
same time, subjective factors of the interpreters are likely to result in diversity of judgment results. Unreliable and unable to meet the requirements of urban monitoring and analysis. Multi-spectral imaging remote sensing images are characterized by wide band and low spectral resolution, which can qualitatively classify urban features. However, due to the spectral characteristics of urban features and the lack of information on the features of urban features, it is difficult to reflect the complex and diverse urban features covering the introverted type, which is not conducive to fine classification and target detection.

In this paper, we develop a new spectral-spatial method which employs the SAM method and SIFT method for urban house detection. Specifically, the SAM mapping result is obtained by using target spectral signature firstly. Then, the SIFT target detection method is done on mapping results. Our experimental results, conducted with a real hyperspectral scene collected by the Rochester Institute of Technology Multi-object spectrometer (RITMOS), show that the method proposed can improve the accuracy of urban housing target recognition.

The structure of this paper is as follows. In section 2, the research status of urban object recognition is introduced. In section 2, the spatial local feature descriptors used in this experiment—SIFT and spectral angle matching (SAM) algorithm are briefly introduced. In section 3, the experiments are done on two datasets and the results are discussed. Finally, we get the conclusion.

2. Related works

2.1 SAM algorithm

Spectral angle mapping (SAM) is a supervised classification technique. SAM directly matches the image spectrum with the reference spectrum. It is an automatic classification method for comparing the image spectrum with the ground spectrum or the spectral spectrum of the spectrum. SAM is calculated by Eq. (1)

\[ \alpha = \cos^{-1} \left( \frac{\sum_{i=1}^{nb} t_i r_i}{\left( \sum_{i=1}^{nb} t_i^2 \right)^{1/2} \left( \sum_{i=1}^{nb} r_i^2 \right)^{1/2}} \right) \]

Eq. 1

\( nb \) represents the number of bands, \( t_i \) represents the target spectrum, and \( r_i \) represents the true spectrum. If the angle between the target spectrum and the real spectrum is smaller, the similarity between the two spectra is greater [6].

2.2 SIFT algorithm

Scale-invariant feature transform (SIFT) has scale invariance and can detect the key in the image. The SIFT algorithm consists of two phases: SIFT feature detection and SIFT feature matching. The SIFT feature detection mainly includes the following four basic steps.

1) Scale space extreme detection—search for images in all scale spaces, and identify potential pairs of points and select invariant points of interest through Gaussian differential functions.

2) Key point location—At each candidate position, the position scale is determined by a fitting fine model, and the key points are selected according to their stability degree.

3) Direction determination—based on the gradient direction of the image locality, assigned to one or more directions of each key point position, all subsequent operations are to transform the direction, scale and position of the key points to provide the invariance of these features.

4) Feature point description—measure the local gradient of the image on the selected scale in the neighborhood around each feature point. These gradients are transformed into a representation that allows for larger local shape deformation and illumination transform.

2.3 Urban house detection by SAM and SIFT

In this paper, we proposed a new house detection by SAM and SIFT (SAM_SIFT). Because of hyperspectral image dataset which consists a huge data cube with hundreds of spectrum bands, we choose SAM result for data reduction. The urban house target has obvious edges and corners, and it
also has obvious contrast with the surrounding environment. That is why we choose SIFT for spatial feature extraction. The procedure is as shown in Table 1.

Table 1. The procedure of proposed method

| Input: the hyperspectral image dataset and target image |
| Output: detection result |
| 1 spectrum mapping by SAM |
| 2 Binary mapping result image by adaptive thresholding method |
| 3 SIFT feature extraction and matching in binary image |
| 4 Return detection result |

3. Experiments and Results

3.1 Experiment setup

The experimental data used in this paper is published by the Rochester Institute of Technology Multi-object spectrometer (RITMOS). The spatial resolution is 0.3 m. The spectral range is 400nm to 1000nm, and the band number is 61. The two images are shown in Fig.1.

Fig.1 (a) The 400nm of hyperspectral image dataset 1, (b) The pseudocolor shown of hyperspectral image dataset 1 (400nm band image as R, 600nm band image as G, 800nm band image as B), (c) the 400nm of hyperspectral image dataset 2, (d) The pseudocolor shown of hyperspectral image dataset 2 (400nm band image as R, 600nm band image as G, 800nm band image as B)

In order to shown the effectiveness of the proposed approach, the SIFT method with PCA (PCA_SIFT) is employed. The 1PCs is selected as the input to binary image for SIFT purpose. The comparison is conducted on Windows 7 PC (Intel(R) Core(TM) i5-1.7GHZ 2.40GHZ with 4.0GB RAM). The software we chose is MATLAB R2017b. The PCA_SIFT detection results shown in Fig.2. And Fig.3 and SAM_SIFT detection results shown in Fig.4 and Fig.5.

Fig.2 (a) The 400nm of hyperspectral image dataset 1, (b) The 1st PCs and target (in red rectangle) of hyperspectral image dataset 1, (c) The SIFT results of hyperspectral image dataset 1

Fig.3 (a) The 400nm of hyperspectral image dataset 2, (b) The 1st PCs and target (in red rectangle) of hyperspectral image dataset 2, (c) The SIFT results of hyperspectral image dataset 2
3.2 Experimental result analysis

We can get information that there are 8 houses which can be seen as same as target house in dataset 1 and 4 in dataset 2. From the Fig.2, we find that only 2 house are detected in dataset 1 by PCA_SIFT method. From the Fig.4, we find that 5 house are detected in dataset 1 by SAM_SIFT while there are still find 2 different house and 5 road sections. From the Fig.3, we obtain that 2 houses are detected in dataset 2 by PCA_SIFT method. From the Fig.5, we obtain that 3 houses are detected in dataset 2 by SAM_SIFT while there are still find 1 different house.

We can conclude that the SAM_SIFT method can get more results than PCA_SIFT method. However, the other more results are not only the right target, but also some false ones. We need do more work for reduce false alarm rate.
4. Conclusion
In this paper, the urban house target detection method is proposed. Specifically, the target spectral information is used to distinguish the targets in spectral domain by SAM firstly. Then, the spatial SIFT feature algorithm is used on the binary image of results of spectral matching, which can improve the accuracy of urban housing target recognition.

In the experiment setup, the two hyperspectral remote sensing images are employed to verify the method. The PCA_SIFT method is also used as benchmark for the method proposed. It can be clearly seen from the results that there are many houses that should be detected and not marked in PCA_SIFT result. The method proposed has higher detection rate. However, false alarm rate is also increased in result analysis. We should do more work for further research.

Acknowledgments.
This work has been supported by the National Science foundations of China (Grant Nos.: 41301382, 61401439) and graduate student innovation and practice program, Xi’an Shiyou University.

References
[1] Wang Liguo, Zhao Chunhui. Hyperspectral image processing technology [M]. National Defence Industry Press, 2013(in Chinese).
[2] Bandos, Tatyana V., L. Bruzzone, and G. Camps-Valls. "Classification of Hyperspectral Images With Regularized Linear Discriminant Analysis." IEEE Transactions on Geoscience & Remote Sensing 47.3(2009):862-873.
[3] Lin Zheng. Application of hyperspectral remote sensing in the identification of urban objects [D]. Guangzhou University, 2008(in Chinese).
[4] Ridd M K. Exploring a V-i-S (vegetation-impervious surface-soil) model for urban ecosystem analysis through remote sensing: comparative anatomy for cities†[J]. International Journal of Remote Sensing, 1995, 16(12):2165-2185.
[5] Li C H, Xu H Q, Chen L C. [Cross-comparison between ASTER and Landsat-7 ETM+ multispectral imagery][J]. Spectroscopy & Spectral Analysis, 2010, 30(9):2518(in Chinese).
[6] Xia Wei. Research on extraction method of hyperspectral image endmember based on TF-IDF model [D]. Nanjing Normal University, 2016(in Chinese).