

EXTRACT PROFILE OF URBANIZED AREA IN BEIJING ASSISTED BY SKEWNESS

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ABSTRACT:

In Beijing, some crop field is similar to urbanized area in spectral space of ETM+ image, and this is an obstacle to extract urbanized area of Beijing from ETM+ image. Furthermore, classical texture such as variance can not improve the separability of such two landcovers. This article proposed a skewness based framework to extract the profile of urbanized area, while skewness was seldom applied in optical images. Firstly, skewness image was generated from the panchromatic image of ETM+, and it was smoothed using low-pass filter. Secondly, skewness and spectral information, from multi-spectral bands, were combined to fully utilized both texture and spectral information. Finally, morphological operation and DEM data were employed to perfect the classification result. Through visual interpretation, the extracted urbanized area is accurate in large scale, so the “profile” of urban was obtained. At last, accuracy assessment showed that accuracy of the skewness based classification was 10% higher than traditional approaches.

1. INTRODUCTION

1.1 Application of ETM+ Image in Urbanization Research

China has experienced a fast urbanization period since the opening and reform strategy was implemented. By Using remote sensing technique to extract the urbanized area, current situation of urbanization can be monitored timely and precisely.

ETM+ images were obtained by Landsat 7, and NASA provides this kind of images from April 15th, 1999 to March 31st, 2004. Compared to the TM images obtained by Landsat 4,5, ETM+ images has a panchromatic band of 15m in spatial resolution. ETM+ image has obvious advantages as follow:(1) The panchromatic band has provided abundant texture information of landcover. (2) The image can cover an area of 185KM*170KM, and such large area can include a normal metropolis (3) University of Maryland supplies such images freely. Therefore, ETM+ images supplied by NASA is an effective resource to study the Landcover from 1999 to 2004.

1.2 Researched Area and its Corresponding Data

Beijing, motivated by economic growth, transportation advancement and 2008 Olympic Games, is experiencing an incredible urbanization. This research employed an ETM+ image (Figure 1, where the black part represents the area outside the image, Path NO:124/033, Date:05/07/2000) and DEM (Figure 2) data to study its urbanization.

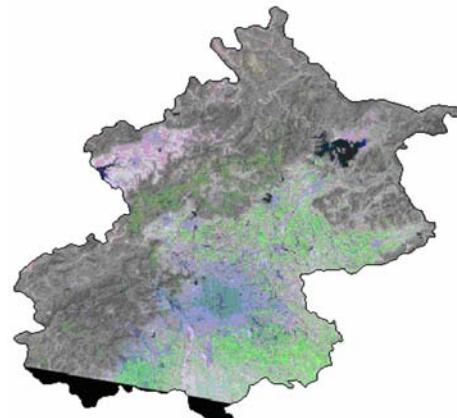


Figure 1. True color ETM+ image of Beijing

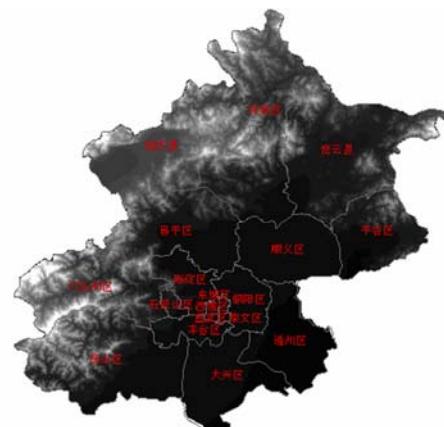


Figure 2. DEM data of Beijing

2. EXTRACTION OF URBANIZED AREA BASED ON SKEWNESS TEXTURE

2.1 Texture Feature in Classification of TM/ETM+ Image

Although the ETM+ image covers a large area and is suitable for resource investigation, the number of bands is too limited to distinguish some landcovers, which share a similar spectral feature. Through a plenty of experiments, we discovered that it is effective to use texture feature to enhance the objects' feature so as to be separated from others. For example, entropy and variance are used to extract lakes from ETM+ (Armenakis, 2003), and edge density assisted by morphological operation is very helpful to find the city boundary in TM images (Hlavka, 1987). However, these textures are ineffective to extract urbanized area in ETM+ of Beijing metropolis.

2.2 Definition of Skewness and its Current Application

Skewness, in digital image, describes the asymmetrical attribute of a group of pixel values. If the skewness is equal to 0, it means the data is symmetrical rigorously, and the farther from 0, the more asymmetrical. For a gray scale image, (x_1, x_2, \dots, x_n) represents a set for all pixel values in a moving window, so skewness is defined as a kind of texture as follows:

$$\text{skewness} = \frac{\sum (x_i - M)^3}{(n-1)(V)^{3/2}} \quad (1)$$

Where n, M, V represent the number, mean value and variance of gray scale values, respectively in a moving window.

As an important statistical measure, skewness is widely used in finance, engineering and atmosphere research. As the come forth of remote sensing, skewness is becoming used in such field, though not widely. Skewness can be used to detect and enhance the edges in the image (Irons, 1981), however the author pointed out that he does not find this feature can be used for landcover classification. And skewness is also a tool to detect small targets in images [Chiang, 2001]. Compared to optical remote sensing, skewness is so widely used in radar data process that ERDAS has a skewness function in the RADAR modular.

2.3 Feasibility of Skewness in Extracting Urbanized Area

For urbanized area, experiencing frequent reconstruction, it is composed by buildings, vegetation, streets, water body, so its symmetry is much less than that of crop field. Since skewness can reflect the symmetry of different landcover, it is an effective and simple feature to distinguish urbanized area and crop field. As the result of spectral analysis, there are various kinds of crops around urbanized area of Beijing, and some of them (Figure 3a) have very similar spectral value to some urbanized area (Figure 3d). So, if they are extracted directly by spectral feature (Figure 4a), they will be misclassified into urban in a high probability.

Calculating the skewness value from the panchromatic band, Figure 3b, 3e were generated from Figure 3a, 3d. A computation on crop field in Figure 3b and urbanized area in Figure 3e show that the average skewness in former one is much lower than the latter one. But these two landcovers are not well separable (Figure 4b) due to big intra-distance in both two landcovers, though their inter-distance is obvious. To enhance

the separability, a low pass filter was used to reduce the intra-distance of patches, so we got a good separability (Figure 3c, 3f, 4c).

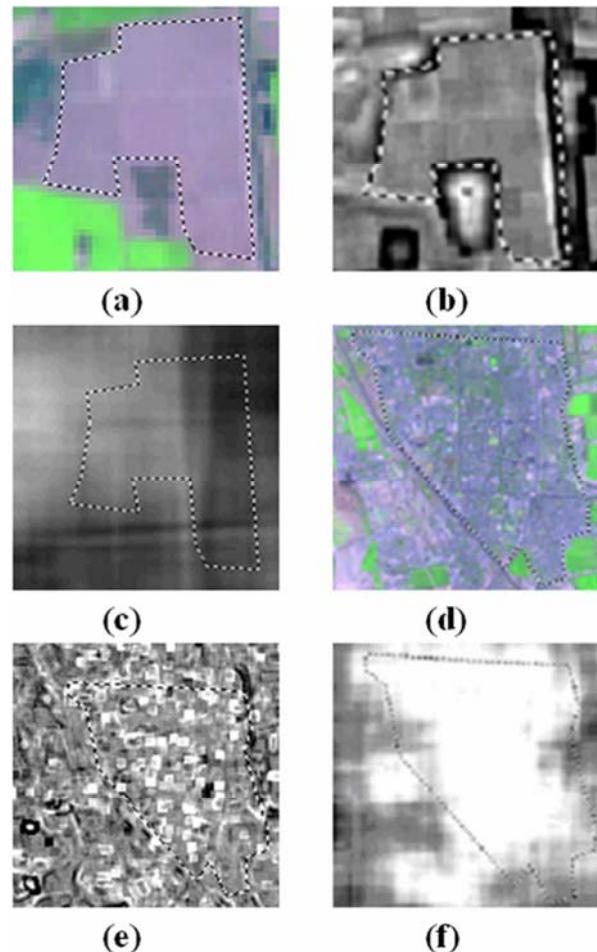


Figure 3. (a) True color ETM+ Image of crop field A (b) skewness value of crop field A (moving window in 9*9 size) (c) low pass operation on Figure 3b (d) True color ETM+ Image of urbanized area B (e) skewness value of urbanized area B (moving window in 9*9 size) (f) low pass operation on Figure 3e

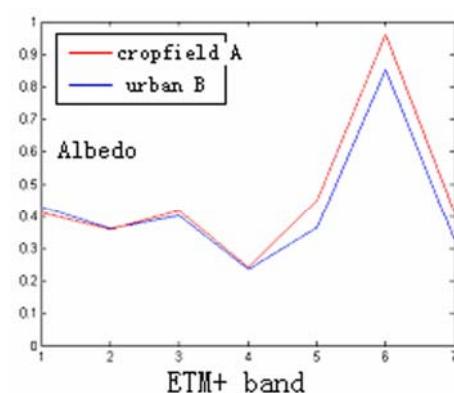


Figure 4(a) Average albedo from crop field A and urbanized area B in the ETM+ image

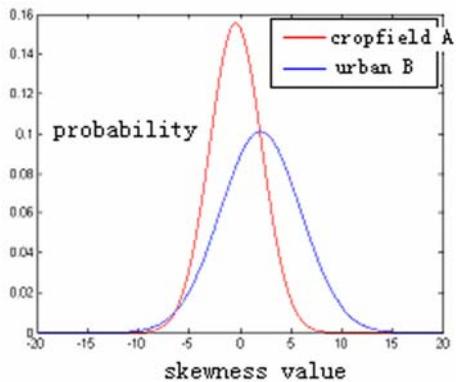


Figure 4(b) Skewness distribution of crop field in Figure 3b and urban area in Figure 3e

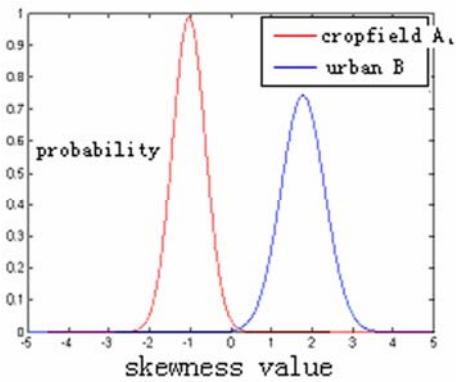


Figure 4(c) Skewness distribution of crop field in Figure 3c and urban area in Figure 3f

4. ALGORITHM AND EXPERIMENT

4.1 Technical Process

Although skewness can effectively extract urbanized area, the misclassification also existed obviously. For instance, the skewness value of beaches around the Miyun Reservoir and some rocks distributed in mountains was similar to that of urbanized area. To correct this kind of errors, multi-spectral information from ETM+ and DEM data was used to eliminate such unurban area. The whole process is stated as follows:

1. Select the proper window size for skewness computation on band 8 of ETM+. Because the band 8 (panchromatic) has a fine spatial resolution which contains abundant detail information, so it is the best band for extracting urbanized area. And the only parameter of the moving window can be controlled is the size, because a too small size can not reflect the symmetrical information, and if it is too large it will confuse different targets. Through a series of experiment, 9*9 size window was best for classification and computation. And then the skewness map was generated as Figure 5.

2. Select a proper low pass filter to equalize the skewness value in patches. Since urbanized areas were distributed in patches, low pass operator can reduce the intra-distance of the same landcover. Unfortunately, the operator can also reduce the inter-distance of adjacent landcovers, so it is important to choose proper low pass filter for a trade-off.

3. Choose a threshold for binarization of the smoothed skewness map, and the higher valued part is the alternative region for urbanization.

4. Combine the alternative region from skewness and multi-spectral bands, the urbanized area was extracted by ETM+ image. The old city region has a lot of vegetation, so the skewness feature is instable where the spectral feature is stable; through many tests, the new urbanized area has a more fixed skewness value, and it can be easily mixed with surrounding crop field. So, it was recommended that pure multi-spectral information is suitable for extract old urbanized area, while the new urbanized area need both skewness and multi-spectral information.

5. Use DEM data to exclude the area improper for construction from the alternative area, generated from the step 4. Since the bare rock in the mountains have very similar texture and spectral feature with new urbanized area, it was necessary to use slope data to delineate the boundary of the mountain area, where very few buildings can be constructed.

6. Take morphological operation on the “urbanized area” generated from the step 5, and a reasonable urbanized area is determined at last. Thousands of scattered “urbanized patches”, in very small area, were distributed in the result. Such area might represent some targets of similar features with the “real urbanized area”, or they were actually urbanized area. To simply overcome this dilemma, erosion-dilation operator was implemented, since if a building is surrounded by large open space, it can not be regarded as “urbanized area” according to laws of urban planning. In the same way, while some other landcover, with small area, are surrounded by urbanized area, such landcover can be regarded as “urbanized area”, so a dilation-erosion operator is used to achieve this goal. Finally, a nearly perfect mapping of urbanized area was finished (Figure 6).

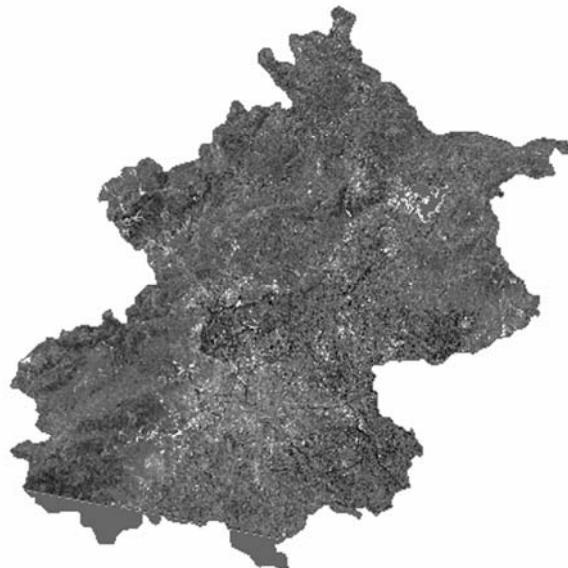


Figure 5. skewness map of ETM+ in Beijing



Figure 6. Urbanized area extracted using skewness

4.2 Classification Result and Accuracy Assessment

Follow the steps in 4.1, based on ETM+ images of Beijing Metropolitan area and DEM data, the urbanized area is extracted. Through visual interpretation, the profile of extracted urban area highly accorded with the real situation.

To compare classification accuracy of different approaches, taking visual interpretation as the true value, 40 patches(22572 pixels) of urbanized area and 40 unurbanized patches (45011 pixels) were selected to generate the confusion matrix:

Approach	Confusion matrix (%)		
		urban	unurban
Skewness texture	urban	73.7	26.3
	unurban	1.9	98.1
Variance texture	urban	64.3	35.7
	unurban	1.8	98.2
Pure spectrum	urban	63.5	36.5
	unurban		

	unurban	1.8	98.2
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Table 1. Comparison of accuracy with different classification approaches

Table 1 shows skewness can effectively improve the classification accuracy compared with traditional approaches. So the use of skewness provides a new way to extract the urbanized area accurately.

5. CONCLUSION

As the fast urbanization occurs in China, setting up a large extent observing system on cities is an urgent task for Chinese government. And ETM+ images from 1999 to 2004 provide an abundant and cheap data resource for such task. Combined with multi-spectral bands, the skewness approach proposed from this paper fully exploits the detail information from band 8, so this is a new way for extensively observing the urban pattern and its change.

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