THE TEXTURAL ANALYSIS AND INTERPRETATION OF HIGH RESOLUTION AIRSAR IMAGES

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Commission II, WG II/2

KEY WORDS: SAR, High resolution, Texture, Analysis, Interpretation, Mapping

ABSTRACT:

This paper goes deep into the airborne SAR (AIRSAR) imagery mechanism, and from the application requirement of surveying and mapping, stresses solving the key technology of AIRSAR application ----- textural analysis and interpretation. Regarding AIRSAR images as experimental data, this paper analyses the texture information of high resolution images through texture analysis methods. An example of AIRSAR image of an area in China and its interpretation from texture is shown that the high resolution imaging radar system designed not only for experimental purposes but also for practical use. This contribution will provide further insights regarding the uses and applications of remote sensing AIRSAR data for topographic mapping purposes.

1. INTRODUCTION

From the end of 20 century to the beginning of 21 century, owing to the great breakthrough of SAR (Synthetic Aperture Radar) technology especially navigation□position location and sensor platform pose control technology, the foreground becomes suddenly clear on applying high-resolution AIRSAR and INSAR technology to topography surveying. The AIRSAR system can attain significantly high resolution through the use of advanced signal processing such as aperture synthesizing and pulse compression. It's of great economic and social significance for SAR with all-weather capturing data to solve image data acquisition with a scale of 1:10000~1:5000 in the difficult districts of aerial photogrammetry, and shorten the basic scales mapping and map updating periods. This paper goes deep into the AIRSAR imagery mechanism, and from the application requirement of surveying and mapping, stresses solving the key technology of AIRSAR application ----- textural analysis and interpretation.

Textural analysis can be especially powerful as an aid in topography mapping. For the image based on texture analysis, the selected texture feature should make some image statistic values such as deviation change obviously after the image texture transformation. There are some classic texture feature description methods such as the deviation texture analysis, Fourier texture description and grey symbiotic matrix feature analysis. We propose to the textural analysis techniques and adapt them to the interpretation of high resolution AIRSAR data. In order to prove the view effect to the texture analysis result of different kind of texture feature images, the statistic data of the AIRSAR images is calculated for the comparison of different texture results of contrast and some other statistic value variation, which can make image interpretation easier. The statistic data such as the grey average, deviation, maximize and minimize grey value and entropy is calculated in different texture feature dimension. An interpretation of radar images can often permit a fuller comprehension of the morphology of the landforms and the nature of the materials that form those landforms when compared with optical datasets. This interpretation is driven by a relationship between surface morphology and composition of particular landform units. An example of AIRSAR image of an area in China and its interpretation from texture is shown that:

1. The images provided by SAR appear quite similar to monochrome aircraft photograph.
2. In addition, SAR can identify objects in a manner different from that of optical sensors, as light and microwaves show different behaviors in scattering and reflection.
3. We confirm the feasibility on the application of high-resolution AIRSAR in the topography of Surveying and Mapping through textural analysis and interpretation.

From all, we can find the high resolution imaging radar system designed not only for experimental purposes but also for practical use. This contribution will provide further insights regarding the uses and applications of remote sensing AIRSAR data for topographic mapping purposes.

2. AIRSAR IMAGES

Figure 1. AIRSAR flight segment

In the experiment, No.38th research institute designed and constructed a high resolution X-band SAR system.

In the following, an outline of the system design is given: the SAR system is configured as one antenna radar with a ground resolution up to 0.5m×0.5m. Figure 1 shows the AIRSAR flight segment.

Due to its compact design, the SAR system can be installed on rather small aircrafts. During the projects mentioned, the system was installed in Y12.

3. TEXTURE ANANLYSIS

3.1 High Resolution AIRSAR Images

High resolution sensor technique has made great process since 1990's. High resolution image can show the object information such as structure, texture and detail clearly. Texture feature is the direct embodiment of the object structure and space arrangement in the image. Recently, resolution of remote sensing image data has been higher, and the tendency has been seen not only for visible sensor images but also for Synthetic Aperture Radar (SAR) images. Textural analysis has also been carried out for SAR. However, it is scarcely discussed that textural features of high resolution AIRSAR images such as river, road and residential area are extracted by texture analysis. In this study, the influences carried by the shadows of residential area, trees and mountain areas that have been considered in high resolution AIRSAR. However, unusual surface patterns are formed clearly due to the fine shadow included the analysis areas using higher resolution images.

3.2 Texture Analysis

Image texture in general is considered the change and repeat of image grey in space, or local pattern (texture cell) in image and its arrange rules. Texture is the important information in remote sensing and significant base of interpretation by manual work and computer. In extracting remote sensing image thematic information, it improves the correction and precise through adding texture information to original image spectral information. Image texture, defined as a function of the spatial variation in pixel intensities (grey values), is useful in a variety of applications and has been a subject of intense study by many researchers. One immediate application of image texture is the recognition of image regions using texture properties.

Applied texture method is to carry out texture analysis. Texture analysis refers to acquire texture character through some image processing technology, then obtains quantitative or qualitative description of texture. It includes two aspects: inspecting basic cells of texture and acquiring the information on basic cells arrange distribution of texture. Statistics-based method, structure-based method and spectrum-based method are put forward (Jiang et al, 2003). Statistic method refers to carrying out texture analysis in the condition of unknown the basic cell of texture, and it mainly describes the basic cell of texture or random and spatial statistic character in local pattern, such as GLCM (Grey Level Co-occurrence Matrices), wave transforms, fractal representation, "visual" properties random field models and other representation. Structural texture analysis focuses primarily on identifying periodicity in texture or on identifying their placement rules.

Texture analysis has been extensively used to classify remotely sensed images. Filtering features and co-occurrence have been compared in several studies, which concluded that co-occurrence features give the best performance. Co-occurrence technique use spatial grey level difference based statistics to extract texture from remote-sensed images.

Rignot and Kwok (Rignot et al, 1990) have analyzed SAR images using texture features computed from gray level co-occurrence matrices. However, they supplement these features with knowledge about the properties of SAR images. Du (Du, 1990) used texture features derived from Gabor filters to segment SAR images. He successfully segmented the SAR images into categories of water, new forming ice, older ice, and multi-year ice. Lee and Philpot (Lee et al, 1990) also used spectral texture features to segment SAR images.

3.3 Grey-level Co-occurrence Matrix

Co-occurrence matrix representation:

1. Method of extracting properties of an image by comparing grey-tone spatial dependencies between pixels;
2. Matrices of the frequencies (probabilities) of going from one gray level to another at a predefined distance and different orientations is derived;
3. 14 Statistical measures of texture can be extracted from the matrix into a feature vector, E.g. Inverse Difference Moment, Energy (Angular Second Moment), Contrast, Correlation, Entropy;

Grey-level co-occurrence matrix is the two dimensional matrix of joint probabilities $P_{d,r}^2(i,j)$ between pairs of pixels, separated by a distance, d, in a given direction, r. It is popular in texture description and based on the repeated occurrence of some grey level configuration in the texture; this configuration varies rapidly with distance in fine textures, slowly in coarse textures.

Finding texture features from gray-level co-occurrence matrix for texture classification in this experiment are based on these criteria (Mihran, 1998):

Energy:

$$\sum_i \sum_j P_{i,j}^2(i,j) \tag{1}$$

Entropy:

$$\sum_i \sum_j P_{d,r}(i,j) \log P_{d,r}(i,j) \tag{2}$$

Contrast: (typically k = 2, l = 1)

$$\sum_i \sum_j |i-j|^k P_{d,r}^\lambda(i,j) \tag{3}$$

Homogeneity:

$$\sum_i \sum_j \frac{P_{d,r}(i,j)}{|i-j|} \quad (4)$$

4. INTERPRETATION

4.1 Radar Image Smoothing

A detailed analysis of the radar image shows that even for a single surface type, important grey level variations may occur between adjacent resolution cells. These variations create a grainy texture, characteristic of radar images. This effect, caused by the coherent radiation used by radar systems, is called speckle. It happens because each resolution cell associated with an extended target contains several scattering centers whose elementary returns, by positive or negative interference, originate light or dark image brightness. This creates a "salt and pepper" appearance.

The homogeneous patches representing the fields have high variability in backscattering due to the speckle noise. This results in a grainy image, which renders difficult the interpretation of the main features of the surface imaged by the SAR. A filer for smoothing noisy radar images is performed.

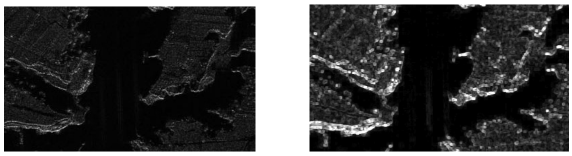
4.2 Extraction of Texture Features

The indistinctiveness and uncertainty of remote sensing data due to multiple factors including random factors, the texture reflected on remote sensing images are not regular and generally do not repeat as cloth patterns. Therefore, texture information only has statistical meaning. Statistical texture analysis method is prevalent now.

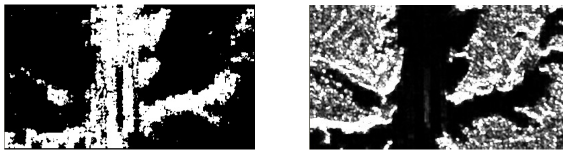
Radar imaging has its own specific characteristics that are quite different from optical and infrared remote sensing. Radar image depends heavily on the scatter of ground objects and its textures sharply vary with different objects. And 14 texture features could be computed from the co-occurrence matrices. By comprehensive analysis and comparison of the 14 texture feature, it is founded that uniformity of energy which is a measure of image homogeneity, variable which reflects a image heterogeneity, entropy which describes the image complexity, are more suitable to identifying the inundated area.

The basic method for water, road and residential area detection is thresholding. A number of threshold levels can be defined to separate various ranges of texture value. We choose the value located at tough point as the threshold from the histogram of texture images. Figure 2 b, c, d respectively represent the water area from the below texture images. It was easily found that the areas shadowed by mountain were mistakenly detected as flooded area. By using the DEM these areas can be automatically detected from the derived images.

Compared with the ground truth, an image interpreted visually from SAR data (shown as the contour line of water bodies). We can find that the main errors distribute in ramification. Of which the result of the extracted water segments using homogeneity feature was best (Yang et al, 1998).

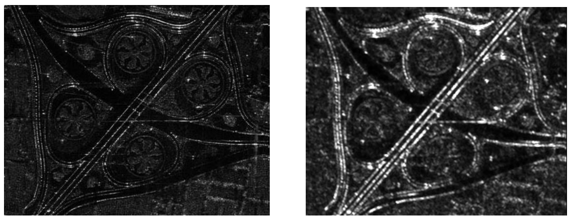


a. Original image b. Using contrast feature

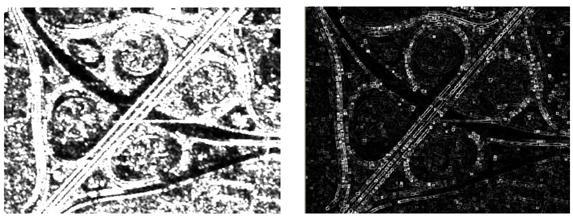


c. Using ST Deviation feature d. Using homogeneity feature

Figure 2. Extraction of water texture feature



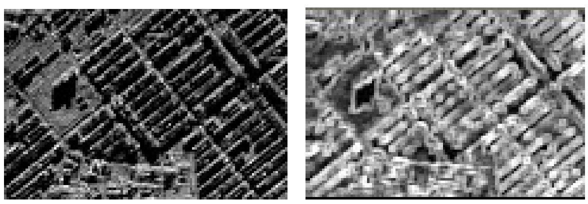
a. Original image b. Using Dissimilarity feature



c. Using contrast feature d. Using Skewness feature

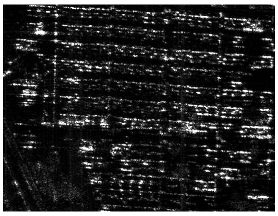
Figure 3. Extraction of road texture feature

Figure 3 b, c, d respectively represent the road area from the above texture images. In general, the combination of using tonal features along with textural features improves the correct extracting rate over using either type of feature alone. But the cement road and river in the SAR images show dark tone. It was easily found that the cement road was mistakenly detected as river. By using the DEM these areas can also be automatically detected from the derived images.

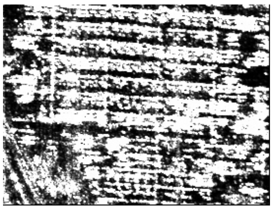


a. Original image b. Using ST Deviation feature

Figure 4. Extraction of residential area texture feature



a. Original image



b. Using contrast feature c. Using Dissimilarity feature

Figure 5. Extraction of residential area texture feature

Figure 4 b and figure 5 b, c respectively represent the residential area from the below texture images. We can use the same texture analysis methods to extract the edge of residential area feature.

4.3 Image Interpretation

Different surface features exhibit different scattering characteristics. From the view of tone, urban areas put up very strong backscatter; forest puts up medium backscatter; calm water puts up smooth surface and low backscatter; rough sea puts up increased backscatter due to wind and current effects.

In the above figure, we can see some mapping elements through the testing AIRSAR data, such as road, water area and residential area.

Figure 6. Mapping element extraction

In figure 6, we make our efforts to take mapping element extraction. Results show that extracting basic mapping element is feasible.

5. CONCLUSIONS

The purpose of this study is twofold: first, to demonstrate the advantages of using AIRSAR data for topographic mapping purposes. Second, to demonstrate the advantages of utilizing the high resolution (0.5-meter) AIRSAR sensor data acquired for surface texture analysis and interpretation purposes. Finally, application of SAR images gives satisfactory results from above experiments.

At present, with the speedy development of China, the timely repairing and updating map, establishing periodically updating geography databases, dynamic monitoring land use change conditions, and deriving various kinds of latest thematic map are the imperative problems. The first important factor that restricts this kind of dynamic monitoring is whether we can provide the practicable, high-resolution, continuously stable and rapidly receiving and useful data sources or not. It is shown that AIRSAR with its full-time and all-weather characteristic becomes optimum remote sensing data sources solving the tradition difficulty district in the topography of Surveying and Mapping.

The various methods for modelling textures and extracting texture features can be applied in four broad categories of problems: texture segmentation, texture classification, texture synthesis, and shape from texture. From the above study, we could perform texture classification through identifying some types of homogeneous regions, and texture segmentation through finding the texture boundaries.

6. ACKNOWLEDGMENTS

The testing AIRSAR image data are provided by 38th institute and CATIC SIWEI.

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