A NEW CLASSIFICATION METHOD USING SPATIAL AND SPECTRAL FEATURES FOR REMOTE SENSING

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ABSTRACT

In this paper a new classification scheme based on spatial and spectral features is introduced. First, using segmentation techniques, a picture is partitioned into disjoint regions that are homogeneous. Then, using the histogram of segments, the spectral intensity corresponding to the peak of the histogram is used as the representative vector of this segment. The classification is made for each segment based on a maximum likelihood classification strategy.

Statistical properties of image segments are analysed and the method for determination of the smoothing parameter is investigated. In order to demonstrate the efficiency of this new scheme, pixel classification is also used. From the experiments, it is demonstrated that the new method can reduce the noise efficiently and improve the classification accuracies greatly.

INTRODUCTION

At present supervised and nonsupervised classification are popularly used in the multispectral remotely sensed images, such as, cluster, maximum likelihood et seq.. Good results have been got in many areas, for example, agricultural and forest areas. These methods only based on spectral features are successful in those images with low spatial resolution.

With the development of remotely sensed technique, much higher resolution sensors have been used, for example, TM image (with 28 meter resolution) and SPOT image (with 20 or 10 meter resolution). In future, even higher resolution sensor would be developed. As the spatial resolution of the sensor becomes higher and higher, image quality is improved and many ground information can be contained. From visual point, the higher the resolution of the image, the more detail and accurate the interplatation. How about the accuracy of the classification for digital image processing on the computer ? Is it same conclusion with the visual interplatation ? Many people are interested in this field. Army Research Center in U.S.A. is one of them and special tests have been done (1) .

In normal opinion, the classification accuracy depends on spatial, spectral and radiometric resolution. In order to study the relationship between classification accuracy and three kinds of resolution, the spatial, spectral and radiometric resolutions of MSS and TM images were simulated using aeroboarder multispectral scanner data and many experiments have been done. The results of this experiment are shown in table 1.

From table 1, it is evident that the best classification result can't be got if only using TM simulation data. The best accuracy is from this image with the combination of spatial resolution of MSS and spectral and radiometric resolutions of TM. This experiment indicated that the accuracy based on pixel classification is not always improved, if spatial resolution of image become higher and higher. In order to improve the classification accuracy of high spatial resolution image, therefore, it is necessary to study the new classification method which not only is based on spectral feature, but also takes account of spatial information and texture characteristics et seq..

In this paper a new classification method based on spectral and spatial features is introduced. First, using segmentation techniques, a picture is partitioned into disjoint regions that are homogeneous. Then, by histogram statistics for each segment, the spectral intensity corresponding to the peak of histogram is used as representative of this segment. The classification is made for each segment based upon a maximum likelihood classification strategy. The new method introduced in this paper can greatly improve the classification accuracy because it takes account of spectral and spatial information.

SEGMENTATION

Segmentation processes are employed in many picture analysis tasks. They provide a means to take into account the spatial information in picture analysis. They can also be used to find atomic regions or primitives, which are the basic constituents of a complex picture description. There are basically two types of approaches to image segmentation, namely, edge detection and region extraction.

In this study, edge detection was used for segmentation. In order to enhance edges, the gradient picture was created using the following gradient type operator:

$$X_g = \left[\sum_{1}^{k} \left\{ (X_{i,j} - X_{i+1,j+1}) + (X_{i,j+1} - X_{i+1,j}) \right\}^2 \right]^{1/2} \qquad (1)$$

where $X_{i,j}$ is the spectral intensity of the pixel in the ith row and jth column, and k is the number of channels.

The gradient picture is then partitioned into segments by using a valley seeking algorithm. Figure 1 is an illustration of the segmentation scheme. For each pixel a search through the 8 immediate neighbors is performed and a directed link is placed to the pixel of lowest gradient value. However, if all neighbors of a pixel have gradient values larger than that at the pixel, then it lies at a local minimum or mode of the gradient and is called a focus. Referring to Figure 1, C is an example of such a pixel. There can never be a directed link originating from a focus. It can be seen that the links form directed trees. The connectivity of the trees can be traced through the links, and pixels belonging to each tree can then be identified and assigned to the segment, which are unimodal in the gradient picture. Since the directed links are always towards lower gradient neighbours, the pixels near the boundary between segments are linked to the respective segment interiors. Thus, the boundaries are formed in the peak of the gradient picture.

To eliminate some of the smaller segments an adaptive smoothing of the gradient value is performed by averaging over a fixed

3 by 3 neighborhood of a pixel, only if the gradient value at the pixel is less than a certain threshold. After smoothing, small valleys are merged and the number of segments is reduced.

There are many objects contained in an image. The difference of gradient value on the boundary between objects is different, some of them are large when the boundary between objects is clear and some of them are small when the boundary between objects is not so clear. For segmentation of remotely sensed images with high spatial resolution one smoothing parameter is not enough. If the smoothing parameter selected is suitable to those boundaries with great difference of gradient value, those boundaries with small difference of gradient value will be missing. On the contrary, if the smoothing parameter selected is suitable to those boundaries with small one, the image area surrounder by boundary with great one will be partitioned into very small region. This contradiction can't be avoided during the processing of TM and SPOT images. For this reason, for segmentation processing of high spatial resolution image, several smoothing parameters based on image feature should be used.

How to determine the smoothing parameter ? The following mean is used in the experiment.First segmentation is processed using one primary smoothing parameter based on the experience. Then, pixel number contained in each segment is calculated. Usually the large segments are necessary to partition into small one, but the small one is not necessary to split it again.

Therefore, the smoothing parameter is related to pixel number of the segments. After first segmentation the pixel number of the large one needes to display on terminal or print out. According to the size of segments, three smoothing parameters which are smaller than primary one selected and input into the computer with the pixel number which will control what smoothing parameter is needed for the segmentation further. For large size segments it is necessary to partition into small region with corresponding smoothing parameter based on the size. After second segmentation the boundaries of segments are drawn and displayed on the screen. Comparing with the image it can be determined that the smoothing parameter is suitable or not. If the smoothing parameter is not suitable, it is necessary to change it until satisfactory.

In this experiment the primary parameter for first segmentation is 7, three modificatory parameters for second segmentation are 40 percent of the primary one if segment size is over 5000 pixels, 70 percent of the primary one if segment size is from 1000 to 5000 pixels, 90 percent of the primary one if segment size is from 500 to 1000 pixels. The result of the segmentation is shown in figure 3. Total segments are 2006 pieces for SPOT image with 256x256 pixels.

STATISTICAL PROPERTIES OF THE IMAGE SEGMENTS

The resulting segments are then used for classification. As the accuracies of classification depend upon the characteristics of the segments found, therefore it is first necessary to investigate the properties of these segments. This investigation involves two aspects, the size and number of segments, and the distribution of pixels in the spectral space. The size and number of segments depends upon the ground features and the smoothing parameter. The more complex the ground features, the more the number of segments. The larger the smoothing parameter, the less the number of segments.

Figure 2 shows the results of an investigation. The X-axis represents percent of total number of segments ordered by size, and the Y-axis represents the corresponding area of these segments in percentage of total area. The results for different smoothing parameters are shown.

The main characteristics to be seen from figure 2 are:
--- 90% of the area is accounted for by less than 50% of the segments.
--- Only 30% of the segments are of relatively large size.
--- 50% of the segments have only a few pixels.

For the large segments we can ask the following two questions: What is the distribution of the pixels in the spectral space ? Is it statistically homogeneous ?

In order to investigate the properties of the distribution of the pixels for the large segments, the one-dimensional histogram of the segment for each channel is made. From the histogram it is shown that most of the points of segment are concentrated in a central cluster, with some points deviating from the cluster. In some segments the deviation is not large and is nearly symmetrical with respect to this cluster. However, in some segments the deviation from the cluster is large and is asymmetrical.

THE METHOD OF CLASSIFICATION

From the analysis of the properties of segments in the previous section there are two kinds of segments, large ones and small ones. For large segments, the histogram usually contains a cluster of pixels, with some outlying pixels.

A new method of classification based on segmentation is now presented and is shown in the form of a flow chart in Figure 4. At first a gradient picture is calculated according to Equation (1), then, using segmentation techniques with dynamic smoothing parameter, the gradient picture is partitioned into different segments. For large size segments, the histogram is calculated and the spectral intensity M_2 corresponding to the peak of the histogram is used as the representative vector of this segment. For small size segments, which have only a few pixels, there is no alternative and the mean value M_1 is calculated from all pixels. The M_1 or M_2 corresponding, respectively, to small segments and large segments, is now considered as the representative vector of the segments. A classification based on maximum likelihood classification strategy is used for each segment. The formula for the likelihood decision is

$$p(M/k) = - \ln(2\pi|\Sigma_k|) - (X-\mu_k)^T \Sigma_k^{-1} (X-\mu_k) \qquad (3)$$

where p(M/k) is the probability of observing M given that M is from class k; M is the mean value of the small segment or the spectral intensity corresponding to the peak of the histogram for the large segment; μ_k is the mean vector of class k; Σ_k^{-1} is the inverse of covariance matrix of class k; $|\Sigma_k|$ is the determinant of Σ_k.

The segment is assigned to the class of highest probability.

In order to compare the accuracies, the maximum likelihood classifications are also used.

THE RESULTS OF EXPERIMENTATION AND ANALYSIS

The test site is an agricltural area at Nanpi County, Hebei Province, imaged by SPOT on May 14, 1986. During this time the main crop is wheat. In this area the soil with saline-alkali soil is pool. According the ground feature in this area eight classes have been selected, namely, wheat, elm, sweet-scented osmanthus, sand soil, light saline-alkali soil, heavy saline-alkali soil, fruit area and residential area. Among them wheat, saline-alkali soil, sand soil occupy the major portion.

The training sample of eight classes can be determined, based on the ground truth collected from the investigation and topographic map. The gray value of the training sample for each class on the image can be taken and mean value, inverse of covariance matrix and determinant for each class are calculated. In order to examine the pureness of the training sample the histogram of the training sample for each class should be made. Usually most of the points of training sample are concentrated in a central cluster with some points deviating from this cluster. These points deviating from cluster should be excluded when statistic data represented this class is estimated. In this tests five training samples are purged.

In order to demonstrate the efficiency of this new scheme pixel classification is also used. For two methods the training sample is same, but the results of classification are different and shown in Figure 5. For pixel classification the result was considerable noise, but for new method the noise was elimilated. The classification accuracy of the new method also was better than pixel classification. For example, for the pixel classification residential area and the land with light salinization of soil appear scattered distribution and part of the wheat was misclassified as fruit area and sweet-scented osmanthus, but for the new method the misclassification in the pixel classification was correctly classified. From experiments, it is evident that for new method the classification noise is reduced and classification accuracy was improved, so it is better than the pixel classification.

CONCLUSION

As the high resolution image taken from satellite, such as TM and SPOT, has been obtained, most people are interested in the classification accuracy of them. From experiment it is demonstrated that the classification accuracy based on digital image processing relates not only to image resolution, but also to classification methods. For pixel classification which is only based on the spectral feature the results appear evidently noise and the accuracies of some classes are reduced. It is also shown that the higher the resolution of the image, the larger the noise and the less stable the classification accuracy. Therefore, for high resolution image the pixel classification method which is commonly used does not satisfy the classification demand. It is necessary to improve the classification method further.

In this paper a new classification method based on spatial and spectral feature is introduced. Because the segmentation technique is used in this method, the accuracies of the classification are also based on the characteristics of segments. For this reason, properties of segments are first investigated. From the investigation, it is found that the size of segments depends on the choice of the smoothing parameter, ground features and image enhancement. It is also found that in the one dimensional histogram most of the pixels of a segment are concentrated in a cluster with some pixels deviating from this cluster. The deviation of some pixels in certain segments is large and asymmetrical.

For the segmentation of high resolution image one smoothing parameter is not enough to detemine the suitable edge. If using one smoothing parameter it is difficult to solve the problem between the strong edge and weak edge. Therefore, it is necessary to use dynamic smoothing parameter. According to ground feature different smoothing parameters are used. From the experiment three or four parameters are enough for SPOT image and suitable segments can be got.

From comparison of results between the new method and the pixel classification, for new method the classification noise is largely reduced and the classification accuracies are effectively improved. Therefore, the new method based on spatial and spectral feature is better than pixel classification method.

Image segmentation is a important technique to form spatial feature . From experiments this technique has great potentialities to improve the classification accuracies for the remotely sensed image with high resolution. Therefore, it is necessary to study this technique further and some practical methods. Image segmentation is not only useful to study spatial features, but also helpful to study the texture of image. For the future the spatial, spectral feature and texture should be concerned for the classification of remotely sensed data. It is predicted that the classification accuracies for high resolution image can be greatly improved and application area can be extended if classification methods are being perfected.

REFERENCES

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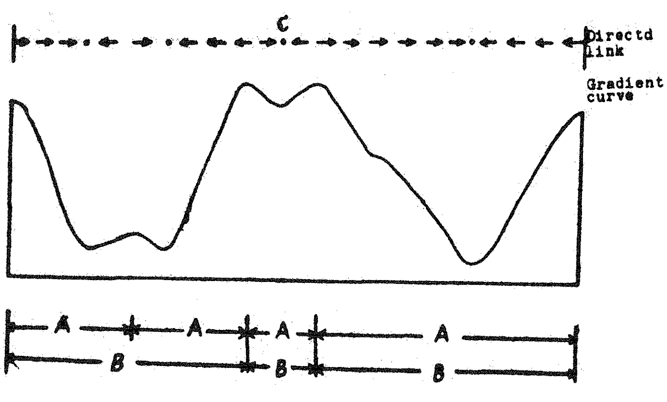


Figure 1, Illustration of segmentation principle used in this study

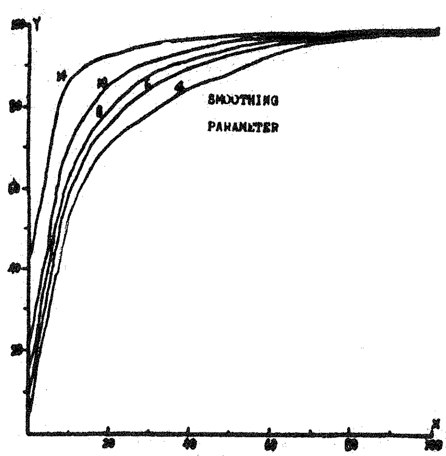


Figure 2, The relationship between segments and smoothing parameter

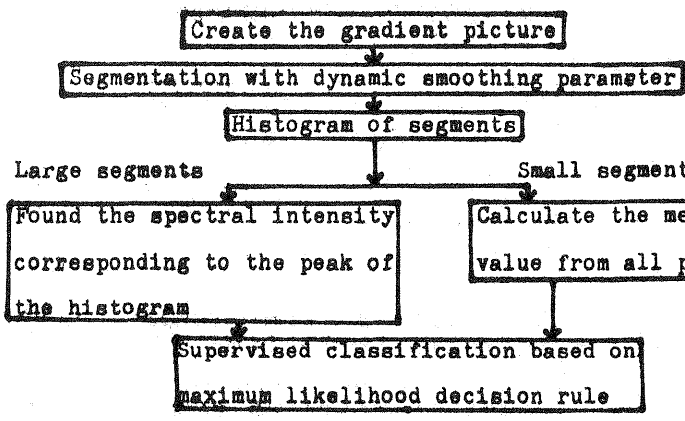


Figure 4, the flow chart for the new classification method

Table 1, Spatial, spectral and radiometric resolutions affect classification accuracy

spatial	radiometric	spectral	II/III total accuracy	I different class accuracy					I total accuracy
				agriculture	forest	water	urban	grass	
TM	TM	TM	71.9	98.4	100.0	81.4	90.0	98.9	93.7
TM	TM	MSS	65.0	97.0	99.9	98.4	75.7	95.7	93.4
TM	MSS	TM	71.9	97.3	100.0	39.5	86.4	98.0	84.2
TM	MSS	MSS	57.1	93.9	99.5	39.3	72.5	93.9	79.8
MSS	TM	TM	89.9	97.4	100.0	100.0	99.0	99.4	99.2
MSS	TM	MSS	79.4	97.8	100.0	34.0	94.2	98.4	84.9
MSS	MSS	TM	84.3	97.9	95.9	34.0	97.9	99.4	85.0
MSS	MSS	MSS	69.6	94.2	100.0	34.0	88.7	93.0	82.0

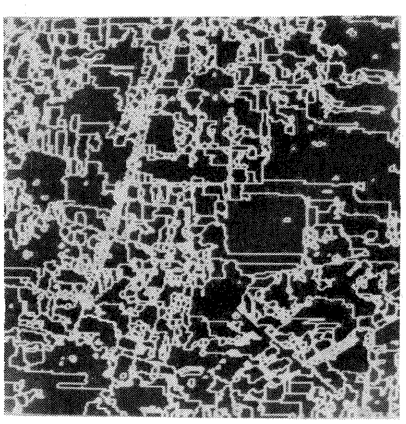
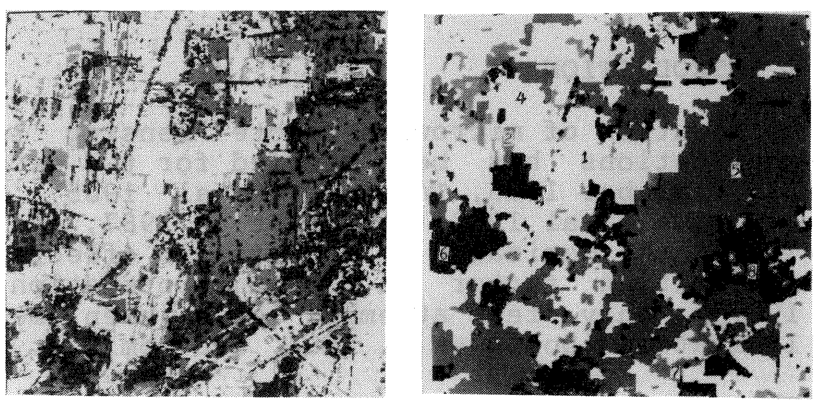


Figure 3, The result of segmentation for a spot image



The result of pixel classification The result of new method

1.Wheat 2.Elm 3.Sweet-scented osmanthus 4.Sand soil 5.Light saline-alkali soil 6.Heavy saline-alkali soil 7.Fruit area 8.Residential area

Figure 5, The classification results for two methods