Crop Field Extraction Method using NDVI and Texture from Landsat TM Images

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Abstract : Land cover and land use classification on a huge scale, e.g. national or continental scale, has become more and more important because environmental researches need land cover and land use data on such scales. We developed a crop field extraction method, which is one of the steps in our land cover classification system for a huge area. Firstly, a crop field model is defined to characterize "crop field" in terms of NDVI value and textual information. Textual information is represented by the density of straight lines which are extracted by wavelet transform. Secondly, candidates of NDVI threshold value are determined by "scale-space filtering" method. The most appropriate threshold value among the candidates is determined by evaluating the line density of the area extracted by the threshold value. Finally, the crop field is extracted by applying level slicing to Landsat TM image with the threshold value determined above. The experiment demonstrates that the extracted area by this method coincides very well with the one extracted by visual interpretation.

1. Background

In recent years, there have been more and more researches which focus on land cover and land use classification on national or continental scale to predict future environmental situation. Such an attention to land cover and use classification on a huge scale is originated from the recognition that land cover and use change is one of the most important factors affecting global environment and as a result global resource base for the continuous human habitation on the Earth.

In fact, implementation of classification methods using satellite imagery reveals major trade-off relationships; accuracy and efficiency. Accurate classification requires not only spectrum information of each pixel but textural information around each pixel, at least. Interpretation of textural information is very "context" dependent and so require visual interpretation by experts. Our final goal is to develop a land cover and use classification system for large areas with sufficient efficiency and accuracy, which utilizes AVHRR and Landsat TM images. As one step of the classification system development, a sub-system to extract crop fields is targeted in this paper.

Physical pattern of crop fields deeply depends on its regional agricultural practice resulting in the cultivation pattern which looks different seasonally. Therefore we propose a crop field extraction system to extract crop fields with the following characteristics or conditions, using both spectral and textural information.

1) South East Asia is supposed to be a target area. It is assumed that potential vegetation is forest and existing forest is extracted out before applying the crop field extraction system. Remaining land cover and land use classes are assumed to be grassland, barren land, paddy fields, crop fields, urban areas and so on.
2) Crop fields with cultivation pattern visually recognizable are targeted. Though we recognize the importance of a system or method to extract crop fields without clear cultivation pattern, we put priority on the system that can provide reliable information through satellite images.

2. Crop field extraction system

Crop fields to be extracted by the proposed method are defined as a crop field model below.

1) They have clear spatial cultivation pattern which is characterized by relative clear and straight lines.
2) They have a mixture of relatively high NDVI values (vegetative cover) and low NDVI values

representing bare soil etc. even in dry season.

3) Some portions of crop fields may not show clear cultivation patterns. But, such areas with unclear cultivation patterns are relatively minor and/or close to ones with clear cultivation patterns.

We assume Landsat TM imagery is observed during dry season.

In order to decrease spatial variations or heterogeneity of NDVI values, at first, spatially averaged NDVI image is generated from an original one. Then, scale-space filtering [1][2][3] is applied to the histogram of the "blurred" image to detect some candidates of threshold NDVI values, one of which can distinguish crop fields effectively.

On the other hand, as spatial textural information, crop field boundaries are represented as consecutive

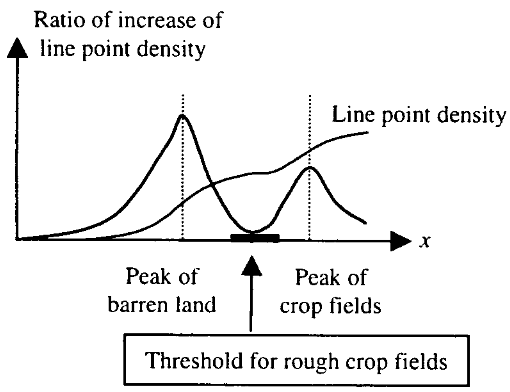


Figure 1 Determining threshold value in discriminating crop fields

and relatively straight edges. Edges are detected from an original NDVI image by Wavelet transform [3][4][5] and only spatially consecutive straight edges (defined as a line) are extracted among detected edges. Line point density is calculated by dividing line points by areas that are extracted by using threshold NDVI value x. According to the crop field model, crop fields have both high NDVI value and line point density value. The most appropriate threshold can be determined among candidates by comparing ratio of increase of line point density as shown in Fig.1. The procedure is below.

1) Each threshold candidate is selected and applied for extraction of areas through level slicing.

2) The line point density is calculated which is included in the area extracted through level slicing. And ratio of increase of its line point density is also calculated.

3) The threshold is automatically determined as the most appropriate one, which show the highest NDVI among ones showing low ratio of increase of line point density.

After determining the threshold, regions are extracted from the blurred image through level slicing. Extremely small regions are excluded. Considering the regions which are not crop fields but show high NDVI (most of which are forest), the regions showing extremely low line point density are also excluded. Thus, crop fields are determined, finally.

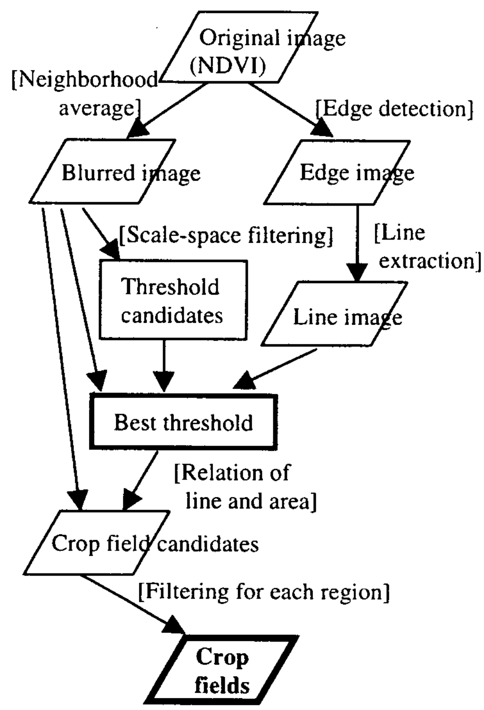


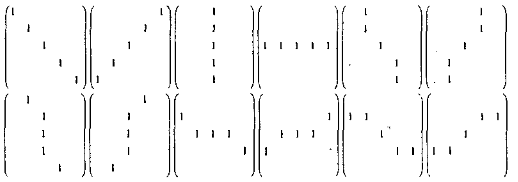
Figure 2 Crop field extraction system

3. Experiments & Results

Landsat TM NDVI image (path 129, row 49, observed date 1989. Jan. 20) was used for the experiment. NDVI value was transformed into 0-255 because thresholds in scale-space filtering could be easily applied. Test area 1 and 2 with the sized 500 line by 500 pixel, located in the northern part of Thailand, include mainly crop fields (sugarcane, cassava and etc.), grassland, barren land, paddy fields and so on. Test area 1 is shown in Figure 3.

The NDVI image was blurred by gaussian function with the width parameter S=10 (pixel), because the average size of crop field unit in this area is more than several hectares. Scale-space filtering is applied to a histogram of NDVI values of the Landsat TM image. By changing scale parameter s from 20 to 5, the detailedness of the histogram changes from low to high. x_i (i=1,m) satisfying $\frac{df}{dx}=0$ (where $f(x)$ is the histogram generated by scale-space filtering with sacle parameter "s") are used as candidates of threshold values. Trajectory of x_i with changing scale parameter "s" is shown in Figure 4.

As for a textural information, firstly edges were detected by Wavelet transform using gaussian function as its mother wavelet. Then, lines were extracted by checking consecutive edges through spatial template as below.



The ratio of the number of line points to crop field area (line point density), was examined by using each threshold candidate in order to determine the most appropriate threshold among candidates selected through scale-space filtering (Figure 5). In determining the "optimal" threshold value, the scale parameter of scale-space filtering is set to be 5. A threshold value among the candidates in Figure 2 is selected as the "optimal" threshold value if the change rate of line point density at the threshold value is minimal. Finally, crop fields are extracted by applying the optimal threshold for the blurred image (Figure 6).

The extracted crop fields were validated by comparison of its total area with the area by visual interpretation in Table 1. Finally, test area 3 with crop fields (2000 line, 2000 pixel) and its extracted image are shown in Figure 7 and 8.

Table 1 Extraction ratio of crop fields

	Visually interpreted area	Extracted area	Extraction ratio
Area 1	94246	88162	93.5%
Area 2	117547	95795	81.4%

(Area is counted by the pixel: 1 pixel =$30 \times 30\,m^2$)

4. Discussion

The extraction ratio in test area 1 and 2 are high (as in Table 1) and the extracted image (Figure 6) seems to be much close to the original image (Figure 3). The common characteristics among misclassified crop fields are that their NDVI are not so high and that they are isolated. In our research, we developed the crop field extraction system based on the crop field model, defined in chapter 2. If the crop fields which the model like those isolated without clear boundaries, it was found that they cannot be extracted. Nevertheless, extraction ratio is rather high and extracted crop field looks rather close to those extracted through visual interpretation. It is demonstrated crop fields involved in the crop field model are automatically extracted with rather high accuracy.

5. Conclusions

We proposed a crop field extraction system. At first, "crop field model" is defined to clarify the boundary conditions and limitations of the extraction method. Under the assumed crop field model, threshold values of NDVI and textural index can be determined automatically through several parameters like a scale parameter should be set up in advance. Experiments showed that the classification accuracy of crop fields is rather good. By integrating this system with a method of classifying vegetation like forest, we expect land use and land cover data covering large areas can be developed.

References

[1] K. Xin, K. B. Lim and G. S. Hong, "A Scale-space Filtering Approach For Visual Feature Extraction", *Patt. Recogn.*, vol. 28, pp. 1145-1158, 1995

[2] S. C. Pei, C. C. Tseng, and C. Y. Lin, "Wavelet Transform and Scale Space Filtering of Fractal Images", *IEEE Trans. Image Processing*, vol. 4, pp. 683-692, May 1995

[3] S. Mallat, "Zero-crossings of a Wavelet Transform" *IEEE Trans. Info. Theory*, vol. 37, pp. 1019-1033, Jul. 1991

Figure 3 NDVI for Test area 1 (500 line, 500 pixel)

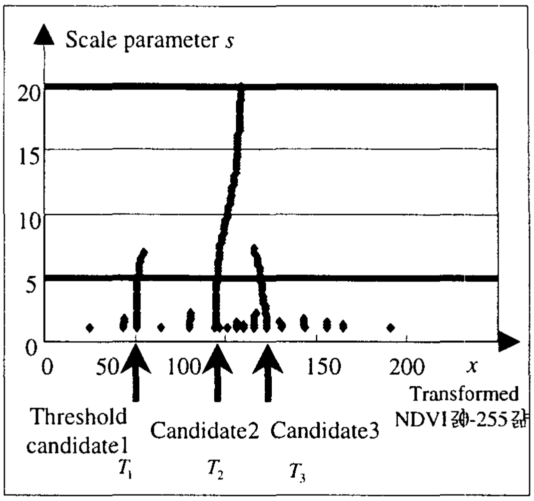


Figure 4 Scale-space for test area 1

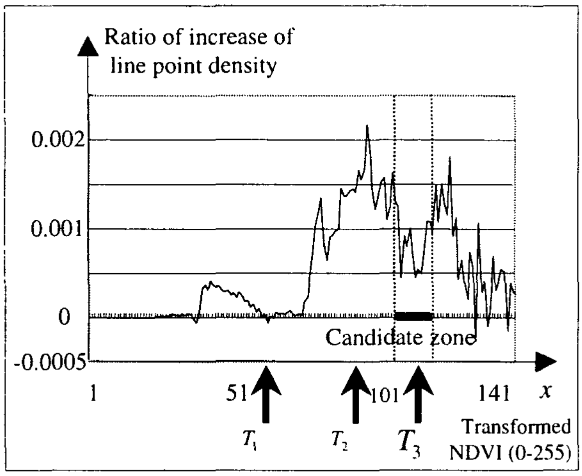


Figure 5 Ratio of increase of
line point density for test area 1

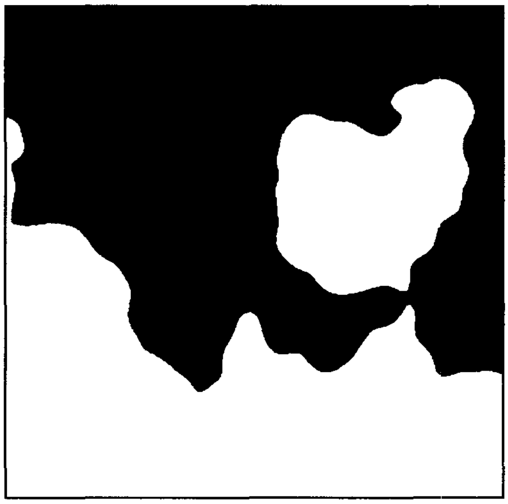


Figure 6 Crop field extraction result
for test area 1

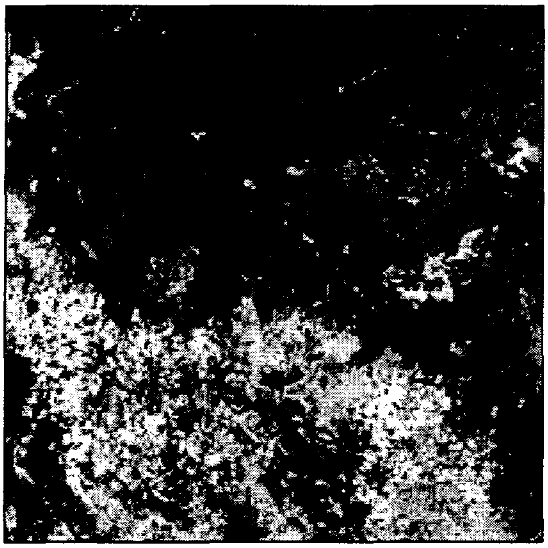


Figure 7 NDVI for Test area 3 (2000 line, 2000 pixel)

Figure 8 Crop field extraction result for test area 3