THE FILTER COEFFICIENTS OF THE NEIGHBORHOOD PIXELS FOR ESTIMATION OF THE MIXED PIXELS WITH MULTI-TEMPORAL SATELLITE DATA

Seiji Ito[1] and Yoshinari Oguro[2]

[1]Assistant Professor, Department of Global Environment Studies, Hiroshima Institute of Technology,
2-1-1 Miyake, Saeki-ku, Hiroshima, Japan; Tel: +81-82-921-7424
Email: seiji@cc.it-hiroshima.ac.jp

[2] Professor, Department of Global Environment Studies, Hiroshima Institute of Technology,
2-1-1 Miyake, Saeki-ku, Hiroshima, Japan; Tel: +81-82-921-9407
E-mail: y.oguro.yx@it-hiroshima.ac.jp

KEY WORDS: Landsat-7 ETM+, Mixed pixel estimation, Nonlinear model, Filter of the neighborhood pixels.

ABSTRACT: In this paper, the estimation method of the mixed pixel has been proposed. A mixed pixel includes the multiple categories (Vegetation, Non-vegetation) and the aim of this study is to estimate the mixture ratios of the two categories. The filter coefficients of neighborhood pixels had been proposed. In this paper, the optimal filter coefficients have been considered in detail. The optimal filter coefficients have been considered with two simulations. We had suggested that the influence of a target pixel is spherically affected by neighborhood pixels from a property of a uniform diffuse reflection, and the optimal quantity of the filter coefficients is 2.0 of the sum of the filter coefficients by the two simulations.

1. INTRODUCTION

Recently, the land cover data have been classified in detail by high resolution remotely sensed images, but even today it is necessary to analyze the middle or low resolution images (Fujiwara 1996, Hayashi 1997). Since the high resolution images are high in cost, and difficult to analyze by the noises as the shadows of the buildings and the small objects. Moreover, previous high resolution images don't exist when we analyze the secular change of the land cover. The several papers for the conventional methods reported that the errors of land cover classification have been generated around the edge of categories especially. A mixed pixel which includes the multiple categories is one of the error factors. All remotely sensed images include the mixed pixels, particularly the middle or low resolution images include the more mixed pixels. If the mixed pixel is forcibly classified into the category, the miss classifications are increased since the information of the multiple categories is included in the pixel. The estimation of mixture ratios on the mixed pixel is necessary to reduce the errors.

The several papers had proposed mixed pixels estimation methods (Chen 2009, Kawaguchi 2006, Kageyama 2003, Ito 2009). The nonlinear model and the filter of the neighborhood pixels had been proposed (Ito 2011). However, the filter coefficients had not been considered. The aim of this paper has been considered about the optimal filter coefficients.

2. THE PROPOSED METHOD

2.1 The mixed pixel model

Mixed pixels include the components of the multiple categories. There are many mixed pixels around the edges of categories. N is the number of category, a_k is mixture ratio of the category k, the mixed pixel of band i ($I(i)$) is given as follows:

$$I(i) = \sum_{k=1}^{N} a_k I_k(i) \tag{1}$$

where, $I_k(i)$ is the representative value of category k on band i. In this paper, we treat two categories (N=2); "Vegetation" and "Non-vegetation". In this case, the mixed pixel model of Eq.(1) is replaced as

$$I(i) = a_v I_v(i) + a_n I_n(i) + a_0 \tag{2}$$

where, a_v and a_n are the mixture ratio of the "Vegetation" and "Non-vegetation" respectively, a_0 is a bias value and $I_v(i)$ and $I_n(i)$ are the representative values of the each category on band i respectively. The aim of this paper is

			F			
	E	D	C	D	E	
	D	B	A	B	D	
F	C	A		A	C	F
	D	B	A	B	D	
	E	D	C	D	E	
			F			

Fig.1 The filter of neighborhood pixels

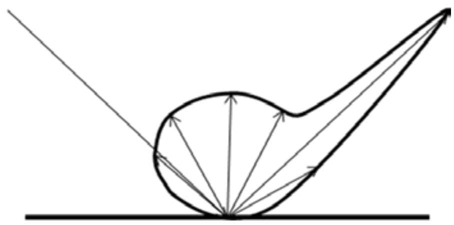


Fig.2 A spatial distribution of radiant intensity.

replaced to the estimation of a_v and a_n from Eq.(2). The mixed pixel model has to be considered about the several objects reflection in a pixel. Eq.(2) means that reflection in a pixel are simply added of the two different object reflection, but the overlap of several reflections is complex. The nonlinear model had been proposed as this equation:

$$I(i) = a_v I_v(i) + a_n I_n(i) + a_{vn} I_v(i) I_n(i) + a_0 \qquad \textbf{(3)}$$

where, a_{vn} the nonlinear term coefficient. $a_{vn} I_v(i) I_n(i)$ is considered interaction of the two objects reflection. Other nonlinear terms are considered; indirectly reflection by atmosphere or cloud, multiple reflection between two objects or atmosphere. In this paper, we select only this nonlinear term, since the mixture ratios cannot be estimated by the several terms mathematically.

In order to estimate a_v, a_n and a_{vn}, “Vegetation” has been regarded as the mixture of “Forest” and “Grass”, “Non-vegetation” has been regarded as the mixture of “Building”, “Soil” and “Water”. $I_v(i)$ and $I_n(i)$ have been calculated from the mixture ratio every 5 percent. The mixture ratios of a_v and a_n have been estimated from $I_v(i)$ and $I_n(i)$ by the method of least squares. If the mixture ratio takes more than 100% or less than 0%, then the mixture ratio has been trimmed into 100% or 0% respectively.

2.2 The filter of the neighborhood pixels

The mixture ratios that have been estimated using the mixed pixel model are modified using the neighborhood pixels filter. In the case of Landsat-7 ETM+, the filter size is 7 x 7 pixels, since object reflection has an effect until 90m in the (Y. Kawata, 2000). Modification quantity e_v, e_n are follows:

$$e_v = \sum_{(p,q)}^{N} \alpha^{(p,q)} \left(a_v - a_v^{(p,q)} \right)$$
$$e_n = \sum_{(p,q)}^{N} \alpha^{(p,q)} \left(a_n - a_n^{(p,q)} \right) \qquad (4)$$

where, (p,q) is the neighborhood pixel, N is the number of neighborhood pixels, $a_v^{(p,q)}, a_n^{(p,q)}$ are mixture ratios of “Vegetation” and “Non-vegetation” respectively. $\alpha^{(p,q)}$ is the filter coefficients of (p,q), and the filter coefficients are concern with the Euclidian distance from target pixels as Fig.1. The mixture ratios are corrected by following equations:

$$e_v^{new} = a_v^{old} + e_v$$
$$e_n^{new} = a_n^{old} + e_n \qquad (5)$$

If the mixture ratio takes more than 100% or less than 0%, then the mixture ratio has been trimmed into 100% or 0% respectively.

Reflection intensity distribution is explained for consideration about the filter correlations of neighborhood pixel. An object has properties both of a mirror reflection and a uniform diffuse reflection surfaces (see Fig.2). A target pixel is spherically affected by neighborhood pixels by a property of a uniform diffuse reflection. However, it is difficult to study in theory the quantity of the reflection intensity by the observation conditions (e.g. weather, angles of object surface).

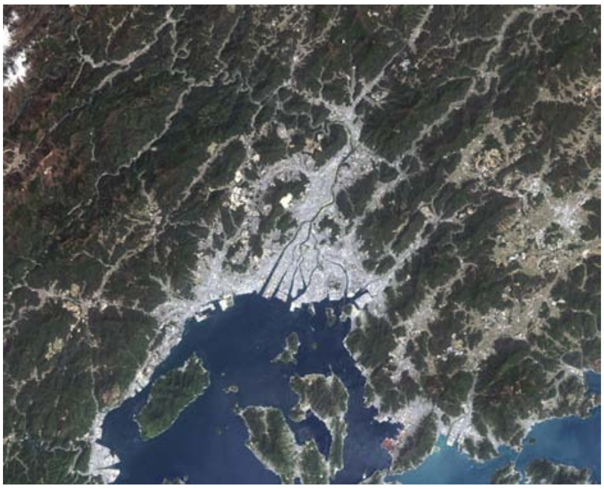


Fig.3 Landsat-7 ETM+ image (2003.4.10. Hiroshima)

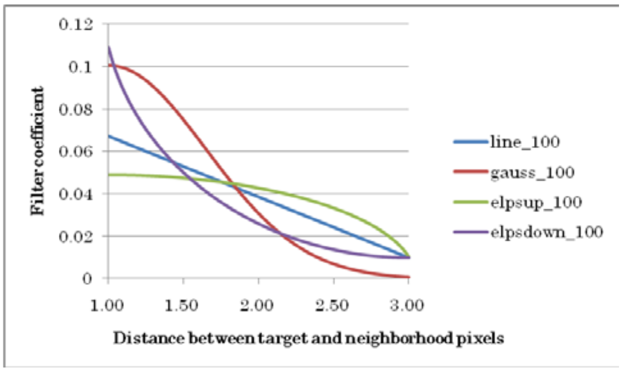
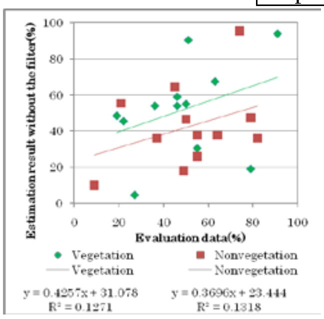


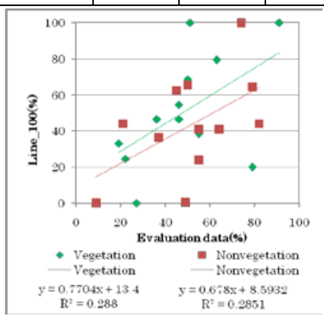
Fig.4 Filter coefficients (four patterns)

Table 1. Filter coefficients of the Simulation 1

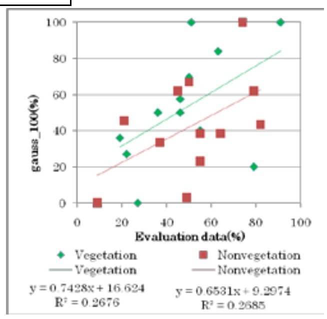
	A	B	C	D	E	F
Line_100	6.7	5.5	3.9	3.2	1.5	1.0
Gauss_100	10.1	8.2	3.1	1.6	0.2	0.1
Elpsup_100	4.9	4.8	4.3	3.9	2.1	1.0
Elpsdown_100	10.9	5.6	2.6	1.9	1.4	1.0



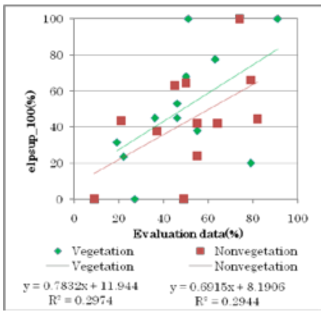
(a) Without the filter



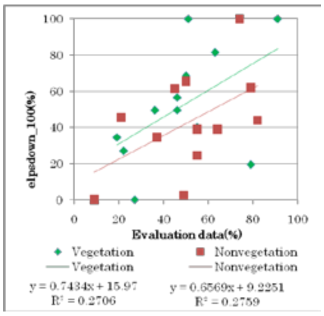
(b) Line_100



(c) Gauss_100



(d) Elpsup_100



(e) Elpsdown_100

Fig. 5 The results of the Simulation 1

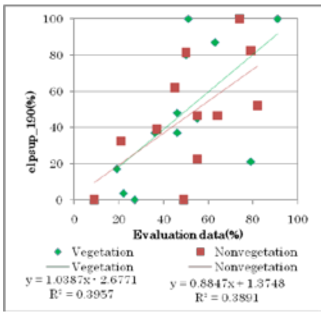
3. SIMULATION

3.1 Simulation condition

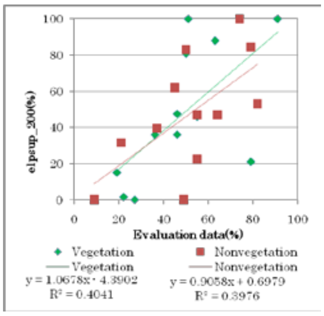
In order to show the effectiveness of the proposed method, the method has been simulated using Fig.3. Fig.3 is around the Hiroshima city in Japan observed by Landsat-7 ETM+ on April 10th in 2003. Around Hiroshima city has several rivers, and is an area adjacent to sea and mountains. Pixel size of Fig.3 is 1600 x 2000 pixels. Evaluation pixels have been selected around Hiroshima Nishi Airport and Sanyo Express way that are less long-term change. Mixture ratios in the evaluation pixel have been obtained by using high resolution images (QuickBird-2 images) on Google Earth. Quantitative evaluations have been regarded as a correlation coefficient and gradient of regression line on a correlation diagram of evaluation data and simulation results.

Table 2. Filter coefficients of the Simulation 2

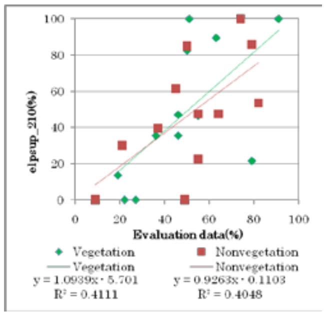
	A	B	C	D	E	F
Elpsup_190	9.3	9.1	8.1	7.4	4.2	1.9
Elpsup_200	9.8	9.6	8.5	7.8	4.4	2.0
Elpsup_210	10.3	10.1	9.0	8.2	4.6	2.1
Elpsup_250	12.3	12.0	10.7	9.8	5.5	2.6
Elpsup_300	14.7	14.4	12.8	11.7	6.5	3.1



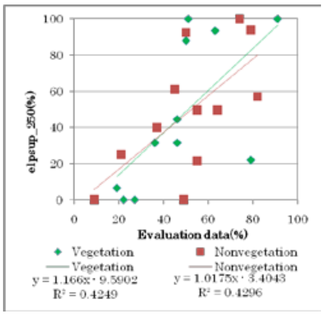
(a) 1.9



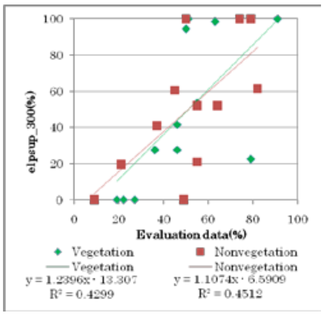
(b) 2.0



(c) 2.1



(d) 2.5



(e) 3.0

Fig. 6 The results of the Simulation 2 (The numbers are described the sums of the filters' coefficients)

3.2 Simulation 1: A consideration about decrease with distance from a target pixel

We have simulated the four patterns filters (Fig.4) about the quantities of the filter coefficients; Gauss, Line, Elpsup (ellipse upper) and Elpsdown (ellipse down) types. Elpsup type is expected to be obtained the best result from Section 2.2. Filter coefficients of the four patterns are shown in Table1. Where, a suffix number of the type name is sum of filter coefficients. In the case of "Line_100", it means Line type and one to one relation between target pixel and neighborhood pixels. Fig.5 shows the correlation diagrams of five simulations (four types filters and without the filter). "Elpsup_100" is the best result in the five simulations, since the correlation coefficients of "Elpsup_100" are the highest and the regression lines' gradients of "Elpsup_100" is the nearest to 1 from Fig.5. Therefore, it confirms that filter coefficients decrease spherically with distance from the target pixel.

3.3 Simulation 2: A consideration about quantities of the filter coefficients

In the Simulation 2, we have considered about quantities of the filter coefficients. It is considered that degree of the influence from the neighborhood pixels is equal to sum of the filter coefficients. The optimal filter coefficients are decided from the five filters in Table 2. The sums of the filters' coefficients are 1.9, 2.0, 2.1, 2.5 and 3.0 respectively. The correlation diagrams of the five filters are shown in Fig.6. The higher sum of the filter coefficients is, the higher the correlation coefficient is obtained from Fig.6. In the case of high sum of the coefficients, however, 0% or 100% of the mixture ratios are increase and the scatter graph likes the step function with the threshold of 50%. In a gradient of the regression line, the result of "elpsup_200" is the nearest to 1 from Fig.6. Therefore the optimal sum of the filter coefficient is 2.0.

4. Conclusion

In this paper, the mixed pixel estimation method with the nonlinear model and the filter of the neighborhood pixel had been proposed. The optimal filter coefficients have been considered with two simulations. We had suggested that the influence of a target pixel was spherically affected by neighborhood pixels from a property of a uniform diffuse reflection by Simulation 1, and the optimal quantity of the filter coefficients was 2.0 of the sum of the filter coefficients by Simulation 2.

As the future work, we will propose the robust filter coefficients on the other season or the other area.

Bibliography

N. Fujiwara, 1996. Pattern Expand Method for Satellite Data Analysis, Journal of RSSJ, 16(3), pp.17-34 (in Japanese)

A. Hayashi, 1997. Analysis of Paddy Fields Using Pattern Expand Method, Journal of RSSJ, 17(2), pp.5-18 (in Japanese)

J. Chen, 2009. Generalization of Subpixel Analysis for Hyperspectral Data With Flexibility in Spectral Similarity Measures, IEEE transactions on geoscience and remote sensing, 47(7), pp.2165-2171

S. Kawaguchi, 2006. Unsupervised Contextual Classification of Remotely Sensed Imagery by Taking Mixel Information into Account, Journal of RSSJ, 26(2), pp107-116 (in Japanese).

Y. Kageyama 2003. Lineament Detection due to Land Cover Information in Mixel Using Landsat TM Data, IEEJ Trans. EIS, 123(6), pp.1086-1093 (in Japanese).

S. Ito, 2009. A High Speed Mixel Estimation Method by Using the Genetic Algorithm, Proc. of IIHMSP, pp.742-745.

S. Ito, 2011. The Mixed Pixels Estimation for the Remotely Sensed Images Using the Nonlinear Model and the Filter of Neighborhood Pixels, IEEJ Electronics, Information and Systems, 131(6), pp.1233-1240 (in Japanese).

Y. Kawata, 2000, Atmospheric Correction on Satellite Image Data Over Land, Journal of RSSJ, 20(5), pp.2-12 (in Japanese) .