ADAPTIVE CONTRAST STRETCHING METHOD FOR VISUAL ENHANCEMENT OF MODIS IMAGE DISPLAY

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ABSTRACT: Main daily MODIS images are affected by heavy cloud. Because of high pixel value of the cloud, the cloud leads to low visual contrast of original MODIS image. Although many standard stretching techniques (linear, Gaussian, histogram equalization, etc.) are applied, the stretching effect is not well shown in the applying cases for original MODIS radiance image. This is caused that it is difficult to stretching that enhance image considering various clouds distribution and amounts and there are many land cover such as land, sea, desert, cast, cloud, snow etc in MODIS data. This study aims to develop an effective and simple adaptive stretching algorithm using MODIS data for effective land monitoring. In this study, it is used MODIS radiance image (MOD02) having various cloud distributions and coverage. As reference data, MODIS cloud mask data (MOD35) is used. For decision of pixel boundary value dividing the cloud and other surface targets, the relationship between area of cloud coverage and boundary value of cloud pixel is analyzed on MOD02 histogram. Using boundary value of cloud pixel, the minimum-maximum pixel value of various surface targets excepting cloud are defined and stretched. Comparing other stretching methods, the adaptive stretching algorithm is more effective to display the MODIS radiance data. In further study, this algorithm will be applied at various MODIS land products.

1. INTRODUCTION

As high temporal resolution satellite image, daily MODIS data was obscured by heavy cloud (Song et al., 2004). Because the cloud has high pixel value, it was caused low contrast of MODIS display. Major land cover type (forest, water, soil, etc) were not classified visually in daily MODIS data (Hagolle et al., 2010). Although standard stretching algorithm (Linear, Gaussian, Histogram Equalization) were applied at MODIS data, stretching effect was not well shown (Kim et at., 2010). Low contrast results of standard stretching algorithms were caused that their stretching range included the cloud pixel value. It was needed to consider cloud pixel value for effective MODIS display. This study aimed to develop a simple adaptive contrast stretching method of daily MODIS data for effective land monitoring. This proposed stretching algorithm considered various distributions and amounts of cloud on daily MODIS data.

2. METHODS

2.1 Dataset used

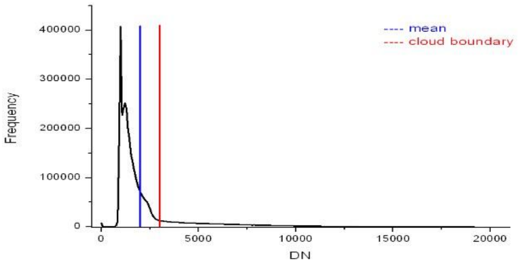
In this study, we attempt to stretch MODIS radiance data (MOD02) downloaded from MoLMoS(MODIS based Land Monitoring System) of Inha Univerisity. For considering various cloud coverage and seasonal variance, we used total 55 MOD02 images obtained from July, 2010 to June, 2011. As Table 1, 55 MOD02 products showed various cloud coverage of 10~78 percent (Table 1). This cloud coverage ratio value is estimated from MODIS cloud mask image (MOD35)(Ackerman et al., 2006). MOD35 is only used as reference data in developing adaptive stretching algorithm .

Table 1. Date and cloud coverage of MOD02 dataset used in this study

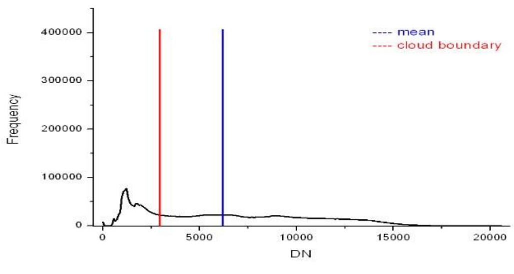
Date	Cloud coverage (%)	Date	Cloud coverage (%)	Date	Cloud coverage (%)	Date	Cloud coverage (%)
2010/07/05	48.84	2010/09/16	22.71	2011/03/24	44.22	2011/05/27	66.62
2010/07/07	30.38	2010/09/23	16.92	2011/03/25	40.75	2011/05/28	42.47
2010/07/09	61.81	2010/09/28	37.19	2011/03/29	25.58	2011/05/30	71.19
2010/07/12	45.04	2010/09/30	12.08	2011/03/30	17.02	2011/06/03	74.54
2010/07/27	61.54	2010/10/05	19.90	2011/04/08	39.85	2011/06/04	51.92
2010/08/03	41.32	2010/10/06	10.47	2011/04/09	43.87	2011/06/06	58.04
2010/08/17	25.05	2010/10/07	16.82	2011/04/12	40.03	2011/06/08	48.29
2010/08/19	40.64	2011/01/27	62.86	2011/04/16	20.37	2011/06/11	39.58
2010/08/20	31.70	2011/01/31	24.15	2011/04/17	45.41	2011/06/15	68.55
2010/08/22	33.13	2011/02/04	77.79	2011/04/19	36.30	2011/05/14	18.61
2010/08/31	52.95	2011/02/05	31.77	2011/04/23	45.53	2011/05/16	55.88
2010/09/08	45.72	2011/02/07	54.99	2011/04/28	42.94	2011/05/23	58.98
2010/09/13	41.96	2011/03/22	42.12	2011/05/02	50.53	2011/05/25	61.00
2010/09/14	22.69	2011/03/23	17.54	2011/05/05	49.57		

2.2 Detection method of cloud boundary value

We designed new stretching method that stretched other surface targets excepting cloud area. To except the cloud pixels, it is needed the range of cloud pixel value. The minimum of cloud pixel value is called as the boundary value of cloud pixel in this study. Although this boundary value of cloud pixel was easy obtained from MOD35 products, this value was detected using only MOD02 statistics without MOD35 image for fast stretching of MOD02 image. First, we analyzed the MOD02 histograms and statistics having various cloud coverage ratio. As Figure 1, location of the mean and boundary of cloud pixel on histogram of MOD02 data is different from cloud coverage.



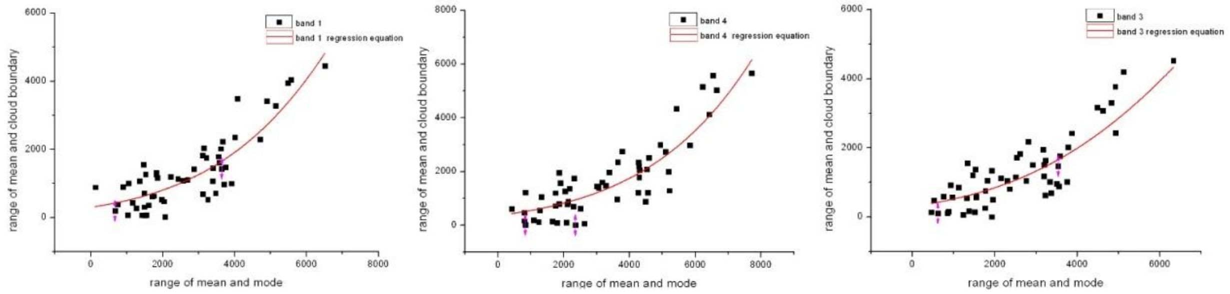
(a)



(b)

Figure1. Two MOD02 histograms of low (16.82%, left) and high cloud coverage ratio (68.55%, right)

By analyzing the statistics of 55 MOD02 histograms, we found that there is relationship between the range from mean to mode and the range from mean to boundary value of cloud pixel (Figure 2). The patterns of scatter plots showed the exponential function.



(a) (b) (c)

Figure 2. Scatter plot between The range of mean and mode and The range of mean and cloud boundary of MOD02 band 1(a), band 4 (b), band 3(c) used in true color composite of MOD02 and regression graph (red line)

The relationship was estimated as formula (1), the coefficient value and coefficient of determination of regression equation were shown in Table 2. Each band of MOD 02 showed high coefficient of determination over 0.7 value .

$$y = e^{(a+bx+cx^2)} \quad (1)$$

x: The range of mean and mode

y: The range of mean and boundary value of cloud pixel

Table 2. Coefficient of determination and coefficient of regression equation

	Band 1	Band 4	Band 3
R^2	0.76373	0.78327	0.76307
a	5.48576	5.71315	5.49627
b	6.47964 E-4	5.08546 E-4	6.62273 E-4
c	-2.85934 E-8	-1.48669 E-8	-2.95849 E-8

Using range of mean and cloud boundary value estimated from regression equation and mean of MOD02 data, the boundary value of cloud pixel was estimated. Because the range of mean and cloud boundary value is the absolute value, the range of mean and cloud boundary value was subtracted or added from mean value according to cloud coverage. Figure 3 shows the relationship between mean, boundary value of cloud pixel, and cloud coverage ratio. When MOD02 data is obtained under 30% cloud coverage ratio, the boundary value of cloud pixel is higher than mean value. Because MOD02 itself has no information about cloud coverage ratio, we used the reference mean values (b1: 2,300, b4: 3,300, b3: 3,200) of MOD02 obtained under 30% cloud coverage ratio. If mean value of MOD02 shows under reference mean value, the boundary value of cloud pixel was estimated by adding ,the range of mean and cloud boundary value from mean value. The range of mean and cloud boundary value was subtracted from mean value in opposite case.

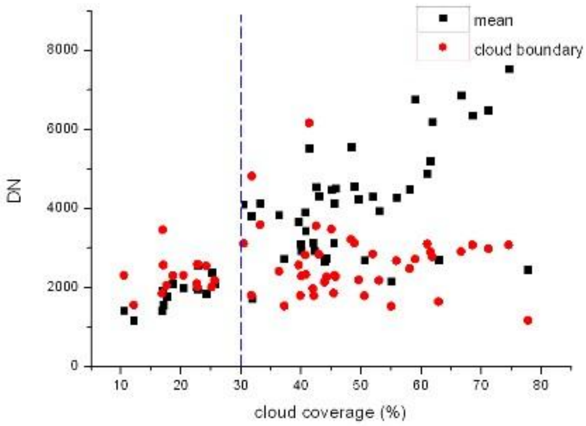


Figure 3. Relationship between mean, boundary value of cloud pixel, and cloud coverage ratio of MOD02 data

2.3 Adaptive contrast stretching method of MOD02

Figure 4 showed the total flow chart of adaptive contrast stretching algorithm of MOD02. After determining the boundary value of cloud pixel, we decided the stretching range as the range between minimum value and boundary value of cloud pixel. This range was the true pixel value of various surface targets. By linear stretching this region, various surface targets on MOD02 image were shown well.

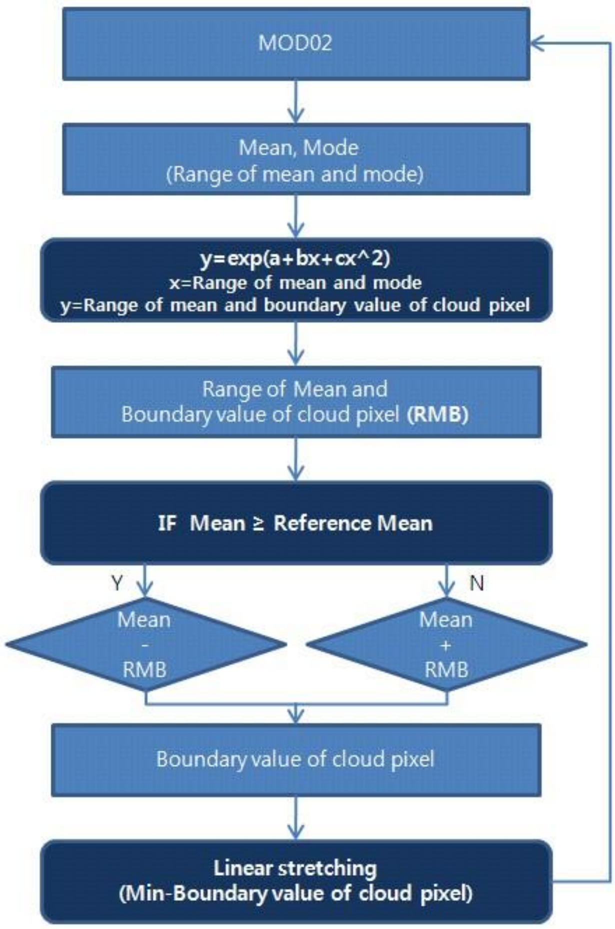
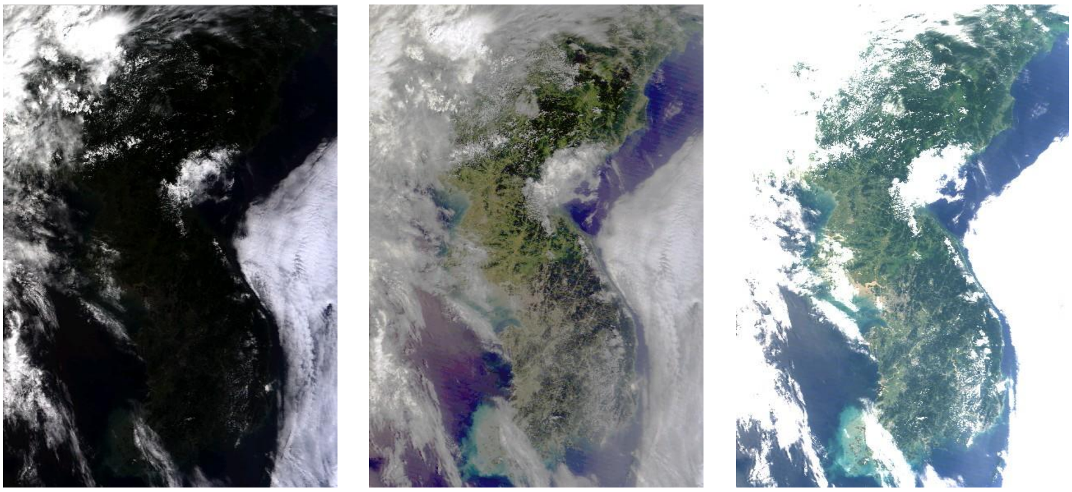


Figure 4. Flow chart of adaptive contrast stretching method of MOD02 data

3. RESULTS

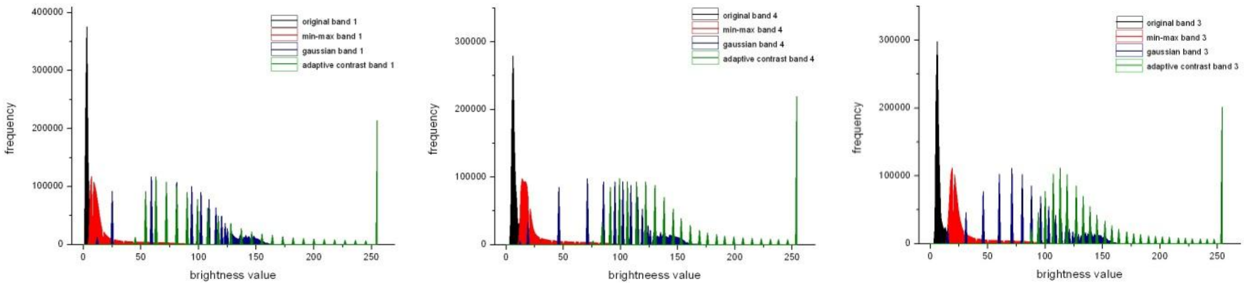
To estimate the effectiveness of adaptive contrast stretching algorithm, we compared three stretching results of min-max linear, Gaussian and new stretching method proposed in this study(Jensen,. 2004). As Figure 5(a), the linear stretching results showed poor contrast visually and various surface targets were shown as low brightness value. Comparing adaptive contrast stretching result, Gaussian stretching method were shown exaggerated stretching results. In adaptive contrast stretched MOD02 image, major land cover types (forest, urban, water etc.) were well classified. Figure 5(c) showed the soil runoff from the mouth of Han River by flooding during rainy season. Comparing other stretching methods, this new stretching algorithm could monitor effectively the disaster damage area. Visually, new stretching method proposed in this study showed good contrast results.

With visual analysis, we analyzed the histograms and statistics of MOD02 images applied three stretching methods only land area(Figure 6 and Table 3). There was little difference between two histograms of original MOD02 and Min-max linear stretching result. Adaptive contrast stretching results showed broadest and flattest histogram distribution. These results were shown also in statistics (Table 3). The new stretching method proposed in this study showed largest standard deviation comparing other stretching methods. High Standard deviation was mean high contrast results and much spectral information. In visual and quantitative analysis results, adaptive contrast stretching algorithm was provided more effective contrast results for daily monitoring land covers using MOD02 data.



(a) (b) (c)

Figure 5. MOD02 color composite data applied Min-Max linear (a), Gaussian (b), and Adaptive contrast stretching method(c)



(a) (b) (c)

Figure 6. Histogram of land area of MOD02 data band 1(a), band 4(b), band 3(c) that applied three stretching methods and original data

Table 3.Mean and Standard deviation values of land area of MOD02 data applied three stretching methods

	Mean			Std		
	Band 1	Band 4	Band 3	Band 1	Band 4	Band 3
Original	6.000	10.023	8.963	5.987	7.560	5.775
Min-max linear	8.138	10.486	12.081	15.668	16.603	17.562
Gaussian	103.221	105.940	96.147	37.272	33.920	36.958
Adaptive contrast	129.452	154.679	155.269	72.301	58.765	55.971

4. CONCLUSIONS

In this study, we suggested develop an effective and simple adaptive stretching algorithm of daily MODIS radiance data display for land monitoring. For effective contrast stretching of MOD02 data, it is important to reduce the effect of cloud coverage having high pixel value. In new stretching method proposed in this study, the threshold value of cloud pixel was estimated only using the statistics of MOD02 image. This stretching method was developed and validated using many MOD02 data having various cloud coverage. In visual and quantitative evaluation results of MOD02 data stretched, adaptive contrast stretching method was shown more effective contrast results than linear and Gaussian stretching method. This new stretching algorithm could be possible effective monitoring of land using daily MOD02 data. In further study, this algorithm will be applied at various MODIS land products.

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