Analysis of Effect of Radiometric Resolution on Radiometric and Phenological Normalization

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ABSTRACT: Recently, the remote sensing sensors have been improved, which has led to improvements in spatial, spectral, radiometric, and temporal resolution of remote sensing imagery data. However, as resolution increases, the complexity of data also increases and results in high data volumes and storage issues. In particular, radiometric resolution refers to the number of bit depth divisions, associated with the sensitivity and processing time in radiometric normalization. Therefore, this study analyzes the effect of radiometric resolution on the radiometric and phenological normalization, which is preprocessing for multi-temporal satellite images. The experiments are carried out using fine and low scale resolution images, and the accuracy and computational time are evaluated. The experimental results show that low radiometric resolution is advantageous in terms of information and computational complexity.

1. INTRODUCTION

Change detection is a method for quantitatively analyzing the change of the target area by using multi-temporal images, which is one of the representative techniques in remote sensing (Choi, 2015). Factors affecting the change detection result include the geometric relationship of the sun-target-sensor, the resolution difference between the sensors, and the difference in the atmospheric and phenological environmental conditions (Hong and Zhang, 2008). Therefore, in order to perform consistent change detection, a preprocessing is required. In particular, the preprocessing associated with the spectral value is performed with a radiometric normalization, and in general a relative radiometric normalization is utilized (Du et al., 2002).

The relative radiometric normalization is performed by selecting a reference image and converting the spectral characteristics of the input image to be the same as the reference image. Most of the relative radiometric normalization algorithms are performed based on regression equations, in which the pixels at the same location in each band are assumed to be in a linear relationship. However, since the surface of the earth is composed of nonlinear distributions and vegetation contains nonlinear characteristics, recent studies have been based on nonlinear relationship (Seo et al., 2017; Bai, et al., 2018). In particular, in order to normalize the phenological characteristic caused by the vegetation changes, Seo and Eo (2018) proposed MLP (Multi-Layer Perceptron)-based relative radiometric normalization.

At this time, in general, as the resolution increases, the complexity of the data increases, which increases the computational complexity and time. Especially, among the various resolutions, radiometric resolution is closely associated with the spectral features of the target (Verde et al., 2018). Radiometric resolution reflects the quantization level that the sensor is capable to record, which influences the sensitivity and processing time in relative radiometric normalization. Furthermore, many studies on spatial and spectral resolution have been performed, but little research has been done on radiometric resolution. Based on these motivations, this study investigates the effect of radiometric resolution on radiometric and phenological normalization.

2. METHODS

2.1 Radiometric and phenological normalization

In this study, radiometric and phenological normalization is performed based on Seo and Eo (2018). Seo and Eo (2018) consists of four steps: 1) Extraction of RCSS (Radiometric Control Set Samples). 2) Selection of spectral indices, 3) phenological normalization based on MLP, and 4) post-processing. In the first step, RCSS is extracted based on NC (No-Change set) method, which is performed using scattergram between near-infrared bands of input and reference images. The second step is performed to provide supplementary information on phenological normalization, and spectral indices, which affect the phenological characteristics, are selected. In Seo and Eo (2018), normalized difference water index, normalized difference vegetation index, soil-adjusted vegetation index, and enhanced vegetation index are selected. In the third step, phenological normalization is performed based on MLP, and in the fourth step, which is the final step, the global radiometric characteristics are adjusted through histogram matching.

2.2 Radiometric resolution compression

As mentioned above, radiometric resolution represents the number of bit depth divisions in images, which is associated with the complexity and training time in MLP-based normalization. In particular, the higher resolution, the more noise and computation complexity is drawn (Miyoshi et al., 2018). Furthermore, while low radiometric resolution reduces complexity, the difference in the information between the high and low radiometric resolution is negligible (Verde et al., 2018). Therefore, prior to performing the radiometric and phenological normalization, radiometric compression is conducted to examine the effect of radiometric resolution. The images are compressed using the linear rescale method, and optimal radiometric resolution is determined through multiple experiments, considering time cost and accuracy.

3. RESULTS

3.1 Study sites and materials

In this study, experiments are performed using images acquired through high-resolution satellite sensors, WorldView-2 and GeoEye-1, which has an 11-bit radiometric resolution. The experimental area, which is a part of the city of Seoul, consists of vegetation, bare land, water, and artifacts. In particular, the images with phenological differences are selected. The input image is the WorldView-2 image acquired on February 10, 2017, and the reference image is GeoEye-1 image acquired on Jun 24, 2018. The size of each image is 1000 × 1000, as shown in Figure 1.

(a) **(b)**

Figure 1. Experimental images of study area: (a) 2017.02.10 WorldView-2, (b) 2018.06.24 GeoEye-1

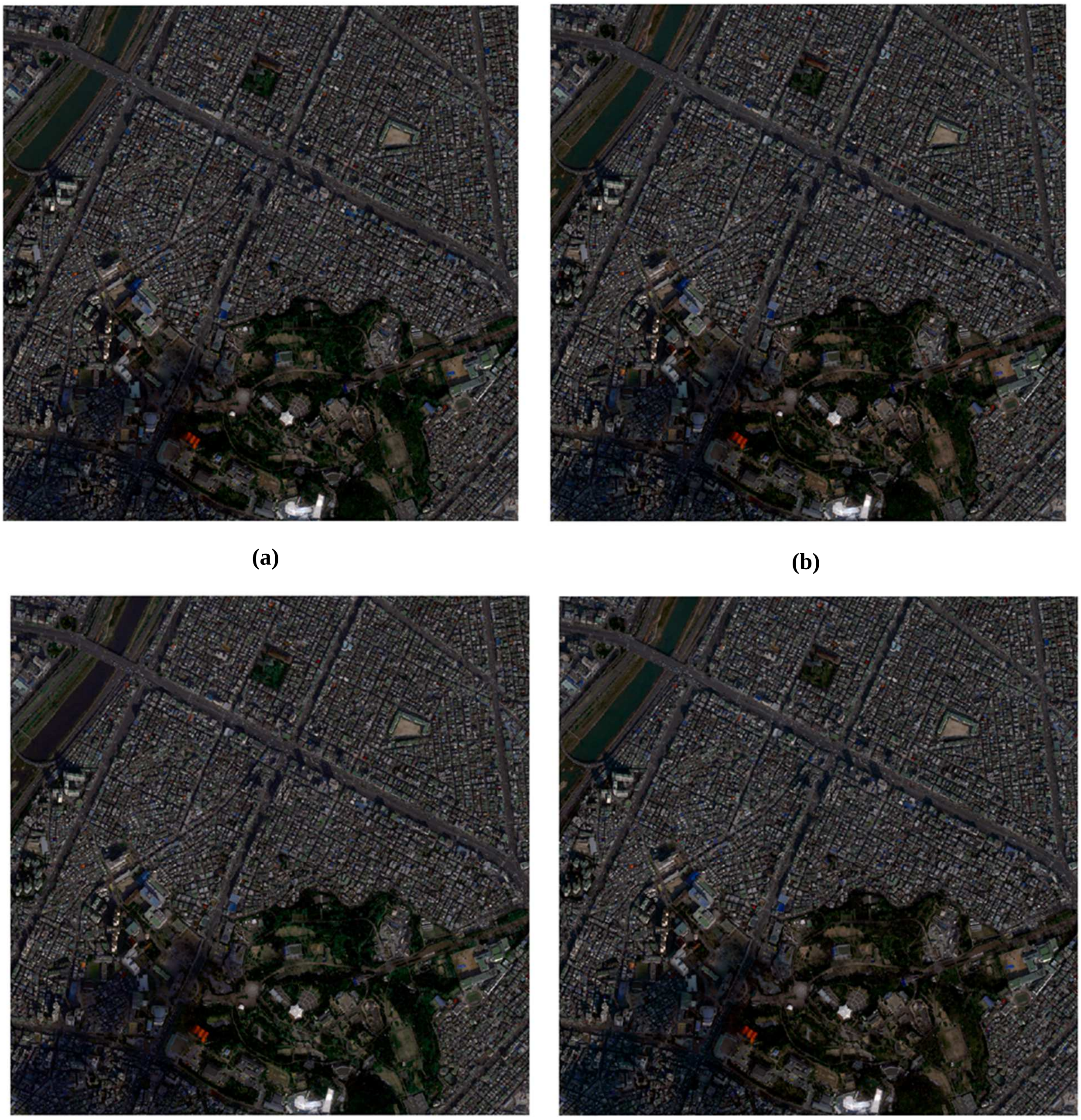
3.2 Experimental results

In order to investigate the effect of radiometric resolution on radiometric and phenological normalization, radiometric compression is performed, and in this study, the range is taken from 8-bit to 11-bit. Then, MLP-based normalization of Seo and Eo (2018) is applied to the experimental images. The result image of each radiometric resolution is shown in Figure 2.

From the visual inspection, it can be seen that the radiometric and phenological characteristics are normalized regardless of radiometric resolution. In particular, the spectral characteristics of the vegetation are normalized to be the same as the reference image in all results. In other words, there is little information difference between low and high radiometric resolution.

Then, quantitative analysis is conducted and NRMSE is utilized. NRMSE is an index for evaluating accuracy, and the lower the value, the higher the accuracy. Furthermore, in order to consider both accuracy and time cost, training time is also obtained, as shown in Table 1 and Figure 3.

The average NRMSE of 8-bit, 9-bit, 10-bit, 11-bit are 0.3384, 0.3389, 0.3382, and 0.3496, which is similar regardless of radiometric resolution, Rather, as radiometric resolution increases, accuracy decreases somewhat. In the case of training time, 382s, 533s, 886s, and 847s are showed at each radiometric resolution. As the radiometric resolution increases, the training time tend to increase, which indicates that the computational complexity increases. In other words, high radiometric resolution interferes with the performance improvements and leads to overtraining.

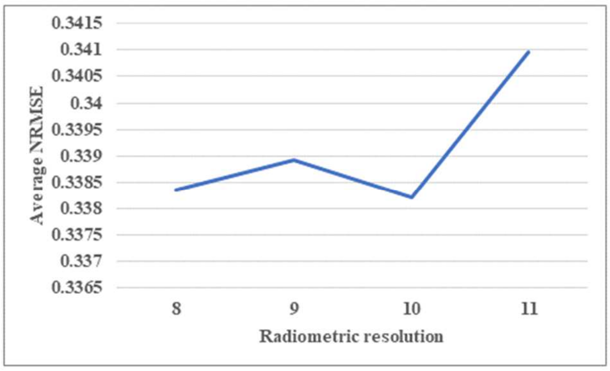


(a) (b) (c) (d)

Figure 2. The result of each radiometric resolution: (a) 8-bit, (b) 9-bit, (c) 10-bit, (d) 11-bit

Table1. NRMSE of each radiometric resolution result

Radiometric resolution	Band1	Band2	Band3	Band4
8-bit	0.197	0.2879	0.441	0.4275
9-bit	0.1969	0.2877	0.4424	0.4287
10-bit	0.197	0.2894	0.4397	0.4267
11-bit	0.1972	0.2879	0.4439	0.4348



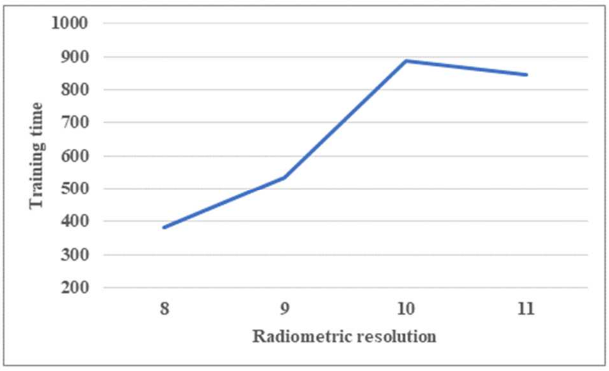


Figure 3. Average NRMSE and training time of each radiometric resolution result

4. CONCLUSION

In this study, the effect of radiometric resolution on the radiometric and phenological normalization are analyzed. The range is selected from 8-bit to 11-bt considering the radiometric resolution of the image. Then, radiometric and phenological normalizations are performed by compressing the images with each radiometric resolution and analyzed visually and quantitatively. As a result of visual analysis, it is confirmed that similar results are obtained regardless of radiometric resolution. On the other hand, quantitative results show that the performance somewhat decreases, and the training time increases with increasing radiometric resolution. In other words, when considering both information and computational complexity, it can be seen that low radiometric resolution is advantageous in radiometric and phenological normalization.

In the future, it is judged that further analysis should be performed by ensuring sufficient input and reference images for each season, period, and sensor. Furthermore, the effects of spectral and spatial resolution other than radiometric resolution should be examined.

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