Simulated recovery of information in shadow areas on IKONOS image by combing ALS data

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ABSTRACT

Retrieval of image density information of shadow areas in IKONOS imageries is investigated to recover image quality degradation due to shadow by combining IKONOS image with Airborne Laser Scanner (ALS) data. Recently, with the development of new technologies in remote sensing, detailed mapping of urban areas is getting possible by using not only aerial photographs but also satellite imageries with high spatial resolution. However, it is usually quite difficult to extract information in urban high-resolution satellite imageries like IKONOS due to high object density and especially high proportion of the shadow-covered areas. In this paper, we recovered the spectral information in shadow areas in IKONOS image by using height data from the ALS. The possible shadow areas were simulated from the height data from ALS, and then the actual shadow areas were extracted from IKONOS image by overlaying the simulated shadow areas on IKONOS image. Subsequently, the image density information over the shadow areas was recovered by comparing the same with the neighborhood bright area. Thus, a model for removing objects shadow was developed in this study. The developed method, which used IKONOS and ALS data as a case study, can be used for shadow extraction from similar high-resolution imageries with little modification in the methodology. The resultant shadow-free satellite image may be utilized in order to not only improve the quality of image but also to apply in urban analysis.

1. INTRODUCTION

Recently, with the development of new technologies in remote sensing, detailed mapping in urban areas is getting possible by using not only aerial photographs but also by satellite imageries with high spatial resolution. In addition, with very high-resolution satellite imageries such as IKONOS, we can clearly see many detailed features such as, building structures, roads, vehicles and trees in the imagery. However, it is difficult to detect them from the imagery with some shadow areas in the same. Especially, there are many shadow areas in urban areas, and it becomes difficult to extract information in these areas from high-resolution satellite imageries like IKONOS due to high object density and especially high proportion of the shadow-covered areas. So these things influence detailed mapping of urban area while using aerial photograph and satellite image. In this paper, first we simulated recovery of spectral information in shadow areas by using IKONOS data and height data from the ALS, and then combined the simulated shadow information and the IKONOS imageries to create only a shadow imagery. Secondly, over the shadow area the image density information was recovered by comparing it with the neighborhood bright area. Through this processe, shadow-free image can be created.

2. IKONOS IMAGE AND AIRBORNE LASER SCANNER DATA

2.1 Overview of IKONOS image

IKONOS image has multi spectral sensor (Red, Green, Blue and Near Infrared) with 4-meter spatial resolution and panchromatic sensor with 1-meter spatial resolution. All images are stored in 11-bit, which has a wider dynamic spectral range than Landsat ETM+ and SPOT. Most objects, including small buildings, individual trees, can be recognized in 1-meter PAN images, but their boundaries are not easily identifiable due to the complex urban scene, and traditional edge-based approaches cannot directly achieve good performance. On the other hand IKONOS image has big shadow areas especially in urban areas. So, it becomes difficult to see the information in shadow-covered area. In this paper, panchromatic image was used for recovering the information in shadow-covered area.

2.2 Overview of ALS data

Airborne laser scanner is an active technique to acquire 3D information describing the earth surface. A typical system can provide pixel data with 15cm vertical accuracy and 50cm horizontal accuracy, and the laser points are almost evenly distributed in the covered areas. Therefore, high quality and homogenous Digital Surface Model (DSM) can be directly derived from ALS data. A number of approaches solely based on ALS data for segmenting buildings and trees have been shown. The density of the ALS data in this research is about $2.5m^2$/pixel.

2.3 Test site

In this paper, IKONOS image (Figure 1) and ALS data (Figure 2) at Shinjuku area in Tokyo are used as a case study. The area of this image is 300m x 150m. This area contains various patterns of urban objects. This area contains a lot of crowded buildings, trees, streets, roads, and bare grounds. Height of road or ground is about from 34 to 36 meters from msl in this area.

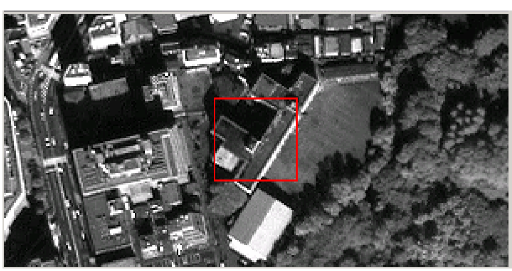

Figure 1. IKONOS image

Figure 2. DSM image

3. Analysis

3.1 Flow

Research flow is depicted in Figure 3.

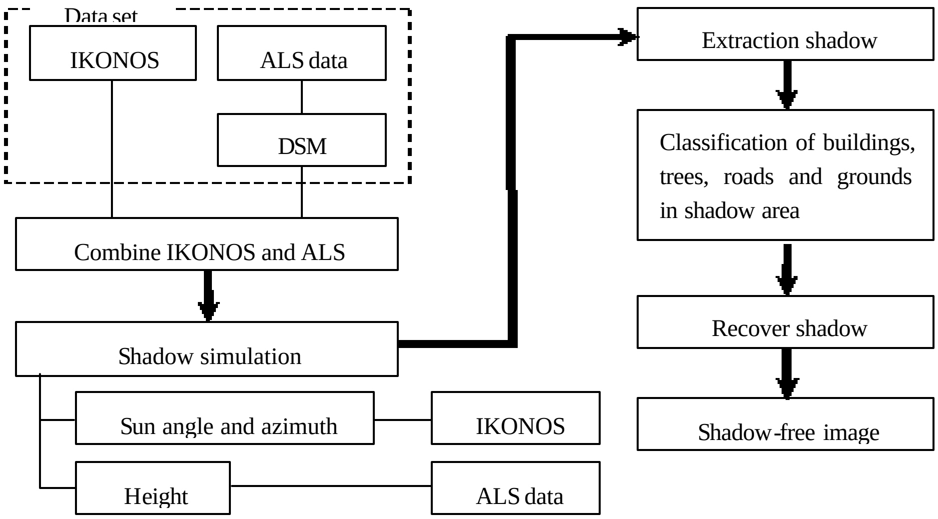

Figure 3. Research flow

First, we have to match either coordinate system, and match same coordinate to unite the position information on IKONOS image and DSM data. Secondly, shadow simulation is conducted using sun angle and azimuth, which are taken from IKONOS image, and height by DSM. By this simulation, the location of shadow area can be estimated. Thirdly, shadow part in IKONOS image is combined to the image by shadow simulation, and only shadow image can be created. Therefore shadow part in IKONOS imagery can be extracted. The extracted shadow image can be classified into four categories in shadow areas, namely shadow area of buildings, trees, roads and grounds using different features of spectral signatures of each category. To classify each category, we create Region of Interest (ROI) for each category. Finally, by using gamma correction method or the amount conversion of statistics, spectral signatures of each category in shadow areas are converted to their representative values in non-shadow areas. This way, we can recover shadow information and shadow-free image can be created.

3.2 Shadow simulation

The aim of shadow simulation is to calculate shadow length to know the shadow direction by using height data from DSM and sun angle and azimuth from IKONOS imagery. The shadow simulation is done as follow. As height data is given, first we calculated shadow direction from the sun-angle obtained from IKONOS imagery. Next, we have to consider the case where other objects stand in the direction of the shadow of an object with height h. The situation is shown in Figure 4(c). If the height of the nearby object, say h1, is more than the height of the object under consideration the shadow from h will not be able to cover the whole height of h1. In this case, the shadow on h1, say of height h2, is not considered as shadow. However, if h1<h2, we consider the shadow from h as a valid shadow.

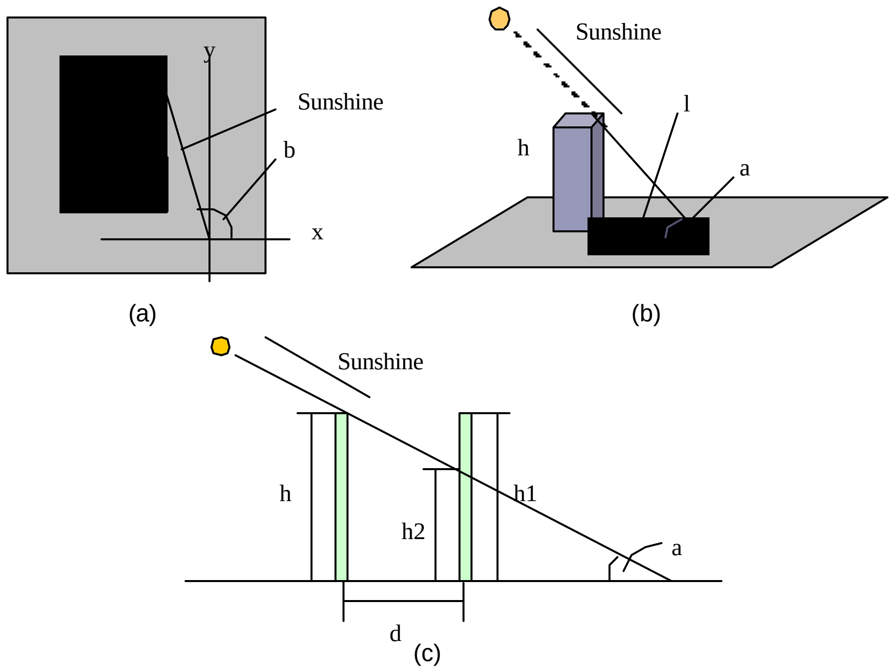

Figure 4. Shadow model using IKONOS image and DSM data
(a): sun angle, (b): sun azimuth, and (c): shadow length

Using this process, the shadow simulation was performed Figure 5. Figure 5 shows the result of shadow simulation. Black parts are shadow areas, and white parts are non-shadow areas in the imagery.

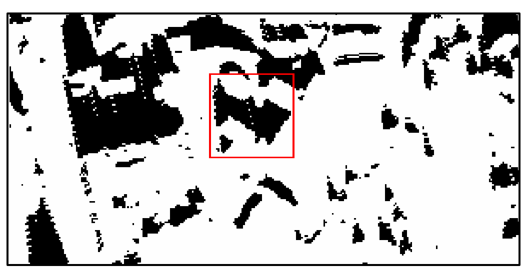

Figure 5. Shadow simulation image

3.3 Extraction shadow areas in IKONOS imagery

Extraction of shadow areas is done by simply overlaying the shadow simulation imagery to the original IKONOS imagery. The portion containing shadows in IKONOS imagery is depicted as the non-black areas in the resultant imagery (Figure 6(b)).

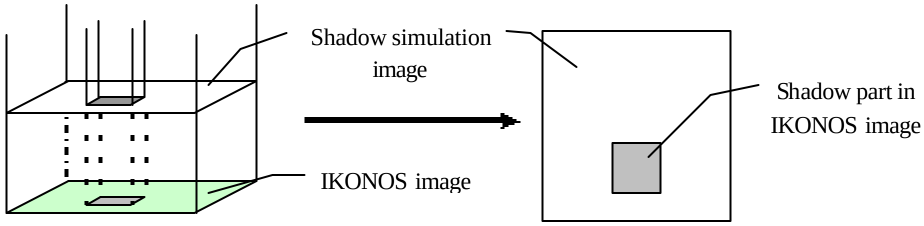

Figure 6(a). Combing shadow simulation image and IKONOS image

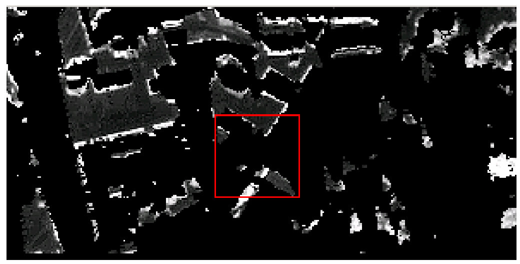

Figure 6(b). Only shadow imagery

3.4 Elimination shadow image

The method of elimination shadow imagery is as follow. Shadow imagery has already been divided into four categories, based on different features of spectral signatures. However, it is not easy to divide them ordinarily unlike shadow-free image, because all parts of spectral signature in shadow are quite similar. So the condition to divide into each category is set. If height is 36 meters or more, the point is considered as building or tree in a shadow. If it is not so, this point is road or ground in a shadow. Then shadow image is divided into two images, and these images are divided into four parts by creating Region of Interest (ROI) to each category.

Next, shadow areas are divided into four parts to make them close to their counterparts in non-shadow areas. The method is to enhance the spectral signature of shadow areas closer to the spectral signatures of their non-shadow counterpart in each category. There are several methods of enhancement. In this paper, we use gamma correction method and the amount conversion of statistics on each category. The formula of gamma correction is described in equation (3).

$$OutPixel = 2047 \times (InPixel \div 2047)^{1/g} \qquad (3)$$

OutPixel: Output pixel value
InPixel: Input pixel value

In this research, *OutPixel* is defined as the average spectral signature of non-shadow area. On the other hand, *InPixel* is defined as the average spectral signature of shadow areas, and, by calculating gamma, it is decided what time spectral signature of shadow is carried out. The imagery which combined IKONOS image and eliminated shadow imagery is shown in Figure 7(a).

On the other hand, the amount conversion of statistics is described in equation (4), and average and standard deviation of each spectral signature about creating ROI to each category are described as Table 1.

$$y = \frac{S_y}{S_x}(x - x_m) + y_m \qquad (4)$$

x : input pixel value y : output pixel value
x_m: average of input density y_m: average of output density
S_x: standard deviation of input density S_y: standard deviation of output density

Table 1. Average and standard deviation of each category

	Shadow		Non-shadow	
	Avg.	Std.	Avg.	Std.
Building	112	12.35	344	160.46
Tree	124	18.68	249	58.71
Road	109	16.09	266	105.40
Ground	116	18.76	265	32.27

In this research, x is the spectral signature of shadow area in a pixel, y is the spectral signature of non-shadow area in a pixel, x_m is average spectral signature in shadow area, y_m is average spectral signature in non-shadow area, S_x is standard deviation of spectral signature in shadow one, and Sy is standard deviation of spectral signature in non-shadow one. The image which combined IKONOS image and recovered shadow is shown in Figure 7(b).

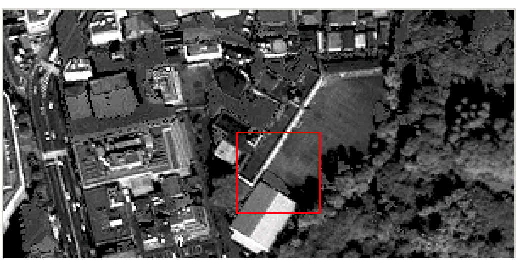

Figure 7(a). non-shadow image by using (3)

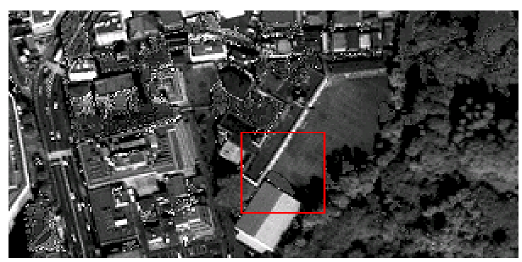

Figure 7(b). non-shadow image by using (4)

The non-shadow imageries with area-details are shown in Figure 7(c). Images in first line are original IKONOS images, which are building, tree, road and ground from the left to right. Second line shows images after using gamma correction method on IKONOS images with shadow areas clearly seen, which are the same as original one. Third line shoes the result after using the amount conversion of statistics showing shadow areas in IKONOS imagery, which are the same as original them. Besides returned shadow area is enclosed with the circle.

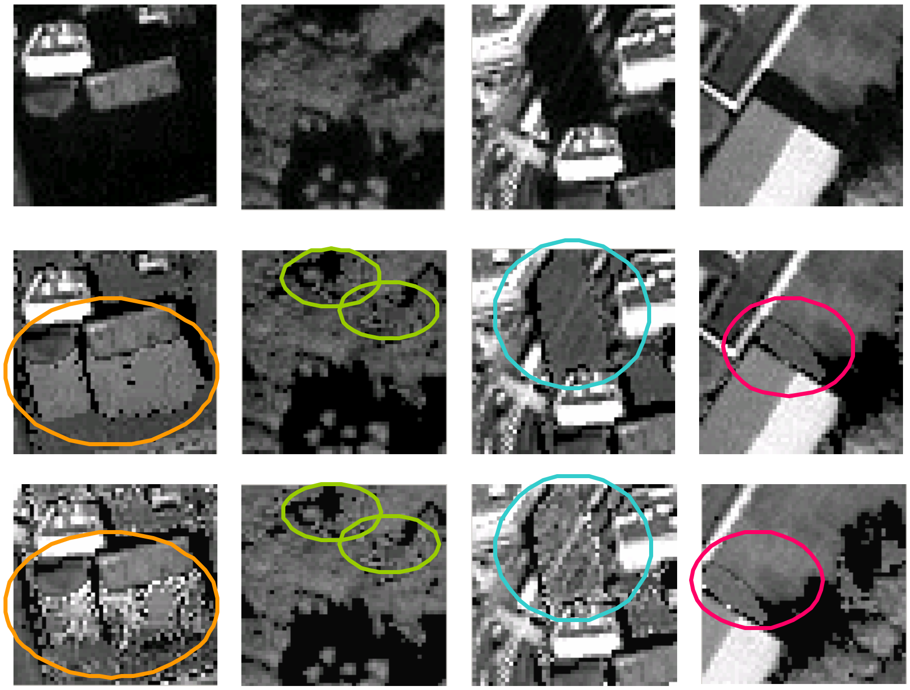

Figure 7(c). Non-shadow imageries with area-details

4. CONCLUSION

In this paper, we described a methodology of creating non-shadow imagery by combing IKONOS PAN image and airborne laser scanning data. Though our research is producing some remarkable results, there are several things to be considered in future work. First, about enhancing the shadow areas: tree and ground areas can be distinctly delineated, but surface with asphalt-toppings (say roads) are hard to be detected using gamma correction method. Therefore, these areas remained as shadow areas in our result which has to be taken care of with appropriate techniques in the future. Moreover, quality of our result highly depends on the accuracy of DEM data. However, the extent to influence in quantitative term is still not investigated and has to be done. With these improvements, the methodology is expected to produce valuable results to support researches using high resolution imageries.

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