CHARACTERISTICS OF SHADOW AND REMOVAL OF ITS EFFECTS FOR REMOTE SENSING IMAGERY

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1. INTRODUCTION

Optical remote sensing sensors, in most cases, use sunlight as a source of illumination. Hence, remote sensing imagery is affected by shadows of clouds, trees, and buildings, etc. Especially for high-resolution satellite images and airborne images, shadow should be paid attention because shadow shares significant portion of imagery. If we use land-cover classification techniques, shadow should be treated as one class although such a class has no meaning as land-cover. Another problem of shadow is seasonal and time-dependence. Even though there is no change in the land-cover, a change of shadow gives a false change to the image.

Due to these reasons, it is very useful if the radiance of shadow areas is corrected to the same radiance as shadow-free areas. There have been several researches on the detection and correction of shadow [1, 2]. But these methods have not been tested for various cases and the characteristics of shadows are not so well investigated. In this paper, the radiances of sunlit and shadowed areas are measured by a spectrometer and the spectral characteristics of shadow are investigated in visible to near-infrared regions. Digital aerial images taken in the morning and in the late afternoon are then introduced, and the comparison of these images is carried out to remove the effects of shadows.

2. MEASUREMENT OF RADIANCE FOR SUNLIT AND SHADOWED AREAS

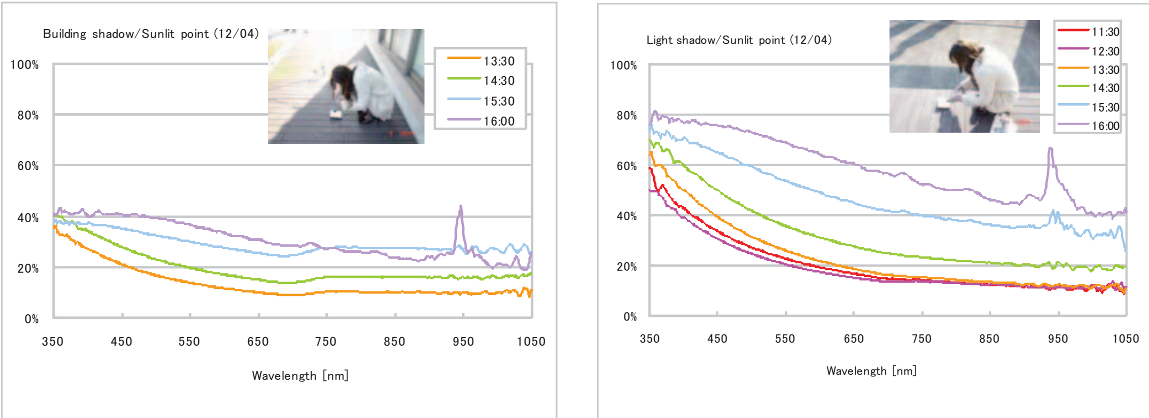
To investigate general spectral characteristics of sunlight, the measurement of spectral reflectance of a white plate was conducted on 4 December, 2008 at the rooftop of an eight-storied building of Chiba University, Japan. A hand-held spectrometer, MS-720 made by Eko Instruments Co., Ltd., Japan, (http://www.eko.co.jp/eko/a/index.html), was used. Figure 1 shows the ratio of the reflectance of the white plate in a sunlit area and that in shadowed areas. Two shadowed areas were selected for the measurement. One area is in a dark shadow of the building wall, and another is in a light shadow of a beam. The measurement was conducted every hour in the afternoon of the clear day.

It is seen from the figure that the radiance ratio (shadow/sunlit) increases as the sunlight gets weaker. It is also observed that the ratio shows a large difference between the dark and light shadows. Based on the figure, it is concluded that the effect of shadow is dependent on time (and season), and the casting condition of shadow. Thus, in order to restore a shadow-free radiance for a shadowed area, the sunlight condition and the shadow casting condition should be known. In other words, the condition to restore a shadow-free image is depending on time, season and location.

3. DIGITAL AERIAL IMAGES AND SHADOW EFFECTS

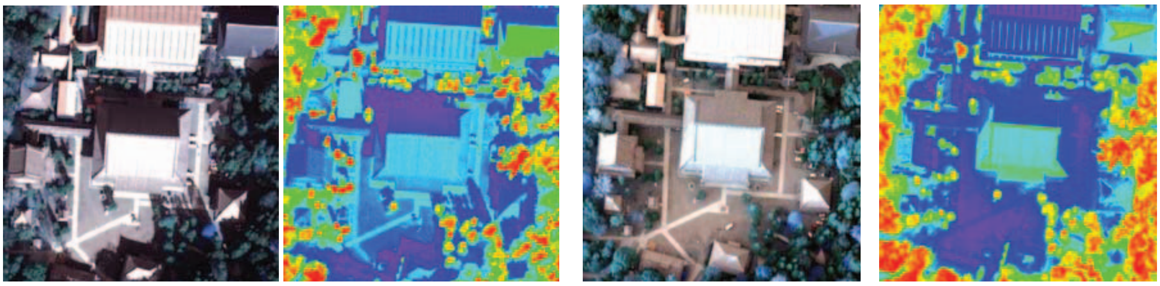
A set of images taken by a digital aerial camera DMC [3] were used to investigate the effects of sunlight and shadow conditions to optical imagery. Figure 2 shows a part of the digital aerial images of Kyoto City, Japan, which were taken on 6 December, 2007 by Geographical Survey Institute of Japan. The digital images were taken by three visible (BGR) and one near-infrared (NIR) bands in the morning (10:30 AM) and in the late afternoon (16:10 PM). True color composite (BGR) images and the normalized difference vegetation index (NDVI) images are presented in the figure.

Shadow looks quite dark in the AM image and the shadowed areas are invisible without brightness enhancement. On the contrary, there is no dark shadowed area in the PM image. Actually, since the elevation of the sun is very low at this time, the radiance in the sunlight area and that in the shadow are rather close. It is seen from the figure that the NDVI value gets smaller if the pixels are located in the shadow. Even in the sunlit area, the NDVI value of a pixel changes with time due to the difference in the spectral contents of sunlight.



(a) Dark building shadow/Sunlit area (b) Light shadow/Sunlit area

Figure 1 The ratio of radiance of the white plate in shadow and sunlit areas, measured on 4 December, 2008 in Chiba, Japan. The ratio changes with time and the darkness of shadow.



(a) 10:30 AM (b) 16:10 PM

Figure 2 Digital aerial images and their NDVI values of a part of Kyoto City, taken on 4 December, 2007.

4. CONCLUSIONS AND FUTURE DIRECTIONS

The effects of shadow in remote sensing imagery are investigated. The measurement of radiance in sunlit and shadowed areas was carried out to investigate the spectral characteristics of sunlight. Based on this observation, it is found that the radiance ratio (shadow/sunlit) increases as the sunlight gets weaker and the ratio is dependent on the wavelength of light. Thus the condition to restore a shadow-free image is depending on time, season and location.

A set of digital aerial images, which were taken over the same area of Kyoto City at the different times of the day, were compared. The effects of shadow are seen to be time-dependent and the shadow looks much darker under the strong sunshine. It is observed that even the NDVI value, which is considered to be a stable index for vegetation, is affected by shadow and sunlight conditions.

Based on these observations, we are currently developing a method to detect shadows of various darkness from remote sensing imagery. The restoration radiance in the shadow affected is also under investigation to remove the effects of shadow and sunlight conditions in image classification.

5. REFERENCES

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