RESTITUTION OF INFORMATION UNDER SHADOW IN REMOTE SENSING HIGH SPACE RESOLUTION IMAGES: APPLICATION TO IKONOS DATA OF SHERBROOKE CITY

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ABSTRACT:

Shadow regions are very present in the high spatial resolution images, particularly in urban environment. Shades have negative effects. They strongly disturb the classical techniques of image analysis by modifying surface appearance and sometimes involve loss of information under the surface they covered. In this study, we try to restore the information masked under the shadow by finding the types of surface covered by the shade. This search is based on the analysis of contextual, spectral and textural information from the shadow and its vicinity.This restitution supposes that shades are well identified, which was the aim of our former work. It takes into account the space configuration of the vicinity between the objects located sun side and surfaces in shade side which are supposed to receive the shadow. The application on an IKONOS image of Sherbrooke show that it is indeed possible to restore the information laying under the shadow and even discriminate several types of surface under the same shade, such as shades of buildings which are projected at the same time on grass, a portion of parking or on another building. The method also makes it possible to correct the shadow effects on the images.

1. INTRODUCTION

The advent of the sensors with very high space resolution (Ikonos, QuickBird, etc) opens a new era for remote sensing, mainly for applications where the need for details is essential as in urban environment. With thus images, we can distinguish clearly detailed features such as building structure, roads, vehicules, and trees (Nakajima et *al*., 2002).

However, the enthusiasm of the users remains measured, because of new difficulties in the analysis of these images. These difficulties are the need of new techniques to extract information from these data and the presence of undesired features like shadow of clouds and high objects like buildings and trees. Despite a suitable choice of the hour of acquisition, shadow is very present on the images of very high spatial resolution mainly in urban environment. The amount of shadow increase with the spatial resolution.

The negative effects of shadowing enormously degrade the visual quality of the images and cause several nuisances during the analysis of these images by modifing spectral response of the part of surface in shadow. Thus, surfaces under shadow are often confused with other types of objects which have a same spectral signatures as the shadow. The results are a misclassification of area covered by shadow. All techniques of information extraction from image are influenced by the presence of shadow by modifing or masking information under shadow. For a detailled mapping of urban area, using a very high spatial resolution images, it is important to recover information under shadow to complete the mapping. But for recovering information in shadow, that shadow must be accurately detected.

The object of this study is precisely to well detect shadow in images and recover information from surface in shadow and also to compensate their negative effects by de-shadowing images.

Some techniques for shadow detection are developped in moving object detection from videographic images (Prati et *al*., 2001); but, in remote sensing, only few works on shadow detection are carried out mainly in builduing detection (Bruce Irvin et *al*., 1989, Chungan et *al*., 1998) and clouds shadow correction. Recently, some works on shadow detection on the very high spatial resolution like Ikonos are published. Methods use principaly color and spectral proprieties to detect shadow (Adler-Golden et al., 2002). Some geometrical proprieties (area, length, width, parallel sides, right angle, etc) are added to improve the detection. Our shadow detection method is based also on spectral and form proprieties, but include the sun azimuth orientation at the acquistion time. Some contextual proprieties (vicinity, relative position sun object and shadow) are also added to improve detction or to confirm the results.

For the restitution of information under shadow, we use the contextual and textural features between the shadow detected and the neighboor surfaces in the shadow side. These surfaces on shadow are supposed to receive projected shadow, even surfaces on sun side are supposed to be objects generating shadow. The main hypothesis is that the texture features are shadow invariant and the neighbooring surface with the same texture like shadow is considered to be the same surface under that shadow.

After the surface under shadow is detected, negative effects can be removed by transforming shadow pixels value. The transforming parameters are calculated for each shadow zone using it mean value and the neighboor segment of the same surface.

In the following section we sum up shadow charecteristics used in most dtection methods and related works in shadow detection and information restitution from shadow. The methodologies used to detect shadow and retrieve information under shadow are explained in section III. The data and sites studies are presented in section IV. Results and their analysis come in section V and we end with conclusion and some recommandations.

2. RELATED WORKS

The main reason of shadows presence in remote snesing images is the obstruction of the sun light by some high objects like tall buildings. Surfaces under shadow are poorly lighted and appear dark on the images. The form and size of the shadow depend geometrically on the sun rise, the height and form of the object which generates the shadow as well as the position of the observer or the sensor. The most characteristics used in image analysis for shadow zone detection or its effects compensation are:

- The low value of shadow pixels in all the visible bands (darkness of shadow regions);
- Shadow is like a silhouette of the object generating it. (so, its form is function of the object form).
- One or more sides of the shadow are oriented exactly in the sun azimuth direction;
- The shadow size depend on the sun elevation and the object height;
- Shadow have three components: the projected shade which represents the silhouette of the object, the self shadow which is the part of the object under its shade and finally the penumbra located at the shade periphery.
- Shadow do not modify the object colour (saturation an taint).
- Some elements of surface texture are shadow invariant. It mean that the texture of a surface do not greatly change when shadowed.

Many works on shadow topic are devoted to the analysis of video graphic images to detect moving objects in video surveillance (Prati et *al*.; 2000). In remote sensing, only few works were carried out on the phenomenon. They are related to the detection of the shades for the recognition of the buildings (Hertas and Nevatia, 1988), (Liow and Pavlidis, 1990), the detection of the shades of the clouds and correction of the effect of shade due to the relief in the zones mountainous.
The majority of the methods for detecting shadow are based on their low value level in all the spectral bands. Thus, a simple threshold of histogram makes it possible to discriminate the zones of shade (Gwinner et *al*., 1997). But certain dark surfaces with low value are merged with the zones of shades, so, the need for integrating other properties or knowledge to differentiate the shades from these other surfaces. Certain assumptions on the vicinity and the form (right angle, parallelism on the sides, etc.) (Chungan and Nevatia, 1998) are used to improve discrimination of the shades.
Over methods use the invariant properties of the color like saturation to discriminate the zones of shade on color images. These invariant properties make it possible to detect surface under the shade in spite of the strong difference of the intensity (El Salvador et *al*., 2001).

Recently few works on shadow compensation or information retrieval are published (Nakajima et al., 2002, Rau et *al*.; 2000). Nakajima et al. use ALS data to simulate shadow imagery at the same configuration as the Ikonos data acquisition. That simulated shadow is used to extract shadow from the Ikonos. Shadow are eliminated by using a gamma transformation to enhance the pixel value in the shadow.
Rau et al. use an local histogram balancing to compensate the shadow effect. Other methods of shadow compensation are based on the physical models simulating the sun and sky illumination (Alder-Golden et *al*., 2002).
Our method for shadow detection is based on a hierarchical analysis of an segment attributes after a segmentation of the image. The attributes used are : radiometric (mean value and standard deviation), geometric (form and orientation), contextual (vicinity, relative position of objects in sun side and shadow side) and textural. For information recovery the method use the textural attribute and the shadow neighbouring segments in shadow side.
Methodologies for shadow detection and for information under shadow recovery are described with the following section.

3. METHODOLOGY

3.1 Shadow detection methodology

The method is based on segment attributes analysis, so the first step began with the image segmentation to produce homogeneous zones (segments), and the calculation of all attributes: spectral (average and standard deviation), form (length, width, surface, compactness and orientation) and contextual (vicinity, under-segments, etc).

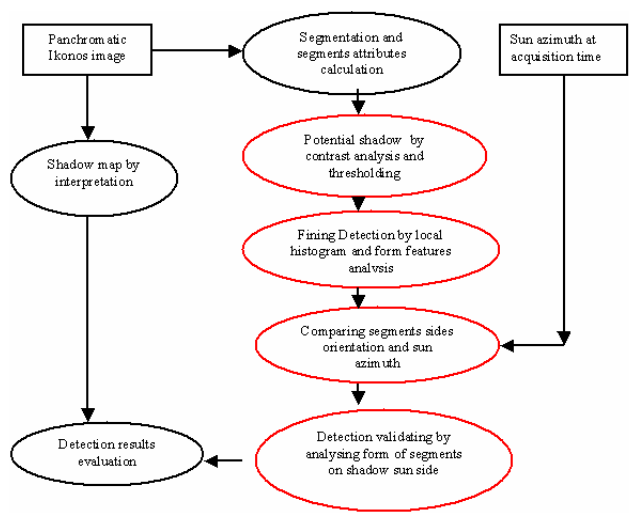

Figure 1: Diagram for the shadow detection

The hierarchical analysis of these attributes to detect shadow is presented on figure 1 and the most steps are:

1. First detection by contrast analysis and threshold to get all potential shadow zones. All segments darker than its vicinity are considered. Segments with grey level lower than a threshold are retained as potential shadow zones.

2. Local histogram analysis and the form attributes are used to refine the shadow detection for discriminating the projected shade, the self-shadow and penumbra. The form criteria used are the area, the length/width and the compactness.
3. The neighbour shadow segments are merged to form a more geometrically significant segment. Then, the orientation of each side is calculated and compared to the sun azimuth direction. If the difference is lower than a fixed tolerance level, the segment is regarded as having one or more sides directed according to the azimuth of the sun and increases its chance to be shade.
4. Each segment detected as shadow, must be confirmed by analysing the form of its neighbouring segments in the sun side. If there is two or more segments, they merged if their mean and variance are closed to get meaningful segment. For a regular form segment, it can be a building and confirm the shadow detected. In other case, the analysis of the under-segments can confirm the shadow by the presence of self shadow, projected shade and penumbra.

3.2 Methodology for information restitution from shadow

The information retrieval under the shade is based on texture invariance by shadow. Considering that a surface texture does not significantly change when shadowed. So to retrieve a surface in shadow, we can use a contextual texture analysis between the shadowed segment and its neighbouring segments in the shadow side. Because surfaces receiving shadow from an object are located at the opposite side of the sun, they are located in the shadow side.
The principal stages of the methodology presented in figure 2 are:

1. For each segment shade, the list of its neighbour in shadow side is checked. If a neighbour segment is a shadowed segment, it is excluded. Then, the textural attributes of the segments in that list are bring out.
2. Analysis of texture between the shadow and all the segments of the shadow side vicinity list. For this analysis, we calculate the difference of texture between each neighbouring segment of the list and the segment shade. The segment having a texture difference close to zero is considered as having the same texture with the shadowed segment. And thus two segments are from the same surface.
3. The surface type represented by the neighbour segment with the same texture as the shadow is identified from a soil occupation map or a classification result. So the segment in shadow is allowed to the same surface.

For the shadow effects compensation, the gamma transformation as formulated in the equation eq (1) was used:

$$OutPixel = 2047*(InPixel/2047)^{1/\delta} \quad (1)$$

Where: *OutPixel* : Pixel value after correction

Inpixel : shadow pixel before correction

δ : parameter of transformation

The parameter of transformation δ is calculated for each shadow area using the shadow segment mean value and its neighbour in sunlight representing the same surface.
Using this parameter, each pixel value in the shadow is corrected using the formula (1) and its new value represents the value that the pixel must have if he isn't in shadow.

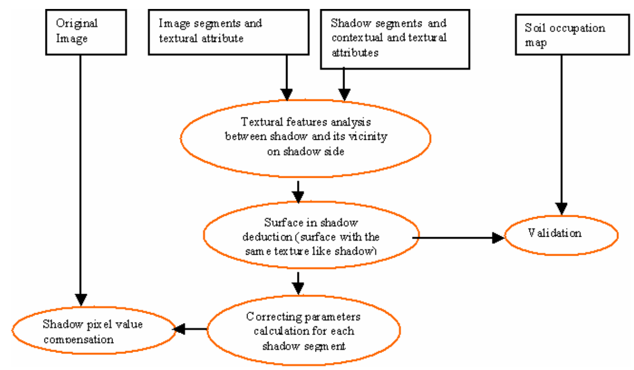

Figure 2: Diagram for information recovery and de-shadowing.

4. DATA AND SITE OF STUDY

4.1 Site study

The site study area is the town of Sherbrooke, selected for the availability of IKONOS images. Two sites were retained for their different characteristics. The first site is the Western Campus of the University of Sherbrooke, with large buildings for collective use. The density of the buildings is low and the presence of shade is well highlighted beside the various buildings. The second site is selected in the town centre, with buildings of various sizes and of different use (trade, utility services, residences, etc). The density of the frame on this site is rather strong.

4.2 Data characteristics

Ikonos images (panchromatic and mutlispectral) covering the city of Sherbrooke were acquired on May 20, 2001. We retain the panchromatic image for this study, because it is the most affected by shadow effects. So, the panchromatic image covering these two sites were extracted for testing the methods. The image was acquired by a very clearly atmosphere and do not need atmospheric correction. The image are georeferenced for calculating the shadow sides orientation to be compared to the sun azimuth. There is no expressed need for geometric correction for testing the shadow detection method and the restitution of information under shadow. An small extract of the panchromatic Ikonos image from the Sherbrooke University campus is presented at figure 3.
Some ancillary data are provided: The positions of the sun and the sensor (azimuth and rise) at the acquisition time to compare with the shadow sides orientation, the land use map to validate the information under shadow restitution. An shadow map derived by image interpretation is also provided to validate the shadow detection results.

Shadow modifies significantly the value of the signature of a surface. To illustrate how shadow change object signature, we have identified some surfaces (grass, bare soil, roads, asphalt parking, etc.) in shadow and the same surface in sun light. In table 1, we present the signature (minimum, maximum, mean and standard deviation) of the surfaces in sun light and in shadow to illustrate how shadow can modify that values.

	Sun light surface				**Shadow surface**			
	Mini	Maxi	Mean	deviation	Mini	Maxi	Mean	deviation
Grass	441	584	520	23,17	124	198	149	12,61
Asphalt (Road)	348	529	420	18,08	127	223	145	16,86
Asphalt(parking)	398	534	464	12,55	133	228	149	21,9
Bare Soil	299	475	386	42,76	130	294	157	27,93
cemented way	451	815	585	73	122	228	147	19,89

Table1 : signatures in shadow and sunlight of some surfaces.

Figure 3: Ikonos panchromatic image of a part of the Sherbrooke University Campus

5. RESULTS

Results from the detection method and the information in shadow restitution are presented and analysed.

5.1 Shadow detection results

Shadow detection method is applied to the campus image. Only the final results of detected shadow are presented in the figure 5. For detailled results indcating the contribution of different attribute used in the methodology can be founded in (Amani et al, 2003). The shadow detection results from this method are evalueted by comparison to the shadow inetrpretation map (figure 4). The overal shadow detection precision on the all campus image is about 91%.

Comparing shadow detection results presented in figure 5 to the shadowed zones detected by image-inetrepretation (figure 4) indicate a very good detection. All the building shadow area are well detected. Dark area with low value considered as potential shadow regions are rejected when the form and orientation attributes are used. The use of compactness attribute permit also to eliminate some trees shadow.

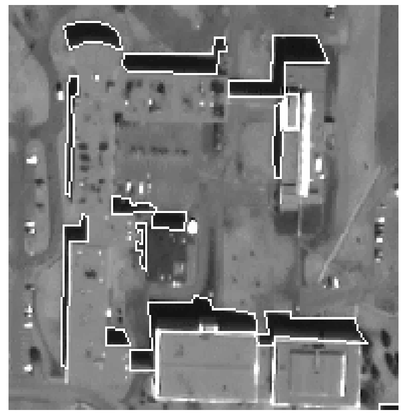

Figure 4: Shadow area from an image interpretation

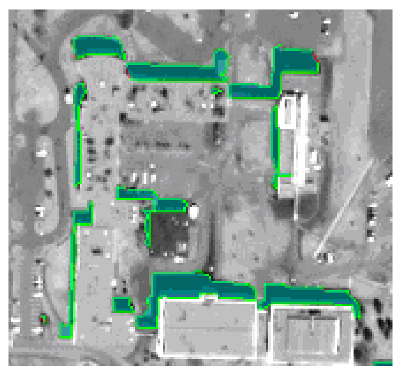

Figure 5: Shadow detection results by the method

5.2 Information restitution results

After the shadow detection, the information recovery method was applied to the campus data. The method use as input : the shadow detected segments, their sub-segments and their neighbouring segments in the shadow side and the original Ikonos image information for texture attribute computing.
Five basic texture features from Haralick (Definiens, 2002) parameters are used and evaluetad : energy, entropy, contraste, homogenity and correlation.
For each texture feature, the neighboour segment with a texture value close to the sadow segment is identified. The result is evaluated by using land use map and ground data. Among the five texture features, the contraste and homogenity give the best results after validation on the soil occupation map.
Results from the contraste texture feature are presented at figure 6. The neighbouring segments with the same texture as shadow segment are in black color.

Some difficulties for calculating the segment texture are related to the size and form of some segments. Few segments are very small and texture on that segments is not significant or is not well computed. Other difficulties are related to the texture at segment borders and the heterogenety inside segment due to the very high spatial resolution.

The shadow effects compensation on image is done on each shadow segment. The gamma compensation parameter is calculated for each shadow segment and all pixels in shadow are corrected using the gamma parameter and its value in shadow. Some results of shadow compensation are presented on figure 7 . The de-shadowed images are visually untached. The only drawback is on the shadow transition area between the shadow and other surounding surfaces.

Figure 6 :Neighbouring segments with the same texture as shadow segment using the contraste texture feature

6. CONCLUSION

The contribution of the contextual and geometric attibues in the shadow detection method is very important. The results are a precise buildings shadow detection on the panchromatic Ikonos images.

The information under shadow retrieval is quite possible using the contextual and texture attributes of shadow and its neighbouring segments. The results are very promizing and have a great potential of application to correct shadow negative effects on images. Results can also be used to complete land use map derived from the very high spatial resolution images

To increase the information retrieval precision, more investigations on the texture attributes computing are recommanded.

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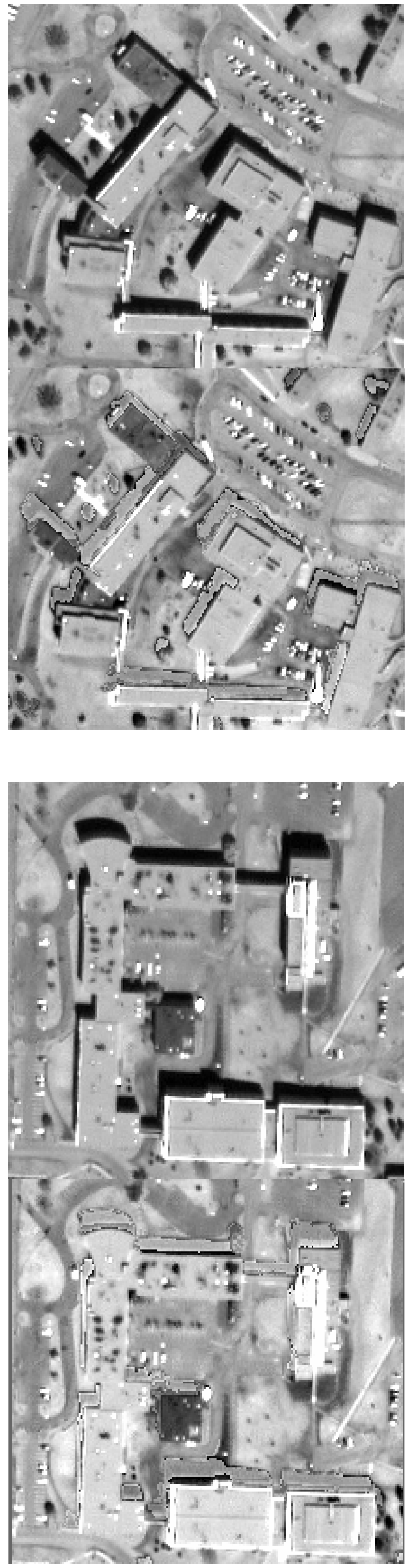

(a) . Blocs 1-7 image with shadow

(b). Blocs 1-7 deshadowed image

(c) Sciences Faculty Bloc image

(d). Sciences Faculty Bloc de-shadowed image

Figure 7 : Shadow and de-shadowed images

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