

# RESEARCH ON THE BUILDING SHADOW EXTRACTION AND ELIMINATION METHOD

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## ABSTRACT:

This paper first generalizes the significance and present research situation of the building shadow extraction and elimination method. Then, an approach of automatic extracting shadows of building from remote sensing image is proposed, which based on the method that grey level statistics is done in one side of the structure lines. The approach, which combines constraints of grey level, geometry and context, and others assistant information, realizes the shadow extraction of buildings. Finally the IKONOS images are experimented to extract shadows of building. Results of the experiment show that this approach is effective and robust.

## 1. INTRODUCTION

Shadow in remote sensing image is conflict information in computer image processing. On the one hand, it can reduce the successful rate of edge extraction, object recognition, image matching, change detection and other processing for the corresponding ground objects in the shadow (Wang et al, 2002; Yan li et al, 2004). On the other hand, it can produce a great deal of useful information about shape, relative position, surface character and other characters of the object generating shadow (Barnes et al, 1999; Ortega et al, 1998; Yang et al, 2002). It is a necessary step to eliminate shadow and restore the scenes in the shadow area before performing object recognition and image matching tasks for the shadow area. Therefore, it is of vital importance and keen interest to discuss and investigate the shadow extraction and elimination technique.

Research on the shadow extraction is few in remote sensing field. Only the research on the tall object recognition (Lin et al, 1998) shadow elimination and shadow compensation (Wang et al, 2002; Yan li et al, 2004; Amani et al, 2004) are carried out. One kind of shadow extraction methods is carried through detection of histogram peak value at present because the grey value of shadow is very low in all visible wave bands (Nagao et al, 1979). But this method can not deal with some complex situations. Statistics of pixel grey values along the structure line is the second kind of shadow extraction methods. But the extraction result of this method depends on the credibility of shadow edge extraction result. When the credibility of shadow edge extraction result is low, shadow extraction will not achieve an accurate result. The building shadow extraction under the multi-constraints is another class of method (Amani et al, 2004; Rau et al, 2000; Babu et al, 2004 ). These constraints consist of the grey condition, the geometrical condition, context condition and other auxiliary information condition. But this method is difficult to carry out and its algorithm is very complex.

Shadow elimination or shadow compensation is often carried out after shadow extraction. The methods of shadow elimination or shadow compensation mainly conclude adjusting light and contrast (Rau et al, 2000), using illuminating model and contextual texture consistency analysis (Amani et al, 2004). Simply adjust the brightness and contrast of the image can approve the image quality, but shadow elimination effect usually is not very good. There are methods restoring the shadows in satellite images using illuminating model. However it can not be copied to aerial images, because camera height for aerial imagery is much lower than satellite imagery, the material feature of the ground object affects to its intensity in the image. When the texture information of shadow area is not consistent with that of its neighborhood, the method contextual texture consistency analysis can not deal with.

In the paper, a comprehensive analysis and discussion is carried out on the present commonly used building shadow extraction methods. Then based on the statistics shadow detection method that detects the shadow area through the statistical analysis and calculation of pixel grey values along the structure line, a new building shadow extraction method under the multilateral constraints is put forward. The new method realizes the shadow extraction by combining the grey constraint, the geometrical constraint, the context constraint and other auxiliary information.

Shadow elimination method is also studied in the paper. First, the pixel grey value of the interior area of the shadow and that of the surrounding region along the shadow edge are statistically calculated and analyzed (Yan li et al, 2004). And then the transform parameter between the interior region and the surrounding area are reckoned through gamma transform. Finally the shadow is eliminated through gamma transform method and the scenes in the shadow are restored.

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## 2. THE BUILDING SHADOW EXTRACTION UNDER MULTI-CONSTRAINTS

### 2.1 Two Directions Determination

Two directions determination means deciding the direction of the building vertical edges and that of the shadow edges of vertical buildings by the auxiliary information.

In projective geometry, parallel lines in real scene converge to one point in image, which is called vanishing-point. Since all vertical edges of the building are parallel, they must have the intersection point in the image. In the frame image, the direction of the building vertical edge can be decided through the image nadir, whose coordinates can be calculated through the image's exterior elements. For the other types of images, the determination of the building vertical edge is relatively more complex. Take the IKONOS image for example, while approximately vertical photography is done, the direction of the vertical edge can be approximately decided by the center point of each scan line. Other conditions, the direction of the vertical edge can be approximately decided by the angle elements of exterior orientation.

Major buildings' shadows, especially the vertical building's shadows have the same direction in the image, which is also just the direction of sunlight. In other words, the direction of the shadow edges of vertical buildings accord with the sunlight direction. So the edge of shadow at the sunlight direction can be extracted first, and then building shadow can be extracted by calculating grey pixels along the structure line statically. Most satellite remote sensing data provide sun azimuth and zenith angle in the header file. For the aero remote sensing image, the direction of sunlight can be decided by the imaging time and the position of the imaged area.

### 2.2 Edge Detection by Canny Operation

After the direction of the building vertical edges and that of the shadow edges of vertical buildings are decided, useful edge detectors can be utilized to detect edges along these two directions.

The canny operator is set up upon the optimal detection rule, the optimal detection rule and the mono-response rule. It can achieve good balance between noise restrain and edge detection and is the optimal choice for step edge under white noise contamination (J F Canny,1986).

To avoid interruption from unnecessary edges and facilitate the subsequent edge extraction, the Canny operator is applied at not the all direction but only the direction of the building vertical edges and that of the shadow edges of vertical buildings.

### 2.3 Straight Edge Track under Constraints

Since the Canny operator has detected edges along these two critical directions, the subsequent work is to track and extract these detected edges using the straight edge track algorithm.

For example, if the edge has " $\theta$ " angle to the positive direction of the "x" axis, the slanting ratio of the edge line can be deduced from " $\theta$ ". Supposing the line equation is " $y = k_0x + b$ ", then " $b = y - k_0x$ ". For any given

image, the range of "b" is easily drawn, " $b_{\min} \leq b \leq b_{\max}$ ", but "b" is treated as an integer during real track. The detailed track procedures are listed as follows.

(1) For a given "b" and slanting ratio " $k_0$ ", a "y" value can be calculated from the equation " $y = k_0x + b$ ". During the first iteration, "b" is set to be " $b_{\min}$ ". Make a judgement on the calculated value "(x,y)" to see whether the point "(x,y)" is the feature point. If it is the feature point, note the value as the first value and the current tracking point, else abandon it and increase the number of "x" by one, until find the first feature point.

(2) Increase the "x" by one, you can get another point "(x,y)". Under if the circumstance that the newly tracking point is known, the distance "D1" between point "(x,y)" and the newly tracking point is larger than the threshold value "d1" and the distance "D2" between the first tracking point and the newly tracking point is larger than the threshold value "d2", the line between the first tracking point and the current tracking point is traced out and is saved. If "D2" is no larger than threshold "d2", abandon the line. As long as "D1" is larger than the threshold value "d1", set the marking "flag=1" and be prepared to trace another line. Make judgment on the point (x,y) and its eight neighbourhood points to see if they are feature points. As long as one of these nine points is the feature point, take it as the current tracking point. Moreover, if "flag=1" is satisfied at the same time, set this new feature point as the starting point of the new line and make "flag=0".

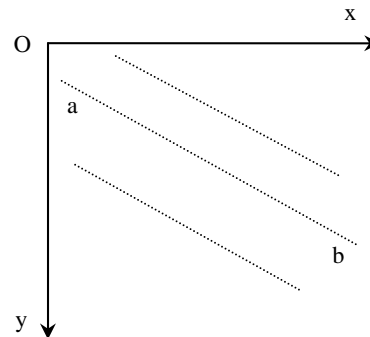


Figure 1. Straight edge track under constraints

(3) Continue step (2) until the value of "x" equals to the width of the image. Trace out all the lines (" $k = k_0, b = b$ ") whose length are greater than the threshold value "d2".

(4) Increment b by one, and repeat step (1), (2) and (3) to trace out all the lines with " $k = k_0$ " whose length are greater than the threshold "d2".

(5) Repeat step (4) until " $b = b_{\max}$ ". Trace out all the lines with " $k = k_0$ " whose length are greater than the threshold "d2".

All the edges can be successfully traced out, whose length are great the threshold value along the direction of the building

vertical edges and that of the shadow edges of vertical buildings.

#### 2.4 Assessment on the Shadow Division Threshold

After tracking out the shadow edge of the vertical buildings using the operator of “the straight edge track under constraints”, the shadow division threshold is assessed. This procedure is composed of two steps which are eliminated the pseudo shadow edges and statistically calculating the grey pixels along the shadow edge.

##### (1) Elimination of the pseudo shadow edge.

The line edges at the vertical building extracted out in the above procedure are not all the shadow edges in fact which maybe roads at this direction, or the building edge. To assess the shadow separation threshold accurately, pseudo shadow edges must be eliminated out. Four constraints are combined to eliminate pseudo shadow edges and keep real ones.

The first constraint is that great difference should exist between grey values of pixels at two sides along the shadow edges. In the experiment the threshold for the pixel grey value difference is set to be one half the image grey variance. The edges with similar grey pixel at two sides will be eliminated out using the constraint, for example, the linear road.

The second constraint deems that the length of the shadow edge should not be too large whose threshold value is set to be the ratio between the real distance in the field and size of image pixel. Through this constraint too long linear roads and railroads will be excluded out.

The third constraint supposes that the shadow edges, especially that of tall buildings will not be too over-dense. In the experiment it is deemed that there will not exist more than two edges in the certain distance at the direction right to the shadow direction. Over dense edges, such as roads and railroads in the high resolution image can be excluded out through this approach.

The fourth constraint is the context information, which assumes the building vertical edges exist near the anti-sun side of the shadow edges, especially for the tall buildings. This constraint can be used as auxiliary rule to exclude pseudo shadow edge which is most advantageous for tall buildings. Moreover the grey constraint that the grey pixel value near the shadow edge at the anti-sun side is generally larger than that of the shadow can also be used to exclude pseudo shadow edge.

These four constraints mainly consider the grey constraint, the geometrical constraint and context constraint.

##### (2) Statistical calculation of pixel grey values at one side of the shadow edge.

After exclusion of pseudo shadow edges, the remained edges are mostly that of shadow, which are called the supposed edges. Statistical calculation is reformed on the pixels with smaller grey values in the certain width along the supposed edge. The width is related to the size of the pixel. Try to find out the peak grey level  $g_{\max}$  in the histogram, and calculate the total grey variance  $\sigma_0$ . Then treat the pixels whose grey values are

smaller than  $g_{\max} + k_1\sigma_0$  ( $k_1 = 1.5$  in the experiment) as samples and do further calculation of the average value  $\mu$  and the variance  $\sigma$  on these samples. In this approach, the false shadow pixels along the edge will be excluded out and only the true shadow pixels are remained for statistical calculation. Finally the grey threshold for the shadow separation is decided as  $\mu + k\sigma$  ( $k_1 = 1.6$  in the experiment).

#### 2.5 Verification of Shadow Extraction Results

Binary separation is performed area based on the above assessed grey threshold. But perhaps the separated interested area is composed of not only the shadows but also the water areas and vegetations with smaller grey. Therefore false shadow areas need to be further excluded out through the verification of the extraction results. After validation, only real shadow areas will be kept. Before validation, speckle reduction and region division will be carried out firstly in the AOI (Area of interesting). Theoretically, region division can be carried out from any point in the adjacent area to the shadow and towards any direction. But it is difficult to realize in algorithm. In the experiment, region division mainly starts from the direction of sunlight (in Figure 2). Then region marking is done to find the belonging of the pixels and give the peculiar sign of the region. The 8-neighbourhood region marking algorithm is taken. Finally the contour of the region is extracted out.

There are three rules for judging whether the region belongs to the shadow area. The first rule is that the area of the region is not too large and the length of the region along the sunlit direction is too long. The threshold of the area is decided upon the image resolution. The threshold of the length takes the pixels length corresponding to room in the field. The second rule is that certain boundaries of the region accord with the sunlit direction and there exists extracted building vertical edges in the anti-sunlit side near the region. The 3rd rule is that the average grey value of certain pixels in the anti-sunlit side near the region is obviously larger than the average grey value of the shadow.

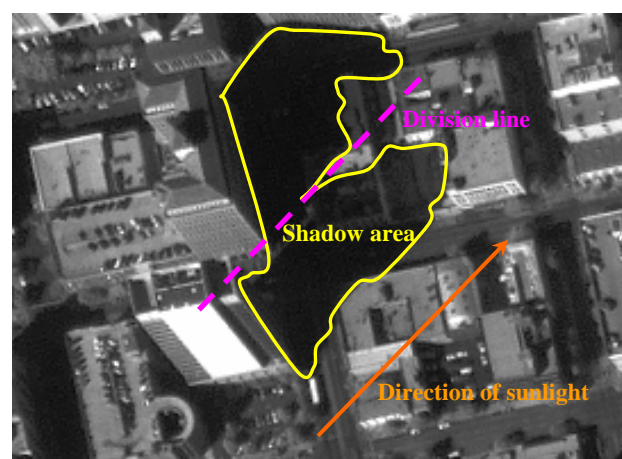


Figure 2. Division for the adjacent areas of shadow

### 3. ELIMINATION OF BUILDING SHADOW

The building shadow elimination method studied in the paper is based upon the Companion Area Intensity Mapping Method (CAIM)(Yan Li et al,2001). The first step of the CAIM method is to make sure the companion area of the shadow, which is usually taken as the frontal area of the shadow area. This area lies before the shadow projection direction, such as picture (a) in Figure 3. The writer observes that the two lines of shadow lateral sides are usually parallel to the sunlit direction. So in the paper the companion area is chosen upon this characteristic, such as picture (b) in Figure 3. As more regions adjacent to the shadow area are taken as companion area, the grey property will be more close to that of the area not overlaid by the shadow.

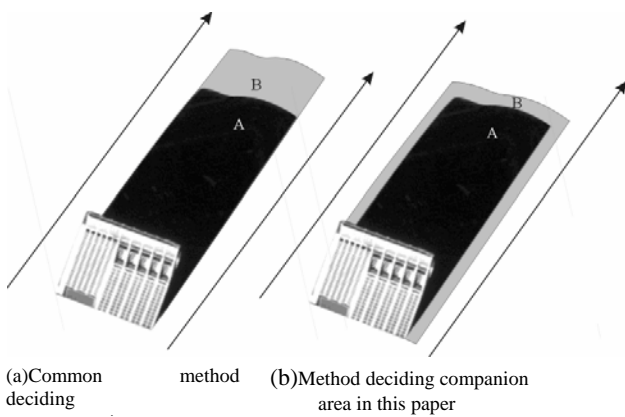


Figure 3. Comparison of method deciding companion area

Where A is shadow area  
 B is companion area of the shadow area  
 → is shadow projection direction

After deciding the area, grey properties of region A and B should be calculated out for gamma transform, which will adjust grey values of shadow. The gamma transform parameters can be computed by putting the average grey values of A and B into the gamma transform equation.

$$Outpixel = 2047 * (Inpixel / 2047)^m \quad (1)$$

Where Outpixel = the grey value after shadow elimination  
 Inpixel = the grey value before shadow elimination  
 m = parameter

Parameter m can be calculated by putting the average grey value of A and B into equation (1). Then the whole shadow region can be restored by calculating the grey value after elimination from that before elimination.

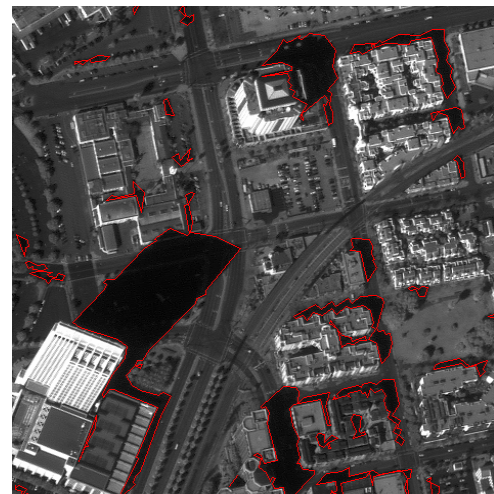
### 4. EXPERIMENT AND CONCLUSION

In Experiment, the building shadow extraction is done with several IKONOS images and high resolution aerial images. The shadow extraction results of one IKONOS image are shown in figure 4. The shadow extraction results of the other IKONOS image are shown in figure 5. Picture (a) in Figure 4 and 5 is

original IKONOS image. Picture (b) is the shadow extraction results. Picture (c) is the shadow elimination results. Results of the experiment show that this approach is effective and robust.



(a)Original IKONOS image



(b)Shadow extraction result

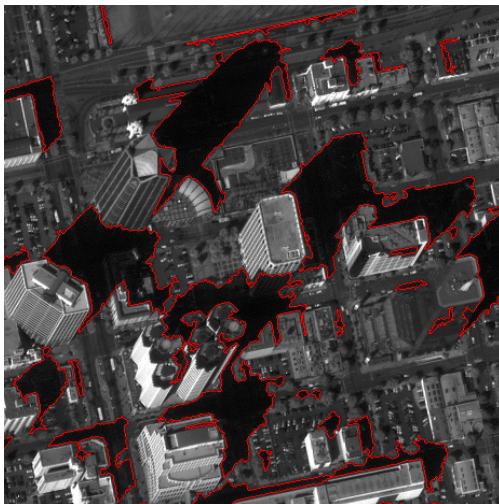


(c) Shadow elimination result

Figure 4. The shadow extraction and elimination results of one IKONOS image



(a)Original IKONOS image



(b)Shadow extraction result



(c)Shadow elimination result

Figure 5. The shadow extraction and elimination results of the other IKONOS image

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