A Review: Shadow Treatments and Uses Researches in Satellite Images

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Abstract:

In this historical survey, we have reviewed researches of shadow phenomenon in satellite images since the beginning of the need for treatment and interpretation in remote sensing. Because remote sensing enters into many applications and is shared with many sciences, studies on the phenomenon of shadows have been conducted with in different ways. In this review, we attempted to link the evolution of remote sensing techniques with growing resolution of space images as research progresses in the treatment of shadows, because the evolution of space sensor abilities sure increases the options for the interpreter and processor of the satellite image in remote sensing and other purposes. There were also problems that appeared only with the emergence of high-resolution satellite images (0.6 meters) such as the problem of the semi-shadow region. Some researches included some weaknesses and limitations that could not be comprehensive for all satellite images, for all regions of the earth, or for all target shadows.

Keywords: Remote Sensing, Satellite Images, Shado.

أستعراض: البحوث المستخدمة لمعالجة الظل في الصور الفضائية

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الخلاصة:

قد استعرضنا في هذا الاستقصاء التاريخي للبحوث المتعلقة بدراسة ظاهرة الظل في الصور الفضائية منذ ظهور الحاجة إلى معالجة ظاهرة الظل والاستفادة منها للتفسير في حقل التحسس النائي. ولأن الاستشعار عن بعد يدخل في العديد من التطبيقات ويشترك في العديد من العلوم، فقد أجريت دراسات عن ظاهرة الظلال بطرق مختلفة. في هذا الاستعراض التأريخي، حاولنا ربط تطور تقنيات الاستشعار عن بعد والتطور المتزايد في الصور الفضائية مع تقدم البحوث في معالجة ظاهرة الظلال، لأن تطور قدرات المتحسسات الفضائية بالتأكيد سيزيد من خيارات مفسّر صور الأقمار الاصطناعية ومعالجها في أغراض التحسس النائي وفي أغراض أخرى. وكانت هناك أيضا مشاكل لم تظهر إلا مع ظهور الصور الفضائية عالية الدقة (0.6 متر) مثل مشكلة منطقة شبه الظل. وشملت بعض البحوث بعض نقاط الضعف والمحددات التي تظهر في حالات خاصة لا يمكن أن تكون شاملة لجميع الصور الأقمار الاصطناعية، أو لجميع مناطق الأرض، أو لجميع الظلال التي تظهر مع الأهداف المرصودة في الصور الفضائية.

الكلمات المفتاحية: الاستشعار عن بعد، صور الأقمار الاصطناعية، الظل.

1. Introduction

The Shadow is a natural phenomenon that resulting from a lack of lighting and concealing in certain areas because of the presence of blinded bodies which prevent these areas from an optical source.

The shadows appear clearly in satellite images when there are a distinctively high blinded objects because of the rays of the sun fall diagonally on targets during the satellite sensors observation [1].

The dark shadow area and a few lighting, dramatically, causing an ability loss of distinguishing monuments located in the shadow area, which means a number of problems in understanding the contents of the image.

The advantage of shadow is when there is a need to know some forms of discrimination especially knowledge about the height, which is not shown in satellite images because of the upper imaging or near-top of the satellite sensors.

There are so many parameters affect the shadows opacity and its boarders [2]. So it has become difficult to treat the shadow area in a simple software, and complex to solve the problems by only arising the value of shadow color information.

2. The Development of resolution in major remote sensors generations

The procedure of shadow treatments can be applied on any proper image, which is just to know certain variables such as spatial resolution, and imaging time (relate to cross equator time). There are several satellite sensors that provide images that can cover whole the Earth surface in adequate properties, like Landsat, SOPT, IKONOS, or QuickBird satellites [3].

2.1. Landsat Series (1 to 8)

The Landsat system has five sensors: RBV^m, RBV^p, MSS, TM, and ETM+ [4].

The **Return Beam Vidicon (RBV^m)**: and RBV^p are used in Landsat 1, 2, and 3, both are panchromatic. They are television camera images earth's surface along the satellite track ground [4]. The resolution of RBV sensor is 40×40 m.

The **Multispectral Scanner (MSS)**: is the principle sensor in Landsat 1, 2, 3, 4, and 5. They are same four bands in Landsat 1,2 and five Landsat 3. The spatial resolution of MSS sensor is 79×97 m.

The **Thematic Mapper (TM)**: it is as MSS device but has improved mechanically, in spectral bands and spatial resolution. It has seven bands with narrower bands than MSS. The spatial resolution of TM sensor is 15 × 15 for panchromatic, 30 × 30 m for visible range, and 60×60 m for thermal infrared.

Table (1) illustrates the date of launch and the resolution of Landsat sensors.

Table (1) Landsat Satellite Specifications[5].

Launch date	Landsat 1 : 23 July 1972 (ERTS 1) Landsat 2 : 22 January 1975 Landsat 3 : 5 March 1978 Landsat 4 : 16 July 1982 Landsat 5 : 1 March 1984 Landsat 6 : 5 October 1993 (failed) Landsat 7 : 15 April 1999 Landsat 8 : 11 February 2013
Orbit	705 +/- 5 km (at the equator) sun-synchronous
Orbit inclination	98.2 +/- 0.15
Orbit period	98.9 minutes

Grounding track repeat cycle	16 days (233 orbits)
Resolution	15 to 90 meters

2.2. SPOT

SPOT is stand for (French: Satellite Pour l'Observation de la Terre, lit. "Satellite for observation of Earth") [6] is a commercial high-resolution optical imaging Earth observation satellite system operating from space. It was initiated by the CNES (Centre national d'études spatiales – the French space agency) in the 1970s.

High-Resolution Visible (HRV) sensors: it is a multi spectral sensor consists of five bands, with ground swath 60 km for the single HRV sensor, the total swath of the two sensors is 117 km with 3 km overlap [5].

Table (2) HRV Specifications [5].

Band (μm)	color	Resolution
0.51 - 0.73	Panchromatic	2.5 & 5 M
0.50 -0.59	Green	10 m
0.61-0.68	Red	10 m
0.79-0.89	Near IR	10 m
5- 1.58 - 1.73	Mid IR	20 m

High Resolution Geometrical instrument (HRG): is the other sensor used with SPOT 5 and up. It offers a high resolution of 10 m in multispectral mode, 2.5 to 5 m in panchromatic mode, and 20 m on short wave infrared[4].

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2.3. QuickBird Satellite Sensor:

QuickBird is a high resolution earth observation satellite, launched in 2001. The resolution of QuickBird is 0.61 m (panchromatic) and 2.44-1.63 m (multispectral).

QuickBird I was launched in November 2000, but it failed to reach it's orbit. QuickBird II launched on October 18, 2001 [4].

Table (3) QuickBird Satellite Sensor [4]

Launch Date	October 18, 2001
Equator Crossing Time	10:30 AM (descending node)
Metric Accuracy	23 meter horizontal (CE90)
Resolution	Pan: 65 cm (nadir) to 73 cm (20° off-nadir) MS: 2.62 m (nadir) to 2.90 m (20° off-nadir)
Image Bands	Pan: 450-900 nm Blue: 450-520 nm Green: 520-600 nm Red: 630-690 nm Near IR: 760-900 nm

2.4. IKONOS Satellite

IKONOS Satellite is a commercial high-resolution Earth observation satellite, it was firstly designed to collect publicly available imagery at 1- and 4-meter resolution. It offers multispectral and panchromatic image [5].

Table (4) IKONOS Satellite Sensor Characteristics [5].

Launch Date	24 September 1999 at Vandenberg Air Force Base, California, USA
Operational Life	Over 7 years
Orbit	98.1 degree, sun synchronous
Altitude	681 kilometers
Resolution at Nadir	0.82 meters panchromatic; 3.28 meters multispectral
Resolution 26° Off-Nadir	1.0 meter panchromatic; 4.0 meters multispectral
Equator Crossing Time	Nominally 10:30 AM solar time
Image Bands	Panchromatic, blue, green, red, near IR

3. Shadows in the big objects and the low-resolution satellite image

In modern research papers, the satellite images that captured by the sensors (MSS, TM, and SPOT) called low-resolution image, because of the resolution of it's recognition fluctuates between (10-30). With compared to the modern high-resolution sensors (0.6 m quality). It is like (IKONOS and QuickBird) satellite sensors that launched in 2001 and other satellites with the same high resolution. Also, In the low-resolution satellite images shadows do not appear directly, and big objects (Mountains, Clouds, Big Building…) shadows appear only in it. This kind of shadows does not cause problems for it's width, and the opacity can be reduced because of the reflection occurs between the atmosphere and dust particles [6].

3.1. Clouds

Clouds cover everything located under them, and they affect thermal imaging significantly because of the low temperature of the cloud. Clouds cover huge areas of the earth's surface and cause serious problems for satellite imaging[7]. The cloud shadow is used sometimes to find cloud height, because the clouds rise up for several kilometers above the earth surface and it's height can be measured from satellite images, because it is very important for the air navigation, As well as the best practical methods are represented by devices on the ground for doing the same task (measuring the cloud height).

The simple way to remove the cloud shadows was by comparing the image that contains the cloud by another image that does not, and compensate for the hidden regions as **Lau B. Theng, 2014** [8] did, but this method doesn't consider a real processing for the clouds shadow.

There are many early attempts to correct the distortion that is caused by the clouds and developing a filter for satellite image as **Mitchell et. al., 1977** [9] and then **Z.K. Liu et. al. 1984** [10] and later **B. Chanda et. al., 1991** [11] where they added improvements for the distorted images which is caused by the thin cloud shadow, which do not cover the earth completely to compensate the damaged regions in the satellite images.

Cihlar et. al., 1994 suggested an improvement and applied it in AVHRR [12], **J. Simpson and J. Stitt, 1998** suggested an improvement on Landsat satellite image [13], as **Caselles et. al, 1989** relied on the multi-dates image to control the effect of the shadow of the cloud [14], and **Salmahn Mill et. al, 2014** tried to improve the origin damage image (Based Image) with the help of another image for the same region (auxiliary images) with a simple algorithm [15].

All of these methods do not compensate for the real loss of optical response but leads to the production of a complete affected scene of the satellite image. where **M. Joseph Hughes and Daniel J. Hayes, 2014** were satisfied in determines the shadow regions resulting from clouds using single satellite image and nonlinear simple algorithm [16]. There are other researchers have developed other ways to deal with the shadow area by special algorithms [17-21].

3.2. The shadows of the mountains

Because of the lack of urban and agricultural areas around the mountains, and because of the satellite imaging is almost 45-degree angle under the mountain, a shadow appears only in very steep mountains. The shadows of the great mountains are large size, which introduces a number of optical and environmental factors to influence the shape and boarders of the shadow[22]. **Iosif Vorovencii, 2006** studied the impact of mountain shadows on nearby areas and process it by comparing it with unshadowed areas by noting the effete of shadow on lighting the earth variation of illumination [23].

3.3. Big Buildings

The building's shape is usually formal with cross-section and top view, but there is some buildings could be nonformal or non-polygonal buildings in it's cross-section and that causes the sophistication of shadow shape because of the shadow is 2D and the building is 3D.

High buildings cause shadows on the ground and the shadows are darker near the building edge. The shape of the shadow can be determined if the building is cute and the ground is equal plane as **Hong-Gyoo Sohn and Kong-Hyun Yun, 2008** did when they studied the impact of mountains and high buildings [24] on airplane colored images, they developed a simple algorithm to determine the shadow based on a simple engineering method, and **Wenxuan Shi and Jie Li, 2012** used airplane image to determine the shadow of small buildings and he tried to compensate the shadow area by increase the amount of light, and that in fact does not really compensate the missing ray response information. In addition, research in the processing of the shadows of the buildings in satellite images with low resolution is few because of the futility of those processors to extract ground information in cities, and because of the emergence of high-resolution images and it's existence [25]. .

4. The form of shadow in high-resolution images

Small shadows disappear in images of low resolution (10-30 meters or less), if we had a single pixel of the satellite image, which is on the ground (10 meters or more) and if there were shadows in those small area of the region, the shadow will disappear in the total irradiance value of that region and do not usually appear.

In the high resolution images the small shadows appear clearly within the limits of 0.6 meters, and the very small shadows is not important in the remote sensing purposes usually, and do not cause major problems.

After the development of high-resolution satellite sensors (QuickBird, IKONOS, and other) in 2001 and later, many researches addressed the problems resulting from the shadows and these researches are trying to take advantage of the shadows in identifying landmarks emerged like [16-22] [24-25].

5. Treatment of shadow in the high-resolution images

Shadow causes the disappearance of a large proportion of the data which are located in the shaded area in the image, so some features can not be distinguished [26]. Also the shadow may be similar in radiance response with other features like asphalt and such landuse, this will cause additional problems in image classification due to the overlapping between the shadow and other similar features .

So, many researches are provided to determine the shadow area, remove or processes it to retrieve the original colors of the shaded area., like [23, 24, 31, 35].

6. Take advantage of the shadow to determine the characteristics of objects with shadows

In the high-resolution images, shadow can be considered as an independent feature, because it can easily be distinguished chromatically; due to the high opacity. The first advantage of the shadow is in gaining the third dimension of large objects (height), a dimension that does not appear due to the top imaging or upper view of the satellite.

There are natural factors used to calculating the height, such as azimuth angle of the sun that are normally approach for (45^o) at the time of imaging, making it easier to rise from the shadows trigonometric equation known account, noting the shape of the ground, which is located under the shadow.

Won Seok, et. al, 2007 used geometric method for calculating the third dimension of objects from a single satellite image of the adoption of the key elements in the system (angle of the sun, scale of the image, and the direction of the shadow), and added to it supposed element is the angle of satellite [27].

Won Seok, 2007, followed in this work **C. Lin and R. Nevatia**, **1998**, who adopted a more complex algorithms to produce a three-dimensional model of a two-dimensional image [28].

Also he followed **K. Karantzalos and N. Paragios, 2008**, which was adopted on the ground information as metadata to find the third dimension (height) of objects in a concise manner [29].

V. Arévalo et. al., 2008, determined the shadow in images of high-resolution satellite QuickBird of resolution (0.6 meters), but he said it's a suitable way for images satellites IKONOS and WorldView. In all fixed rate for the angle of the Sun taken, and **V. Arévalo** supposed: it is a very complex to calculate sun angle at over particular day of the year [30].

Yan Li, et. al., 2009 only design algorithms to select shade and remove it from the image without a real compensation for shaded areas [31].

Paul M. Dare, 2005, studied the shadow in urban areas, determine the shadow technique and propose to remove it programmatically [32]. The most important thing in this study is that it pay attention to the problem of semi-shadow area (penumbra). **Paul M. Dare** also concluded that the semi-shadow is resulted from the sun disk width, and he concluded trigonometric equation to calculate the area depends on the angle of the sun, it's width, and height of the building.

And continued to look at the semi-shadow area, analyze the optical nature for shadow and distribute it trying to determine the shadow strongly and the abolition of semi-shadow area digital manner as did **Jiahang Liu, et. al., 2011** [33] by a very complex algorithm.

Jyothisree V. and Smitha Dharan, **2013,** offered step in the color analysis of shadow, concluded that the possibility of identifying shadow more accurately by a histogram equalization of the image and increase the contrast according to histogram distribution [34], but this study was applied to simple pictures not to satellite images.

The analysis of semi-shadow area and different techniques were invented as in the study of **G. Gayathri, 2015**, in his way to remove the shadow from the satellite image [35].

Sarita A. Ingale, Dr.Karbhari V. Kale, 2015 tried to remove the noise in the shadow area by multi-classifications operations frequently [36].

7. Make use of the oblique view in SPOT satellites

SPOT Satellite has its own advantage served on the topic of the shadows and is its ability to imaging in oblique angle (± 27^o) about the vertical axis, and provides portability oblique vision the ability to large swath (about 900 km)[3].

Another advantage to the oblique view is the lateral imaging of three-dimensional objects, which also provides another element in calculating the height of the building in side of the shadow, which is the side view of the apparent high objects.

Won Seok, et. al, 2007, suppose satellite inclination as it mentioned previously [27], except that the only application of this assumption is slanted vision of the SPOT satellites.

V. Arévalo, et. al., 2008, used the side images to produce a stereoscopic vision to produce the third dimension (height) of the two satellite images [30], which also supports the ability to infer height of the building from the shadows.

Using Satellite Images SPOT **V. K. Shettigara & G. M. Sumerling, 1998,** calculated the height of the trees and buildings, and succeeded in calculating the height of the buildings accurately, while were not high accuracy in the calculation of tree height results due to informal form of trees [37].

Dominik Brunner, et. al. 2009, used images of (VHR SAR) sensor in the SPOT satellite to see the height of urban structures, but it is not up to the high accuracy due to the lack of mathematical equations [38].

However, the weak point that leads to a lack of precision in previous researches is neglect the change in the angle of the sun, because the expense of change is very complex [30].

8. Software methods to tackle the shadows and select

Satellite images which are on a digital formats can be inspected, processed, and provide the chance to extract information from them digitally.

Both **Gayatri Gurav et. al., 2014** [39] and **Shibam Das et. al., 2013** [40] numbered some of the methods and algorithms devised by researchers in the shadows to identify and address the shadows. Here, they were addressed for the treatment of shadows in satellite images methods with noting the advantages and disadvantages of them.

As we will review some of the ways used by other researchers, we will display them successively with some other details:

8.1. Seed pixels method

It is devised by **V. Arévalo et. al., 2008,** [30] and used by a numbers of researchers like **Yashpal G. Mul & A.V. Gokhale, 2012** [41].

It is noted that in this method the lighting conditions, the edges of buildings, and the picture color system.

This method needs the choice of points in the lighting area and then put it in the shaded as a seeds, manually select by the user in the image, selection by clicking with the mouse, and then the computer investigated areas related to those points which have the same values in the shadow area and then replaces the color.

It is a fortuitous way that they are highly efficient [42], and the disadvantages they do not work efficiently when there is a high gradation in the shadow area or in the area of lighting, they also need to manual work depends on the user experience in the selection of the points [40].

8.2. Dual-Pass Otsu Method

It is a method based on the choice of a threshold between the shadow and non-shadow region [39] [43] [44] [45], by selecting threshold several times until the shadow area is separated from what environs.

The advantages of this method is that it does not require high technology and software [40], and can be made by simple algorithm in MATLAB.

The disadvantages of the performance is the poorest among other methods [40], and is not efficient in small areas or narrow shadows, and do not work as if the shadow is graded or in gradual noise [46].

8.3. Edge Subtraction and Morphology Method

This method uses Canny edge detection filter to detect "background edge and foreground edge. Resultant edge image is calculated by difference of both background and foreground edge" [40]. This method relies on the efficiency of the Canny filter, but it is used in a large size features and regular geometrically such as cars. The applying to the satellite image leads to pass many small shadows. Also, from the disadvantages, they needs to complicate algorithm to program in the computer [40].

8.4. Contrast reduction methods

The contrast reduction method are the ways that depend on reducing the contrast between the shadow region and neighbor pixels, which lead to the technical removal for shadow only, not compensate for the lost information by only a small percent, **Odell & Weinman, 1975,** [47].

It relies on prior knowledge about the intensity of lighting in the vicinity resulting from the strength of the sun lighting [48]. As well as the method needs to complicated algorithms.

8.5. Snake filter method

It is a method in image processing used to determine the forms of features single color, based on the statistical method of pixels and investigate different color value to determine the difference in the color [49].

This method allows to efficiently determine the limits of the shadows and quickly neglect the complexity of software. But it does not work very well in the graded shadows or with big noise [50].

Lau Bee Theng, 2006 applied filter snake in determining the shape of the buildings, and this filter was still potent when applied to irregular shapes [51].

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