

# Aerial Image Series Quality Assessment

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**Abstract.** With the growing demand for geospatial data, the aerial imagery with high spatial, spectral, and temporal resolution achieves great development. It is imperative to evaluate whether the acquired images are qualified enough, since the further image mosaic asks for strict time consistency and a re-flight involves considerable resources. In this paper, we address the problem of quick aerial image series quality assessment. An image series quality analysis system is proposed, which includes single image quality assessment, image series quality assessment based on the image matching, and offering a visual matching result in real time for human validation when the computer achieves dubious results. For two images, the affine matrix is different for different parts of images, especially for images of wide field. Therefore we calculate transfer matrixes by using even-distributed control points from different image parts with the RANSAC technology, and use the image rotation angle for image mosaic for human validation. Extensive experiments conducted on aerial images show that the proposed method can obtain similar results with experts.

## 1. Introduction

The aerial remote sensing is a major component of remote sensing research, which achieves rapid development. Compared to the satellite remote sensing, the aerial imagery has many advantages, e.g. high spatial and spectral resolution, high time frequency, and flexible. The aerial image is widely used for tactical assessment and planning purposes.

As we known, present geospatial applications usually ask for high quality series of aerial images, which ask for high quality for single image and strict consistency among images. However, many factors (e.g., climate, environment, pitch, roll, and yaw of flight, cloud cover, overexposure, and so on) may affect the quality of images captured by both of the manned and unmanned aerial vehicles. In many cases, images need to be re-shot or additional shot inevitably, which cost extra manpower and material resources. Besides, images captured at different time tend to include larger differences in many respects, e.g., illumination, hue, scale, land appearance and so on. Furthermore, it is impossible to re-shoot or additional shoot sometimes, e.g., real-time reconnaissance and battlefield surveillance. Therefore, it is imperative to evaluate whether the acquired images are qualified enough, since the further image mosaic asks for strict time consistency and a re-flight involves considerable resources. Actually, there are strict rules in airborne remote sensing application, which provide critical standards of image rotation angle, side overlap and forward overlap. For different applications, these criterions are different; however, they still share a lot in common. In general, the image quality includes two aspects: quality of the single image and quality of the image series.

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The image quality assessment is an important step of image processing, and a lot of great research work has been done [1][2][3][4]. However, general image quality assessment methods cannot meet requirements of different images and applications. Regarding the remote sensing image, the quality assessment and image selection is done manually at first. In recent years, some related work has been done about the quality assessment for remote sensing images. Fiete et al [5] analysed the SNR image quality metrics for remote sensing systems by comparing several SNR metrics used in the remote sensing community. Duan et al [6] introduced an image quality evaluation based on image matching for the unmanned aerial vehicles remote sensing system. Wang et al [7] adopted Harris corner to conduct an image geometric quality assessment algorithm.

In this paper, we address the problem of quick image series quality evaluation of the aerial remote sensing image. We propose a general framework for aerial remote sensing image quality assessment, which can be used during the image capturing and is with convenient human-computer interaction function. We design a three-fold quality analysis system to assess the image series quality. The first fold is single image quality assessment. The quality assessment methods for general images and remote sensing images can be used. Specific candidate is according to the actual situation. The second fold calculates transformation matrixes between adjacent image pairs based on SIFT descriptor and RANSAC with uniform distributed control points. The matrix is used to assess the consistency of the image pair. If the predefined criterion is not met, the image series is quality dissatisfaction, and related region needs re-shoot. The third fold offers a visual matching result for human validation when the computer achieves dubious results. Since the mosaicked image is for manual validation, we just rotate one image in the image plane according to the image rotation angle and mosaic it with the other image.

## 2. The proposed quality assessment framework

Although research on image quality assessment has been done for a long time, still no definition of quality is universally accepted. Actually, the definition of image quality depends on specific kind of images and application [8]. Same situation is met for the remote sensing image analysis. In this work, for the aerial image series quality assessment, we define the quality as two aspects: the single image quality and the quality of adjacent image pairs. Therefore, the proposed quality assessment framework is composed three parts: 1) Single image quality assessment. The quality assessment methods are according to the actual situation. We use the sharpness, Human Vision based SNR, and cloud cover ratio as three quality parameters. 2) Image series quality assessment. The transformation matrix between adjacent image pairs are calculated based on SIFT descriptor, and the matrix is used to assess the consistency of the image pair. 3) Offering a visual matching result in real time for human computer interaction. The final validation is given by human when the computer achieves dubious results (the rotation angle for two images in the image plan is quite large).

### 2.1. Single image quality assessment

**2.1.1. Sharpness.** The sharpness is one of most important parameters to assess the digital image quality, which determines the amount of detail an image can convey. For the remote sensing image quality assessment, a lot of work adopt the EAV model  $P = \sum_a^b (df/dx)^2 / |f(b) - f(a)|$ , where  $df/dx$  is the gray gradient in the perpendicular direction of edge, and  $f(b) - f(a)$  is the overall gray level change in the corresponding direction. In the field, the improved EAV are calculated using all pixels in image considering 8-neighbour pixels [9]. We will use the SIFT descriptor which emphasizes the principal direction, so we propose an improved EAV, as

$$P_{extra} = \lambda_1 \frac{\sum_{i=1}^{H*W} \sum_{a=1}^8 |dI/dx|}{H*W} + \lambda_2 \frac{\sum_{i=1}^{H*W} \max_{a=1}^8 |dI/dx|}{H*W} \quad (1)$$

where  $\lambda_1$  and  $\lambda_2$  are two coefficient,  $\lambda_1 = \lambda_2 = 0.5$  in our experiments,  $dI/dx$  is gray gradient of image  $I(j, k)$ ,  $(1 \leq j \leq H, 1 \leq k \leq W)$ .

**2.1.2. Human Vision based SNR.** To assess the image quality by the Signal Noise Ratio (SNR) in a blind way, we adopted the Human Vision Signal Noise Ratio (HVSNR) introduced in [10]. The HVSNR is based on the Contrast Sensitivity Function (CSF) founded by Mannos et al [11]. Given an image  $I(j, k)$ , the HVSNR is calculated as

$$HVSNR = 10 \log_{10} \frac{255^2}{K} \quad (2)$$

$$K = \frac{\sum_{j=1}^H \sum_{k=1}^W Q(j, k) S(j, k)}{H * W}$$

where  $Q$  is the contrast sensitivity weights map of the image and calculated by using the CSF  $Q(f) \approx 2.6[0.0192 + 0.114f] \exp[-(0.114f)^{1.1}]$  [11], and  $f$  is calculated as (normalized to [0,60])

$$f(j, k) = \sqrt{\frac{1}{mn} \left\{ \sum_{j=2}^m \sum_{k=2}^n [I(j, k) - I(j, k-1)]^2 + \sum_{j=2}^m \sum_{k=1}^n [I(j, k) - I(j-1, k)]^2 \right\}}, m=4, n=4 \quad (3)$$

$S$  is noise points distribution in image, and calculated as follow

$$S(j, k) = \begin{cases} 1, & \text{if } \min(|g_0(j, k)|, |g_{90}(j, k)|, |g_{45}(j, k)|, |g_{135}(j, k)|) > th \\ 0, & \text{else} \end{cases} \quad (4)$$

where  $th$  is a predefined threshold (50 in this work),  $g_i(j, k)$  are gradients in  $i$  degree directions.

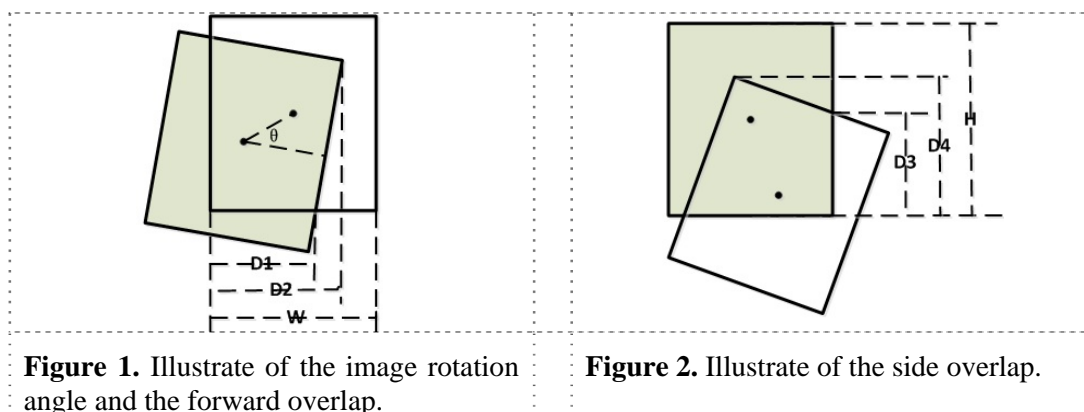
**2.1.3. Cloud Cover Ratio.** It is generally known that the cloud in aerial images can seriously influence the image quality. The thick cloud keeps out the ground situation which causes information loss. Even more, large piece of cloud may result in useless images. Therefore, we include calculating the cloud cover ratio as a necessary step of our single image quality assessment. We use our previews cloud detection method [12] to detect cloud, then, calculate the proportion of the area covered by cloud in one image as cloud cover ratio. If the ratio is larger than a predefined threshold, the image quality is low. This color based approach cannot detect thin cloud regions which are translucent relative to underlying surfaces, and highlighted earth surfaces may also be detected. However, these mistakes do not influence the result of image quality assessment, since the thin cloud influence little and some highlighted regions are low quality.

## 2.2. Image series quality assessment

The image series quality assessment focuses on measure the spatial location relationship of images in series with overlap, which are defined as adjacent images. In this work, for the image matching, we employ the SIFT descriptor based method [13]. Considering characteristics of large scale aerial images (very large area, large distortion in a single image, and similar texture distribution in different images), we use the RANSAC technology [14] with additional descriptor selection. The descriptor selection makes the used matching points distribution in an image as average as possible, since the overlap of image pairs are not too narrow. So one matching point is kept in a small image region ( $32 \times 32$  pixels

in our experiments), while other points are abandoned to equilibrium the global density of matching points in one image. This strategy prevents algorithm over-fitting caused by local region with dense matching points. Then, we calculate three parameters for image series quality assessment. The image rotation angle  $\theta$  is shown in Figure 1. The forward overlap is  $FO = \min(D1, D2)/W \times 100\%$ , as shown in Figure 1. The side overlap is  $SO = \min(D3, D4)/H \times 100\%$ , as shown in Figure 2.

For a fully automated image quality assessment process, if the one of the following situation is met, the image quality system will ask image re-shoot. The failed situation includes: the image rotation angle is larger than a threshold ( $15^\circ$ ); the side overlap is less than a threshold (50%); if the forward overlap is less than a threshold (50%). For a manned system, to verify the quality assessment results of in a human-computer interaction way, our system will present a warning if  $\theta > 15^\circ$ .



**Figure 1.** Illustrate of the image rotation angle and the forward overlap.

**Figure 2.** Illustrate of the side overlap.

### 2.3. Image mosaics in real time

Most of image mosaics methods adopt the RANSAC technology to calculate affine transfer matrix. However, for two images, the affine matrix is different for different parts in the image, especially for images with multiple views and wide field. The traditional matching and mosaics methods may lead unbalance distortion to the mosaicked image. Therefore, we propose a novel method to mosaic images. There are two possible ways. The first is to calculate several affine transfer matrixes for different image parts, named as multi control points, and use the mean of them for image mosaic. The second is to use the image rotation angle calculated in Section 2 for mosaics. In order to speed up, the second one is adopted in our system. Without whole image transformation, we rotate one image in the image plan according to image rotation angle and mosaic it with the other image, since the mosaicked image is just for manual validation. This strategy costs little computing and avoids large image distortion.

## 3. Experiments and Results

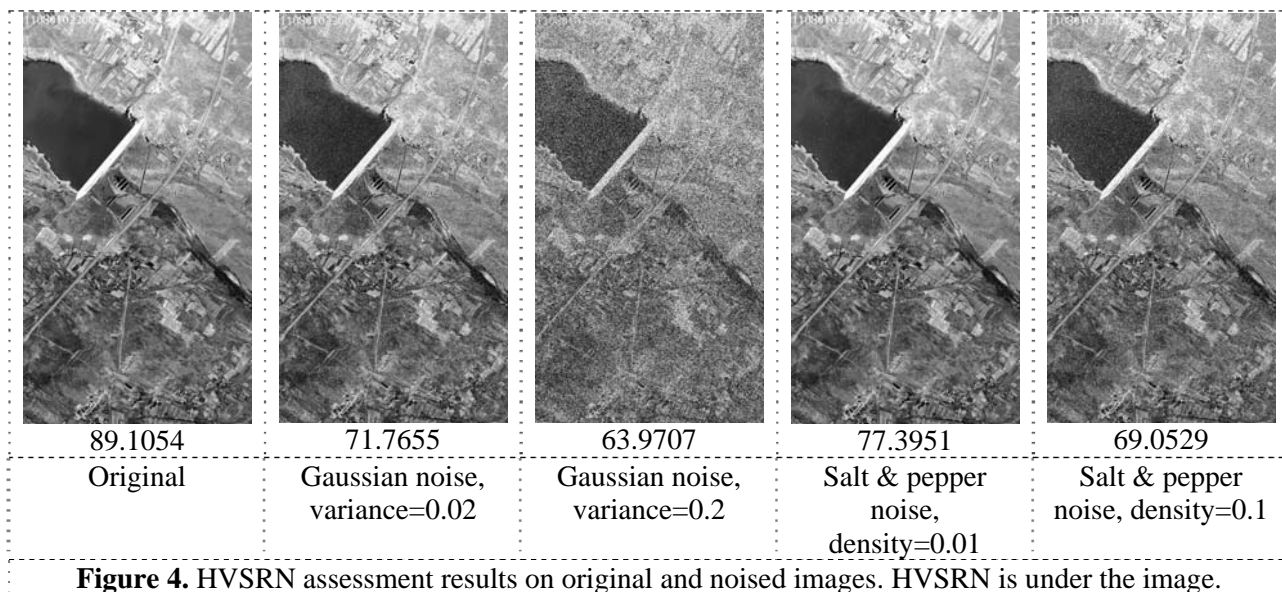
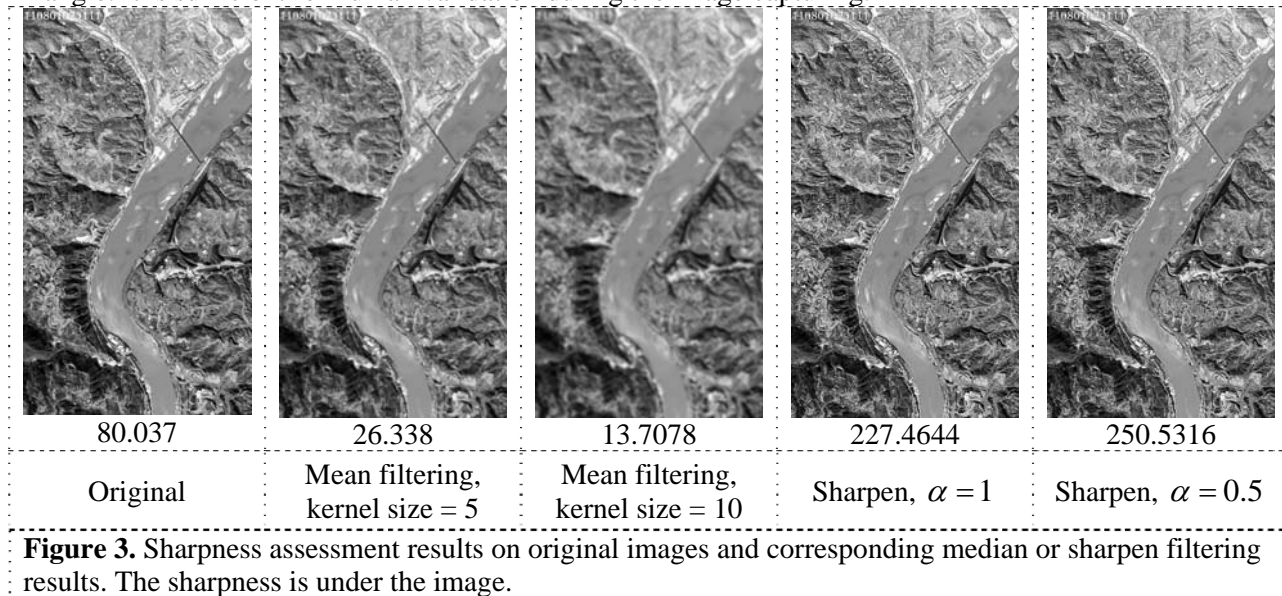
Experiments are conducted a selection of aerial images from three different places, and these three series are named as S1, S2 and S3. Color images are converted into gray images and down sample by a factor of 0.25.

Firstly, we show results on simulative low quality images. The sharpness assessment method is tested on original images and corresponding median filtering or sharpen filtering results. Some examples are shown in Figure 3. Then, we add noises to images and test the HVSRN method. Some examples are shown in Figure 4. Please refer to [12] for more details about cloud ratio.

Secondly, details and results of image series quality assessment experiments are shown in Table 1. If the angle difference of the image rotation angle calculated by algorithm and by human is larger than  $5^\circ$ , the result is regarded as an error one. The error rate is the ratio of the number of error and the number of same flight track image pairs. The failed matching rate is the ratio of the number of failed matching and the number of image pairs. Most image pairs achieve good matching, which meets actual situation of these image series. For image pairs with rotation angle larger than  $15^\circ$ , human

validation gives similar results for most of times. Experimental results demonstrate that the proposed method can obtain similar results with experts. However, these are some failed matching image pairs, some of these mistakes may be caused by down sampling or due to the limitation of the method.

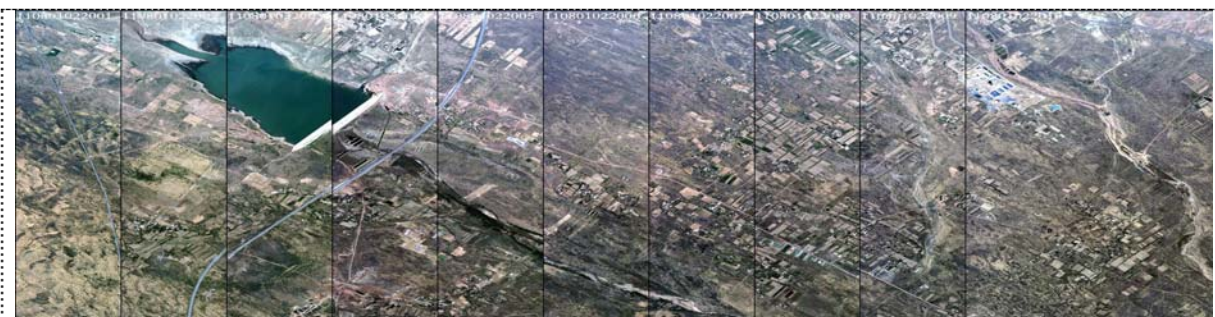
Thirdly, Figure 5 shows a mosaic result of several adjacent images based on the image rotation angle. It is sufficient for human validation during the image capturing.



**Table 1. Experimental details and results of image series quality assessment**

	No. of images	No. of flight tracks	No. of adjacent image pairs		No. of image rotation > 15°			Error rate (%)	Failed matching rate (%)
			Same track	Adjacent tracks	Detected	Detection error	Missing error		
<b>S1</b>	348	3	345	233	33	5	2	2.03	0.17
<b>S2</b>	941	22	919	718	57	10	2	1.31	0.37
<b>S3</b>	1070	11	1059	897	86	23	10	2.17	1.38





**Figure 5.** A mosaic result of several adjacent images based on the image rotation angle.

#### 4. Conclusions

In this work, we propose a general image series quality assessment framework that can be used during the aerial image capturing. The framework considers the single image quality and the adjacent image spatial relationship, and also provides a quick image mosaic method which is suitable for artificial verification. Experiments illustrate that the effectiveness of the framework. The proposed real time human interactive quality assessment method is used in the practical work of commercial mapping application and increases effective and efficiency of the digital cartography system.

#### Reference

- [1] Wang Z., Boyik A C Sheikh H R and Simoncelli E P 2004 Image Quality Assessment: From Error Visibility to Structural Similarity *IEEE Transactions on Image Processing*. **13**(4) 600-612
- [2] Eskicioglu A M and Fisher P S 1995 Image Quality Measures and Their Performance *IEEE Transactions on Communications* **43**(12) 2959-2965
- [3] Pappas T N and Safranek J 2000 Perceptual Criteria for Image Quality Evaluation *Handbook of Image and Video Processing* 669-684
- [4] Li X 2002 Blind image quality assessment *Proceedings of 2002 International Conference on Image Processing*. **1** 449-452
- [5] Fiete R D and Tantolo T 2001 Comparison of SNR Image Quality Metrics for Remote Sensing Systems *Optical Engineering* **40**(4) 574-585
- [6] Duan F and Zhao W 2009 Method of Aerial Remotely Sensing Image Quality Evaluation Based on Image Match Science of Surveying and Mapping **35**(6) 57-58
- [7] WANG M, YANG S and WU Q 2011 A Geometric Quality Assessment Algorithm of Remote Sensing Image Based on Corner Detection *Acta Geodaetica et Cartographica Sinica* **40**(2) 175-179
- [8] Janssen T. and Blommaert F 2000 A Computational Approach to Image Quality Displays **21**(4) 129-142
- [9] Qang H, Zhong W, Wang J and Xia D 2004 Research of Measurement for Digital Image Definition *Journal of Image and Graphics* **9**(7) 828-831
- [10] Guo B, Zhang Z and He Y 2009 Blind Image Quality Assessment Based on Property of Human Vision System *Journal of Military Communications Technology* **30**(1) 76-80
- [11] Mannos J and Sakrison D 1974 The Effect of A Visual Fidelity Criterion on The Encoding of Images *IEEE Transactions on Inform Theory* **20**(2) 525-536
- [12] Li B and Li X 2012 Cloud Detection Based on Segmentation with Statistical and Geometry Features *Proceedings of 2012 IGARSS* 6020-6023
- [13] Lowe D G 2004 Distinctive Image Features From Scale-invariant Keypoints *International Journal of Computer Vision* **60**(2) 91-100
- [14] Fischler M A and Bolles R C. 1981 Random Sample Consensus: A Paradigm for Model Fitting with Applications to Image Automated Cartography *Communication of the ACM* **24**(6) 381-395