AUTOMATED IMAGE INTERPRETABILITY ASSESSMENT BY EDGE PROFILE ANALYSIS OF NATURAL TARGETS

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ABSTRACT

While ground sampling distance has been misleadingly used as the most popular measure of image quality among image providers, satellite manufacturers and general public, user community may be keen to the interpretability of remotely sensed imagery. As one measure of image interpretability, the NIIRS (National Imagery Interpretability Rating Scale) has been used. Currently, this measure is included in the metadata of some high resolution satellite images. Traditionally, the NIIRS is estimated by deploying specially made tarps of uniform reflectance. Due to this, estimating NIIRS is costly and not carried out often. Our previous study evaluated the possibility of using natural targets available in the image for NIIRS estimation. The purpose of this study is to automate the NIIRS estimation by extracting and analyzing edge profiles of natural targets automatically. First we apply simple edge selection criteria for finding good candidates for edge profile analysis. Then we scan through perpendicular to edge directions around the candidate point for constructing edge profiles. From edge profiles, parameters for the GIQE and NIIRS are calculated. We compared the NIIRS values obtained through automated edge analysis with the values from human operators and with the NIIRS values provided in the image metadata. The results showed that automated NIIRS estimation provided comparable results to the NIIRS from manual edge selection. This indicates that NIIRS values can be estimated for all images without special arrangement. The contribution of this study is that we provided the feasibility of the automated edge analysis method for calculating NIIRS values so that the value of NIIRS is systematically calculated at satellite ground stations.

INTRODUCTION

High resolution images, from satellites or airplanes, are becoming an indispensible infrastructure of this internet-driven information world. They are now everywhere and easily accessible by general public. Many commercial entities provide high resolution imagery of the Earth surface globally or locally. More and more satellites are being launched to acquire up-to-date high resolution images of the Earth. Many new airborne imaging sensors are being developed and utilized.

While the accessibility of high resolution images is increasing, the quality aspects of them are not being addressed sufficiently. Image quality can be expressed by many technical terms, ground sampling distance (GSD) being probably the most popular one. This term specifies the distance between the locations of two adjacent image pixels projected onto the Earth surface. For well-designed imaging devices, this can indicate to some extent the resolving power of images. However this is not an ultimate parameter to describe 'quality' of images. Images with same GSD, for example, may have very different interpretability. More sophisticated terms such as modular transfer function (MTF) or signal to noise ratio (SNR) can be used. However they are mainly for technical people such as satellite manufacturers, optical engineers or electric engineers. Image users may not understand the effects of them on image quality and may not judge how good or bad an image will be from a MTF or SNR number.

For this reason, NIIRS (National Imagery Interpretability Rating Scale) has been proposed as a measure of image quality in terms of interpretability (IRARS, 1996). NIIRS describes interpretability of images by numbers ranging from 0 to 9. At each level, NIIRS defines objects that should be able to observe within images. NIIRS defines observation objects for military targets originally and it extends the definition of observation objects for man-made and natural targets. For example, at NIIRS level 4 one should be able to detect basketball court, tennis court and valley ball court in urban areas and at NIIRS level 5 identify tents larger than for two persons at established recreational camping areas and distinguish between stands of coniferous and deciduous trees during leaf-off condition (IRARS, 1996). For satellite images at 1m GSD, NIIRS level of 4.5 is known to be nominal. In users point of view NIIRS is probably the best measure of determining the goodness of images with respect to interpretability. For this reason, NIIRS numbers are provided within the metadata of high resolution images such as Quickbird.

In principle, NIIRS is to be estimated by human operators: Trained and certified operators observe features in an image and judge a NIIRS value. Research has been carried out to relate technical quality measures such as GSD, MTF and SNR to NIIRS through regression analysis. As a result general image quality equation (GIQE) was proposed (Leachtenauer *et* al., 1997). GIQE estimates NIIRS from parameters such as GSD, edge response, which is related to MTF, and SNR. GIQE enables NIIRS estimation using the analysis of technical parameters, alleviating the necessity of manual observation of human certified experts. More recently studies were carried out to assess NIIRS values of high resolution satellite images after launching the satellites (Helder *et al.*, 2004). For this purpose, specially manufactured artificial targets, two or more tarps of uniform reflectance, were used. Before the satellite pass, tarps were deployed within the field of view of images. Edge response and SNR were estimated by analyzing edge profiles across the boundary between tarps (Ryan *et al.*, 2003). NIIRS values were estimated using GIQE. Previous study also indicated that orientation of tarps should also be specifically arranged to get edge profiles in X- and Y-direction (Ryan *et al.*, 2003)

At authors' affiliations, research was performed to replace the need of artificial targets to any targets present within the images for NIIRS estimation. It was reported that edge points on natural targets such as object or shadow boundaries, measured by human operators, could be used to estimate NIIRS values of images (Kim et al, 2008). The estimated NIIRS values agreed with manually accessed ones and showed meaningful differences among different satellite images. The purpose of this study is to advance the previous research by automating the NIIRS estimation. We replace the manual selection of edge points with automated edge point selection and edge profile generation. Descriptions of processing steps and experiment results are to follow.

AUTOMATIC EDGE PROFILE ANALYSIS

The GIQE for NIIRS estimation can be written as below (Leachtenauer *et al*. 1996).

$$NIIRS = 10.251 - a * \log GSD + b * \log RER - 0.656 * H - 0.344 * \frac{G}{SNR}$$

where RER is regularized edge response, H the overshoot, G noise gain and a and b fixed constants whose values are determined by steepness of edge profile and image type. RER can be calculated by analyzing the slopes of edge profiles within the image. RER represents MTF characteristics of the image (Blonski *et al*., 2006). RER is calculated by the difference of normalized edge responses at +0.5 and -0.5 pixels from the edge center. H is overshoot height of normalized edge response (Blonski *et al*., 2006). SNR can be calculated by analyzing the average and standard deviation of brightness values within the dark and bright sides of an edge profile (Helder at el., 2004). G is the sum of coefficients of MTF correction kernels. For NIIRS estimation, MTF correction kernels and GSD have to be given from outside.

In this paper, we aim to calculate RER, H and SNR from analyzing edge profiles extracted automatically from natural targets. For this purpose the following processing steps were employed. We applied edge filtering in order to select initial edge points and edge orientations. Sobel filters of the size of 5x5 pixels were used. Then image brightness values were sampled along the perpendicular direction to the edge orientation at 0.25 pixel interval. For brightness value interpolation, we used bilinear interpolation. From the interpolated brightness values, normalized edge profiles were extracted. Extracted edge profiles underwent several screening procedures. They were discarded if the brightness difference between the dark and bright side was not sufficient, if there were multiple edge responses, or if dark or bright side of profile showed too high variability.

The significant difference between this and previous approaches, both with artificial targets (Ryan *et al*. 1996) or with natural targets (Kim *et al.*, 2008), lies in the extraction of edge profiles. In previous approaches, edge profiles were extracted for X- and Y-directions separately: RER and H values were estimated in X- and Y-directions separately and they were geometrically averaged (Blonski *et al*., 2006). For this purpose, the deployment of tarps required special angular arrangements. One had to place tarps within certain angles along the satellite pass so that tarp boundaries were appeared near X- and Y-directions within images. In this paper, it was not easy to find edges of good property from natural targets whose edge orientation was near X- or Y-directions. We included edges in every direction for analysis.

RESULTS

We used the following three images for experiments: Quickbird, Ikonos and Kompsat-2 images (figure 1). Table 1 describes the image characteristics. GSD values were taken from the metadata of each image. G values were acquired either from the literature or from email correspondences to image providers.

Quickbird Ikonos Kompsat-2

Figure 1. Images used for experiments of automated NIIRS estimation.

Table 1. The characteristics of images used for experiments

	QB	IK	K2
Acquisition Date	2005. Jan 15	2002. Feb. 7	2007. Feb. 23
Acquisition Area	Taejeon	Taejeon	Damyang
GSD X(m)	0.793	0.9	1.086
GSD Y(m)	0.711	0.96	1.039
G(Noise Gain)	4.16	4.16	2.34

The number of manually selected edge points was 100 for all three images. From automated edge selection, 2000 points for Quikbird, 870 for Ikonos and 1612 for Kompsat-2 images were selected. Edge profiles were extracted for each image and RER, H and SNR were calculated from manual and automatic edge points. Figure 2 shows the edge profiles from manual selection and automatic selection and Table 2 compares the results between the two methods. Results from manually selected points show better image quality for all parameters estimated. This can also be checked from the slope of edge profiles in figure 2. The profiles from automated edge point selection are more oblique than those from manual selection. This indicates more rigorous selection criteria for edge point selection is required.

Nevertheless, NIIRS values from automatically selected edge points were very similar to those from manual selection. In table 2, the last column shows the NIIRS value included in the metadata (for Quickbird) and available in the literature (for IKONOS). These values can be compared with the two NIIRS estimated here. For Kompsat-2 the difference of NIIRS values between the manual and automatic selection was somewhat large. Further investigation on the cause of this is required. Among parameters of GIQE extracted, SNR showed largest deviation between the two methods, although the effects of SNR for NIIRS estimation are not significant. This observation also indicates the requirement of rigorous edge point selection and more precise definition of dark and white sides of an edge profile. Table 2 also includes the column for ground resolvable distance (GRD). This aspect will be explained next.

Further analysis on the extracted edge profiles were carried out. Point spread function (PSF) is one of the fundamental characteristic functions of an imaging system. From edge profiles, PSF can be extracted by simple differentiation. Figure 3 shows the PSF curves for all three images. Similar to the edge profile comparison, PSF curves from manual edge selection show higher and sharper peaks, indicating better resolving power. The width of the two half peak position within a PSF indicates the resolving distance of the image. Table 2 compares the GRD for the two methods.

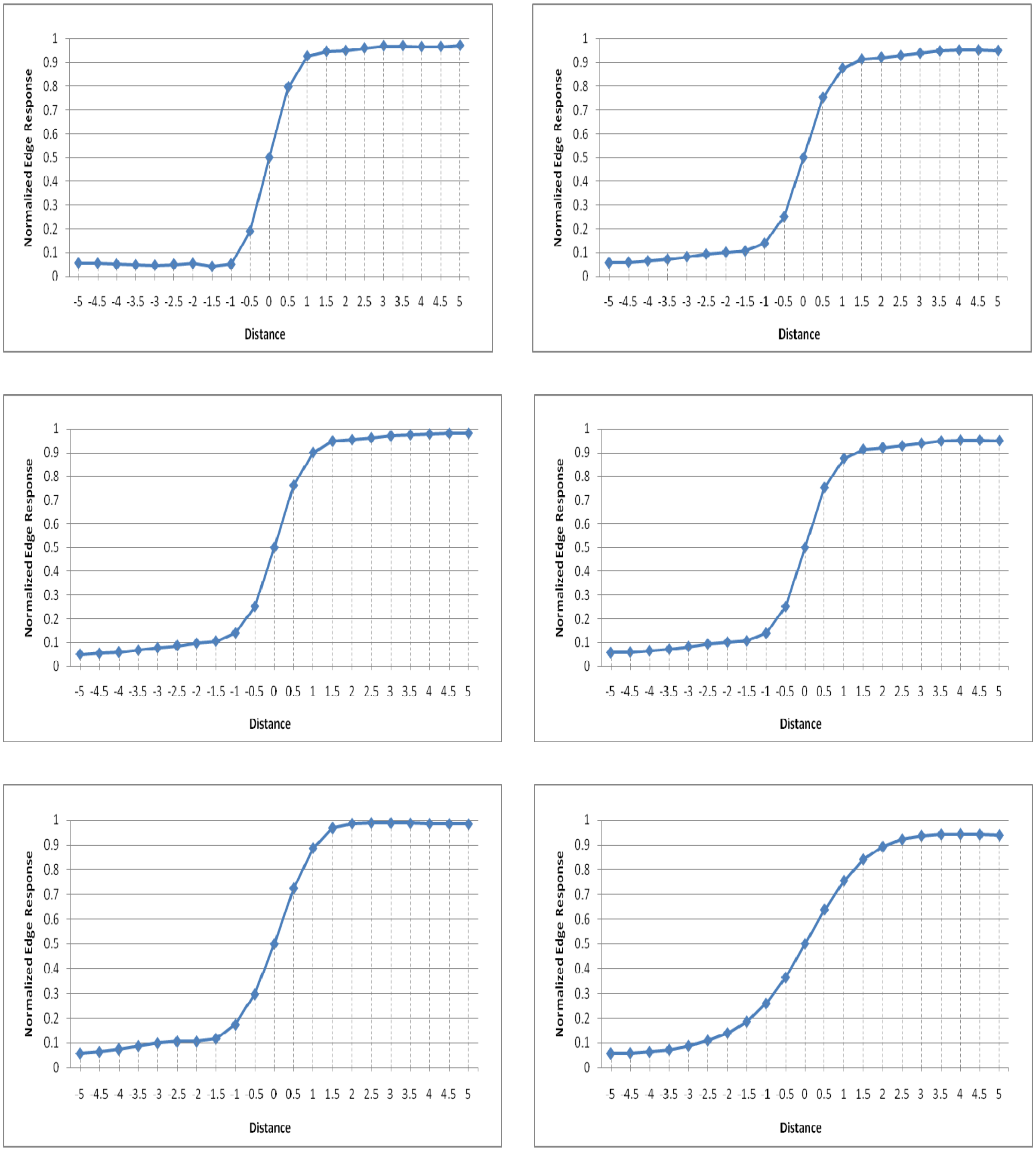

Figure 2. Edge profiles from manual edge selection (left) and automatic edge selection (right) for Quickbird (top), IKONOS (middle) and Kompsat-2 (Bottom).

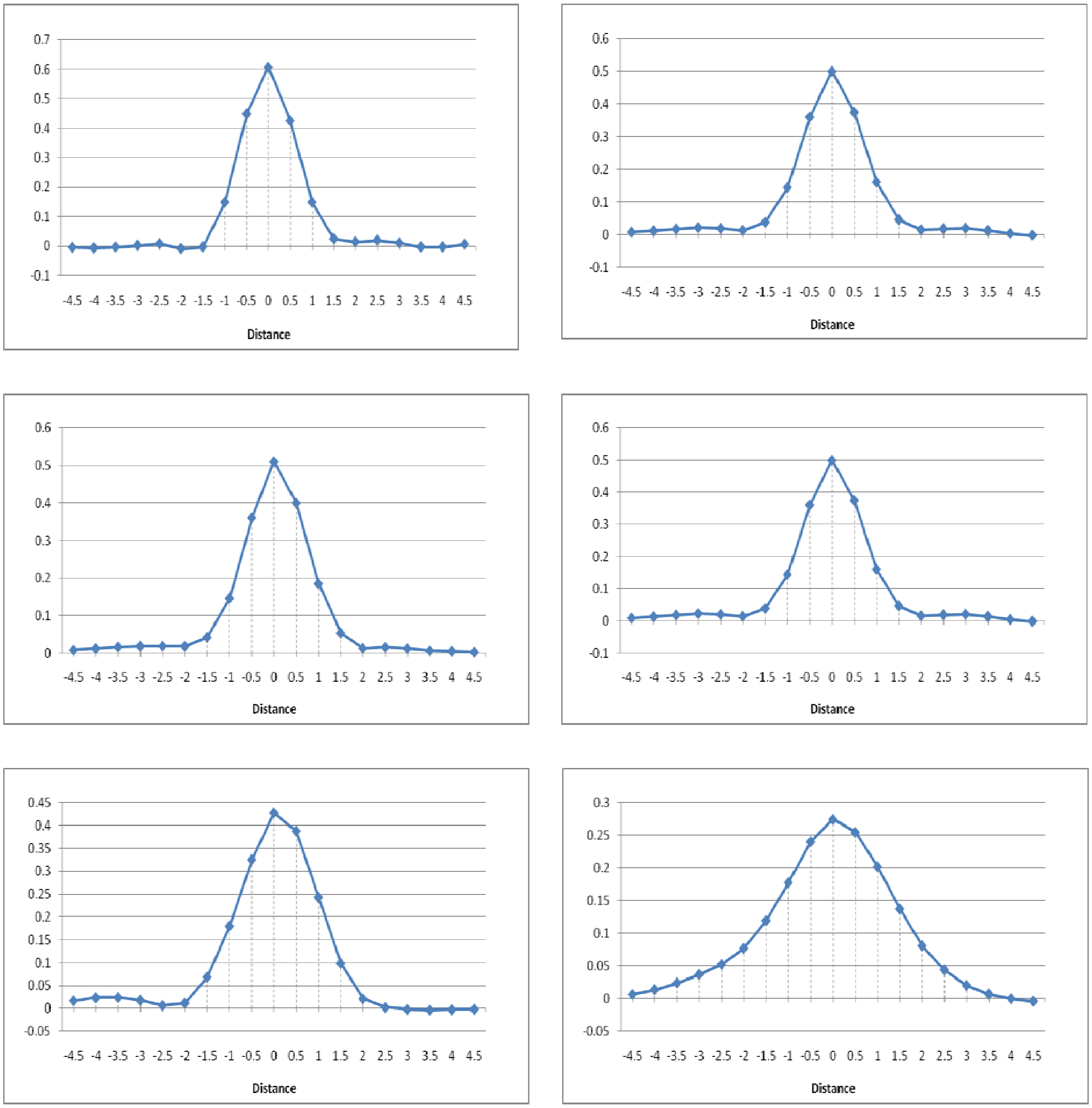

Figure 3. PSF curves from manual edge selection (left) and automatic edge selection (right) for Quickbird (top), IKONOS (middle) and Kompsat-2 (bottom).

Table 2. Results of edge profile extraction and NIIRs estimation. The rows with (1) indicate the results from manually selected edge points and (2) from automatically selected points.

Image		GSD(m)	SNR	RER	H	NIIRS	GRD	published NIIRS
QuickBird	(1)	0.79/0.71	55.0906	0.6079	0.9503	4.3122	1.4778	4.5000
	(2)		34.7102	0.5015	0.9154	4.0336	1.4819	
IKONOS	(1)	0.90/0.96	42.9696	0.5116	0.9440	3.7949	1.8368	4.3000
	(2)		31.9417	0.4409	0.9085	3.6066	1.9488	
Kompsat-2	(1)	1.09/1.04	42.4730	0.4269	0.9502	3.4180	2.2464	
	(2)		25.4691	0.2746	0.8381	3.0641	2.9647	

CONCLUSIONS

This paper reports the experiments for estimating NIIRS by selecting edge points automatically from natural targets. The results show that this approach is comparable to NIIRS estimation from manually selected edge points and that this method can produce feasible NIIRS values. This indicates that NIIRS values can be estimated for all images without special arrangement. The contribution of this study is that we provided the feasibility of the automated edge analysis method for calculating NIIRS values so that the value of NIIRS is systematically calculated at satellite ground stations. The results also indicate that more rigorous edge point selection criteria are required.

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