ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

Estimation of NIIRS, for High Resolution Satellite Images, Using the Simplified GIQE

Eng. Mohamed Ahmed Ali* Dr. Fawzy Eltohamy* Dr. Gouda I. Salama*

Department of Aircraft Electric Equipment, Military Technical College, Cairo, Egypt*

ABSTRACT: The 'quality' of satellite images are expressed by many technical terms such as ground sampling distance (GSD), modulation transfer function (MTF), and signal to noise ratio (SNR) in addition to user community term "National Imagery Interpretability Rating Scale (NIIRS)". Many of the visible and infrared imagery applications such as target acquisition, fire control, target detection, target classification and identification, and Intelligence, Surveillance and Reconnaissance (ISR) tasking's require personnel to interpret the imagery information quickly and accurately. The NIIRS was created to provide a user-friendly metric to define the image quality. It is a 10-level scale that helps analysts to assess quantitatively the quality of images for exploitation. The GIQE was developed specifically as a tool to estimate the NIIRS as a function of imaging system design parameters. It enables system designers to optimize sensor performance to meet a required NIIRS level sought.

In this paper the simplified version of GIQE which includes only 3 terms is briefly described and applied to estimate NIIRS values for different five high resolution remote sensing images acquired by Ikonos-1, WorldView-2, WorldView-3, Pleiades-1A and GeoEye-1 satellites. The results were compared with the published NIIRS values. Results showed that the NIIRS values provided in the literature are very close to that estimated using the simplified GIQE. These results indicate that the simplified GIQE can offer a useful tool for quick assessing image quality of various imaging systems.

KEYWORDS: The National Imagery Interpretability Rating Scale (NIIRS), General Image Quality Equation (GIQE), Relative Edge Response (RER), Ground Sampling Distance (GSD), Signal to Noise Ratio (SNR).

I. INTRODUCTION

The quality of satellite images are expressed by many technical measures such as ground sampling distance (GSD), modulation transfer function (MTF), and signal to noise ratio (SNR). However, these parameters can specify only some aspects of image quality. Besides, these parameters are used mostly by images providers (remote imaging sensors designers). While images users may not understand the exact meaning and moreover they will not understand easily how high quality images will be with GSD, MTF and SNR values [1]. The most of interest for images users is the image interpretability or usability.

For this reason, NIIRS has been proposed as a measure of image quality in terms of interpretability. NIIRS describes interpretability of images by ten levels numbered from 0 (worst quality) to 9 (best quality) [2, 3]. At each level, NIIRS defines objects that should be able to observe within images. NIIRS defines observation of objects for military targets originally and it extends the definition of observation of objects for man-made and natural targets. For example, a satellite image of 1 m GSD has NIIRS level of 4.5 is known to be nominal [1].

Research has been carried out to relate the technical quality measures (GSD, MTF and SNR) to application quality measures such as NIIRS. As a result GIQE was proposed. It estimates NIIRS from GSD, edge response, which is related to MTF, and SNR. Using this equation, we can estimate the interpretability or goodness (quality) of images from technical terms [1, 3].

II. NATIONAL IMAGERY INTERPRETABILITY RATING SCALE (NIIRS)

NIIRS overview and methodology is given in [2]. The initial NIIRS was developed by a government/contractor team in the early 1970's. The team operated under the auspices of the Imagery Resolution Assessment and Reporting Standards (IRARS) Committee of the US Government. Briefly it is an image quality reference scale used by image

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

analysts to perform image evaluation for a variety of tasks such as target detection, classification, identification and acquisition from visible and infrared images. Moreover, the scientific/technical community that conducts research, development and assessment of sensors also uses the NIIRS to assess and evaluate the performance of imaging systems. NIIRS allows the translation of a sensor's outputs into information that is user-friendly and easily understood by military personnel and image analysts, thus providing a more efficient and effective working environment to exploit the imageries [3]. The main advantage of NIIRS is that, it provides a systematic approach to measuring the quality of photographic or digital imagery, the performance of image capture devices, and the effects of image processing algorithms. It has a 10-level scale that helps imagery analysts to perform qualitative assessment of an image.

The GIQE (General Image Quality Equation) was developed to translate the NIIRS values into a set of technical parameters that are useful for designing a desired imaging system. The GIQE predicts NIIRS values as a function a number of parameters such as image resolution, scale, image contrast, post-processing image enhancement and signal-to-noise ratio [3].

III. General Image Quality Equation (GIQE)

The GIQE was developed primarily to estimate the NIIRS for both the visible and infrared images. Studies have been made to extend the GIQE methodology to assess the image quality of Synthetic Aperture Radar (SAR) imagery; but a functional version of the GIQE for SAR imagery has not yet been made available [3, 4, 5, 6]. The GIQE treats three main attributes: scale, expressed as the ground-sampled distance; sharpness, measured from the system modulation transfer function; and the radiance noise as the signal-to-noise ratio. The GIQE estimates NIIRS as a function of Ground Sample Distance (GSD), Relative Edge Response (RER), Signal-to-Noise (SNR), Convolved Gain (G), and Edge Overshoot (H). The GIEQ-version 4 is the current standard operational version; it models the NIIRS values using the mentioned five parameters, and has the form [3, 4]:

$$NIIRS = A_{sys} - a\text{Log}10\ GSD_{GM} + b\text{Log}10\ RER_{GM} - 0.656H_{GM} - 0.344\ (G / SNR) \qquad \text{eq. (1)}$$

Where: Asys = 10.251 for the visible, and Asys = 10.751 for the infrared images. GSDGM is the geometric mean (GM) of ground-sampled distance (GSD) in inches, RERGM is the geometric mean of the relative edge response (RER), HGM is the geometric height of overshoot due to post-processing image sharpening, G is the noise gain due to image enhancement, and SNR is the signal-to-noise ratio. The coefficients $a = 3.32$, $b = 1.559$ if $RER \geq 0.9$, and $a = 3.16$, $b = 2.817$ if $RER < 0.9$.

A sample of 359 visible images and a sample of 372 infrared images with NIIRS values assigned were used in determining the coefficients for the GIQE [3]. One half of the images were used to generate the coefficients; the other half of the images was used to evaluate and validate the GIEQ's prediction performance.

It has been observed that the GIQE predictions are dominated mostly by the parameters GSD and RER [3]. The other parameters H and G in the GIQE have only minor effects on the estimated NIIRS values. It has also been shown that at high G/SNR (> 10), the effect of noise does not influence the estimated NIIRS values very much [7]. Over a range of G/SNR values from 10 to 50, the estimated NIIRS value changes by only about 0.15 with image sharpening. In comparison, the standard error of the estimated NIIRS is 0.3 in GIQE [8]; thus the SNR has a very minor role in predicting the NIIRS. It is reported that the GIQE is not valid when images have a $SNR \leq 3$ [9, 10].

According to the study given in [11], the revised GIQE is validated over the conditioned range of the parameters listed in Table (1). The accuracy and validity of the GIQE outside of these bounds is unknown.

Table 1 Range of parameters values of GIQE

parameter	Min value	Max value
GSD	0.076 [m]	2.032 [m]
RER	0.2	1.3
Overshoot	0.9	1.9
Noise Gain	1	19
SNR	2	130

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

IV. THE SIMPLIFIED VERSION OF THE GIQE

The most effective parameters in the GIQE can be distributed as follows: the Ground Sampling Distance (GSD) represent about (72%), the Relative Edge Response (RER) gives about (20%) and Signal to Noise Ratio (SNR) gives less than (1%) of the total final result [12].

In the equation (1) H is the height over-shoot of the RER parameter caused by image enhancement processing. This is relevant only when image enhancement procedures are applied to the image. The G is the noise gain parameter describing the increase in the image's overall noise as a result of image enhancement. When calculating NIIR, before image enhancement, the value of NIIRS would be function of GSD, RER and SNR only. Hence, an unenhanced pre-processing form of the GIQE for visible/infrared imagery can be expressed, in the simplified form, [3]:

$$NIIRS = 10.251 - a*\log10(GSD) + b*\log10(RER) - 0.344/SNR \qquad \text{eq. (2)}$$

Where the noise gain parameter G is set equal to 1 in the noise term [3] and the edge overshoot parameter H due to image enhancement is removed in equation (2) when image post-processing is not being considered.

GSD for digital cameras is calculated, figure (1), using the following formula:

$$GSD = (h/f)\,x \qquad \text{eq. (3)}$$

Where: his the platform height above the ground, fis the optics focal length, and x is the detector pixel size.

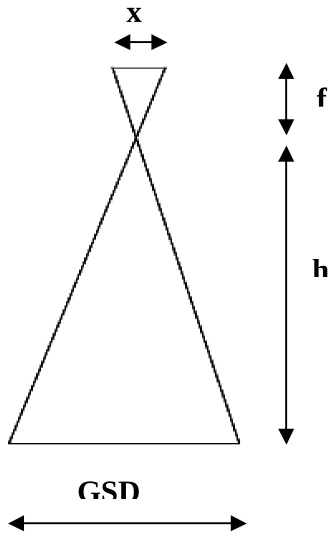

Fig.1 GSD is a function of (h, f, x)

The SNR is one of the elements of the image quality that characterizes the radiometric noise. The image noise quantifies the variation of the radiances at a given radiance level for a uniform landscape. It is defined as [12, 13]

$$SNR = \mu / \sigma \qquad \text{eq. (4)}$$

Where: µis the mean of a series of radiances for a uniform landscape and $\sigma$is the standard deviation of this series.

Relative Edge Response (RER) is a measure of the sharpness of an image and can be calculated by three different techniques [14]:

1- When calibration is possible, RER shall be estimated using slanted-edge method in accordance with ISO 12233.
2- When no calibration is possible, RER shall be estimated using the partial-reference technique.
3- When no partial-reference technique is possible, RER shall be estimated using the no-reference technique described in MISB RP 1203.

In the third technique, the estimation of RER is derived from the Blind blur (BM) metric, the Edge Intensity (EI), the perceptual-RER (PRER), and the Frequency Ratio (FR) as follows [14]:

$$RER(BM) = 1.17 - 1.15*BM \qquad \text{eq. (5)}$$

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

$$RER(EI) = -0.28 + 1.3*(EI/100)^{(1/4)} \quad \text{eq. (6)}$$
$$RER(PRER) = 0.10 + 0.55*Prer \quad \text{eq. (7)}$$
$$RER(FR) = -0.26 + 3*(FR)^{(1/4)} \quad \text{eq. (8)}$$

The no-reference RER estimate is the average of the four individual RER:

$$RER = (RER(BM) + RER(EI) + RER(PRER) + RER(FR)) / 4 \quad \text{eq. (9)}$$

V. Experimental Work

In this experimental work, the values of NIIRS were estimated, using the simplified GIQE, (equation 2), on selected set of five high resolution remote sensing satellites images. For the calculation of the three individual terms of the simplified GIQE, a MATLAB R2010b, 7.11.0 was used. The obtained results were compared with the published values of the corresponding satellites images, given in [15, 16, and 17].

VI. The Set of High Resolution Remote Sensing Images Used

The data set used consists of five different satellite images. "Image-1" is a panchromatic with 1m resolution acquired by Ikonos-1 satellite which was launched in 1999. "Image-2" is a panchromatic with 0.5 m resolution acquired by WorldView-2 satellite which was launched in October 2009. "Image-3" is a panchromatic with 0.3 m resolution acquired by WorldView-3 satellite which was launched in 2014. Image-4 is a panchromatic with 0.5 m resolution acquired by GeoEye-1 satellite which was launched in September 2008. Image-5 is a panchromatic with 0.5 m resolution acquired by Pleiades-1A satellite which was launched in December 2011 Figure (2) shows the selected images data set [18]. Table (2) gives the characteristics of these images.

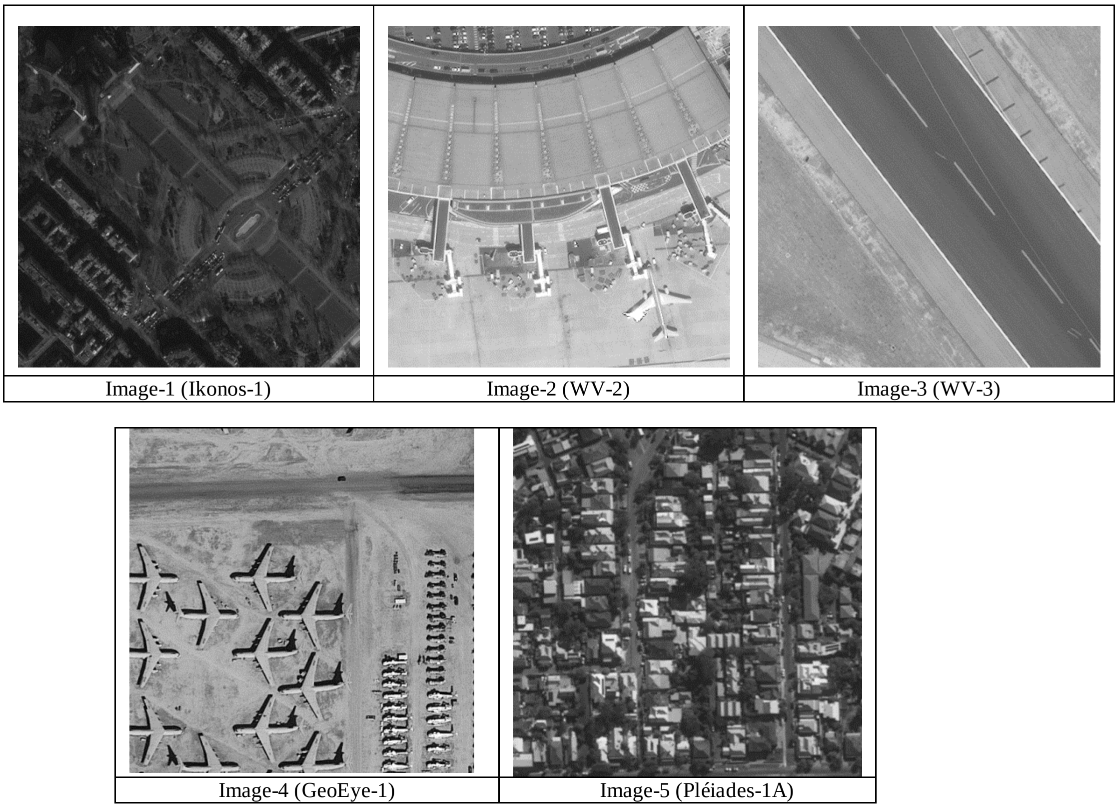

Image-1 (Ikonos-1) | Image-2 (WV-2) | Image-3 (WV-3)

Image-4 (GeoEye-1) | Image-5 (Pléiades-1A)

Fig.2data set used

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

Table 2 Characteristics of data setused

Satellite	GSD [m]	Band [µm]	Location	size (pixels)
Ikonos-1	1	0.45 – 0.8	Vancouver-Canada	512 x 512
World View-2	0.5	0.45 – 0.8	Shanghai-China	512 x 512
World View-3	0.3	0.45 – 0.8	Colorado-USA	512 x 512
GeoEye-1	0.5	0.45 – 0.8	Arizona-USA	512 x 512
Pleiades-1A	0.5	0.48 - 0.83	London-UK	512 x 512

Calculation Steps

1- Calculation of the GSD, using equation (3), of the test images according to the design parameters of the imaging sensors and the flight altitude of the five satellites [19]. The results are given in table (3).

Table 3 Calculated values of GSD according to the mission parameters

Satellite	CCD pixel Size (um)	Sat altitude [Km]	Focal length [m]	Calculated GSD [m]
Ikonos-1	12	681	10	0.820
World View-2	8	770	13.3	0.463
World View-3	8	617	13.3	0.371
GeoEye-1	8	681	13.3	0.409
Pleiades-A	13	694	12.905	0.699

2- Calculation of RER using the no-reference technique. Table (4), gives the result for the blind blur metric (BM), the Edge Intensity (EI), the perceptual-RER (pRER), and the Frequency Ratio (FR) for each image and the estimated relative edge response (RER) as the averaging of the four values.

3- Selection of the coefficients (a) and (b), equation (2), according to the RER value ($a = 3.32$, $b = 1.559$ if $RER \geq 0.9$, and $a = 3.16$, $b = 2.817$ if $RER < 0.9$),the results are given in table (4).

Table 4 the Estimated Relative Edge Response (ERER)

Satellite	BM	EI	pRER	FR	ERER
Ikonos-1	0.9413	0.6331	0.2842	0.8925	0.687775
WorldView-2	0.9377	0.6808	0.3698	0.6376	0.656475
WorldView-3	0.9580	0.5570	0.3398	0.4949	0.587425
GeoEye-1	0.9107	0.6404	0.3344	0.6352	0.63017
Pleiades-1A	0.7515	0.7564	0.3329	0.7123	0.6382

4- Calculation of SNR. It is performed by calculation of the mean of a series of radiances for each image then dividing the calculated values by corresponding standard deviation to get estimated values for the SNR for each image [13]. The results are given in table (5).

Table 5 the estimated SNR (ESNR)

Satellite	ESNR
Ikonos-1	15.8451
WorldView-2	26.0873
WorldView-3	25.0607
GeoEye-1	18.5946
Pleiades-A	22.2857

5- Comparison of the obtained results (estimated NIIRS) with the NIIRS published in [15, 16, 17], are given in table (6),which illustrate a sufficient performance of the simplified GIQE as the values obtained are very closed to the published values.

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2016

Table 6 the estimated NIIRS compared with published NIIRS

Image type	Estimated NIIRS		Published NIIRS	
	Value	Level	Value	Level
Ikonos-1	5.003	5	4.5	5
WorldView-2	5.72733	6	>5	6
WorldView-3	5.96359	6	5.7	6
GeoEye-1	5.8536	6	5.5	6
Pleiades-1A	5.137	6	6	6

VII. CONCLUSION

In this paper, a simplified GIQE is described as a fast method to estimate the NIIRS of high resolution satellite images. We can differentiate between (NIIRS) for different satellite images even if there are small GSD differences of the given images. The results proved also that the estimated value of RER as example in case of Ikonos-1 image, table (4), is nearly closed to the value given in [20], which said that for these levels of NIIRS for the TIFF imagery, the RER is approximately 0.7. Also the results show that the range in average NIIRS values for the entire sample of TIFF and GeoTIFF images in case of Ikonos-1 image were 3.61–5.28, with NIIRS values increases asthe values of GSD decreases [20].

REFERENCES

1. Taejung Kim, Hyunsuk Kim and HeeSeob Kim, “Image-Based Estimation and Validation of NIIRS for High Resolution Satellite Images”. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B1, Beijing 2008.
2. John M. Irvine “National Imagery Interpretability Rating Scale (NIIRS): Overview and Methodology”. SPIE Vol. 3128 on 14 Nov 2011.
3. S. Wong and R. Jassemi-Zargani, “Predicting Image Quality of Surveillance Sensors” Defence Research and Development Canada (DRDC), DRDC-RDDC-2014-R97, October 2014.
4. Doug Griffith “General Image Quality Equation (GIQE)”,Joint Agency Commercial Imagery Evaluation Conference, USA, April 2012.
5. Ronald G. Driggers , James A. Ratches , Jon C. Leachtenauer , Regina W. Kistner “Synthetic aperture radar target acquisition model based on a National Imagery Interpretability Rating Scale to probability of discrimination conversion”. SPIE Opt. Eng. 42(7), 2104-2112 (Jul 01, 2003).
6. Daniel Gutchess, John M. Irvine; Mon Young, Magnús S. Snorrason “Predicting the Effectiveness of SAR Imagery for Target Detection”. SPIE Algorithms for Synthetic Aperture Radar Imagery XVIII 8051, 805110. 2011.
7. Leachtenauer, J.C, Driggers, R.G. “Surveillance and Reconnaissance Imaging Systems” Artech House: Boston, MA, USA, 2001.
8. Ronald G. Driggers, Michael Kelley, Paul G. Cox “NIIRS and the probabilities of detection, recognition and identification” SPIE Infrared Imaging Systems: Design, Analysis, Modeling, and Testing VII Opt. Eng. 36(7), pp.1952, July 1997.
9. R. G. Driggers, P. Cox and T. Edwards, “Introduction to Infrared and Electro-Optical Systems”, Norwood, MA: Artech House, Boston, 1999.
10. Samuel T. Thurman and James R. Fienup “Application of the general image quality equation to aberrated imagery”, Applied Optics, Vol. 49, issue 11, pp.2132, April 2010.
11. Jon C. Leachtenauer, William Malila, John Irvine, Linda Colburn, and Nanette Salvaggio “General image-quality equation: GIQE” Applied Opt., Vol. 36 issue 32, pp.8322, 1997.
12. Lin Li, Heng Luo, and Haihong Zhu “Estimation of the Image Interpretability of ZY-3 Sensor Corrected Panchromatic Nadir Data” MDPI, Remote Sensing open access journal 2014.
13. Philippe Blanc, Lucien Wald “review of earth-viewing methods for in-flight assessment of modulation transfer functions and noise of optical space borne sensors” HAL Id: hal-00745076 Submitted on 26 Oct 2012.
14. MISB RP 1203.3 “Video Interpretability and Quality Measurement and Prediction” 27 February 2014
15. Pleiades imagery user guide, Astrium EADS, v 2.0,118 pp, 2012.
16. Andreas Brunn, Ralf Reulke “Requirement to Image Quality”, JACIE 2013, St. Louis, DIN 18714, April 2013.
17. Bill Baugh, Seth Malitz, Nathan Longbotham, Casey Adams, Sonya Starr, Matt Clark “WorldView-3: Seeing the World in New Ways” Digital-Globe Proprietary. November 3, 2014.
18. Sensors used in satellite images http://www.satimagingcorp.com/satellite-sensors.
19. Satellite mission database https://directory.eoportal.org/web/eoportal/satellite-missions.
20. Robert Ryana, Braxton Baldridge, Robert A. Schowengerdt, Taeyoung Choi Dennis L. Helder, SlawomirBlonski. “IKONOS spatial resolution and image interpretability characterization”. Elsevier Inc, Remote Sensing of Environment 88 (2003) 37 – 52, 2003.