MINISTRY OF EDUCATION AND TRAINING
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STUDY ON IMAGE QUALITY ASSESSMENT FOR OPTICAL REMOTE SENSING IMAGERY OF VIETNAM

SUMMARY OF TECHNICAL PHD THESIS
MAJOR: SURVEYING AND MAPPING

Ha Noi, 2022

The thesis was completed at Department **of Photogrammetry and Remote Sensing, Faculty of Geomatics anf Land Administration, Hanoi University of Mining and Geology**

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INTRODUCTION

1. The urgency of the study

Optical remote sensing image data that user access is mostly at level 1A, 2A or higher; at the same time, vendors often give their image quality criteria based on the concept of resolution categories. Therefore, data at a lower level such as level 0 is of little interest.

To assess image quality, there are many parameters that are divided into two groups as: the group related to the spatial factor and the group related to the radiation factor.

The influence of the parameters on the image quality is not the same; it is necessary to define what parameters characterize the image quality clearly and can be assessed; moreover, they also show the operating status of the payload on the satellite.

Two commonly used parameters are signal-to-noise ratio, abbreviated as SNR, and modulation transfer function, abbreviated as MTF.

In the conditions of Vietnam, the PhD student proposes to choose two parameters MTF and SNR to assess image quality. These are two parameters that not only represent the image quality but also can be calculated only with the test site. Therefore, these two parameters are suitable for assessing the quality of Vietnam's optical remote sensing images in the current situation.

The harsh operating conditions in space and the launch process lead to the deterioration of the equipment on the satellite. There have been many studies and methods to evaluate the quality of satellite imaging systems, and the indirect evaluation method using image data is a widely applied approach.

Image data obtained by optical remote sensing satellite systems is huge, but not any image data can be used to evaluate image quality, they need to meet specific criteria.

Based on the study of existing methods, the PhD student carried out the project "Study on image quality assessment for optical remote sensing imagery of Vietnam", a process to evaluate the quality of optical remote sensing images was proposed, and it is suitable to the actual conditions of our country. The results obtained will indicate the specific image quality thresholds for the parameters used to evaluate the SNR and MTF.

2. Targets of the study

The targets of the study are:

- Proposing parameters to assess the quality of optical remote sensing images in accordance with the conditions of Vietnam.
- Select the method and propose a process to evaluate the quality of optical remote sensing images for the conditions of Vietnam.

3. The research contents

In order to achieve the above targets, the thesis needs to carry out the following research contents:

- An overview study on the assessment of optical remote sensing image quality for satellite systems around the world. On that basis, it is proposed to select the image quality evaluation parameters suitable to the conditions of Vietnam..
- Research on the scientific basis and method to assess the quality of optical remote sensing images through two parameters SNR and MTF. From there, choose a method suitable to the conditions of Vietnam.

- Research on the Canny edge extraction method for the calculation of MTF from optical remote sensing image data.
- Generating a process to assess the quality of optical remote sensing images with two parameters SNR and MTF. From the need to use images the image quality level for each given ratio is proposed in reality
- Testing VNREDSat-1 image quality of Vietnam, proposing image quality level (according to SNR, MTF parameters) for each specific user need.

4. Subject and scope of the study

The subject of the study is the signal-to-noise ratio (SNR) and the parameter of the modulated transfer function MTF.

Spatial scope includes an artificial test sites at Salon de Provence (France) Buon Ma Thuot city (Dak Lak province); and natural test sites: deserts in Africa andwaters in the Atlantic Ocean.

Data scope: VNREDSat-1 image data of Vietnam at level 0 and level 1A.

5. Research methodology

- Analytical and synthesis methods
- Data collection method
- Remote sensing method
- Professional method
- Experimental method

6. Scientific and practical significance

6.1 Scientific significance

- Contributing to the scientific basis and methodology in the assessment of the quality of optical remote sensing images of Vietnam.

- Developed a process to evaluate the quality of optical remote sensing images of Vietnam.

6.2 Practical significance

- The research results of the thesis have proved that the quality of optical remote sensing images of VNREDSat-1 satellite still meets the technical criteria when designing the system, ensuring to provide quality images,. meet technical requirements up to the time of assessment;
- The process of evaluating the quality of optical remote sensing images proposed in the thesis can be applied to satellite generations of Vietnam.
- Currently, Vietnam is operating the VNREDSat-1 and SPOT 6, 7 imaging stations; In the future, more KOMPSAT3 image data will be collected. Therefore, it is necessary to evaluate the image quality before it is released to the market. Procedures and methods proposed in the study can be applied to assess the quality of these types of data.

7. New contributions

- Proposing the selection of SNR andMTF parameters to evaluate the quality of optical remote sensing images in accordance with the conditions of Vietnam, thereby building an evaluation process that incorporates additional user needs to divide them into different levels

specific image quality;

- Using the Canny edge extraction method instead of the previous linear algorithms in calculating the MTF from the test site.

8. Hypothesis

The first hypothesis: The use of two parameters: the modulation transfer function and the signal-to-noise ratio is ensuring the conditions to evaluate the quality of optical remote sensing images of Vietnam.

The second hypothesis: The Canny edge extraction method to calculate the MTF modulated transfer function from the test yards is suitable for image quality assessment in Vietnam.

9. Structure of the thesis

The thesis includes an introduction, 04 chapters, a conclusion, references, published works, and appendices. The main content is presented in 4 chapters:

Chapter 1: Overview of the research problem

Chapter 2: Scientific basis and method to evaluate the quality of optical remote sensing images

Chapter 3: The process of the quality assessment of optical remote sensing images

Chapter 4: Experiment: assessing the quality of VNREDSat-1 optical remote sensing images of Vietnam.

CHAPTER 1. OVERVIEW OF RESEARCH PROBLEM

1.1 The concept of optical remote sensing image quality assessment

1.1.1 The concept of optical remote sensing image quality

Optical remote sensing image quality is the degree to which a set of specifications of optical remote sensing image data meets the payload design requirements.

1.1.2 The need to assess the optical remote sensing images quality

The information related to the image quality is provided by the image providers, but we do not have the conditions to check the accuracy of that information.

The evaluation of the payload quality is divided into three stages: before launching when entering orbit and operating in orbit. The first two phases are carried out in a short time, the third phase is conducted regularly and continuously throughout the satellite's operation life.

Vietnam operates the remote sensing system as VNREDSat-1, and will add other satellite systems in the future. Therefore, it is necessary to develop a method and process to assess image quality.

1.2 Parameters express the optical remote sensing image quality

1.2.1 Spatial related parameters

a. Modulation Transfer Function (MTF): is a parameter that characterizes the contrast degradation of image data.

b. Image distortion: is the optical distortion of the image data, the position between the satellite and the Earth and the non-linear imaging speed.

c. Angular sampling distance: related to satellite displacement, causing geometrical deviations.

d. Pointing accuracy: is the deviation of the object surface from a flat surface and by the object movement.

e. Ground sampling distance: is the distance between two consecutive points on the earth's surface that are sampled.

f. Swath width: is the range on the earth’s surface that the payload can capture images of objects.

1.2.2 Radiance related parameters

a. Signal to noise ratio (SNR): is the characteristic parameter for radiance noise.

b. Dark Signal (DS): is the fixed radiative shift measured in the absence of radiation at the receiver.

c. Pixel Response Non-Uniform (PRNU): includes the difference between each detector on the sensor itself in response to the signal; the distribution of electrons and photons on the sensor surface in the presence of a signal.

d. Dynamic range: is an amplitude band representing the difference between the lightest and darkest areas of the scene.

In the current actual conditions of Vietnam, some of the above-mentioned parameters are not yet capable of assessment, some parameters are not necessarily assessed. These parameters include image distortion, angle sampling distance, pointing accuracy, swath width, dynamic range andground sampling distance.

1.3 Overview of optical remote sensing image quality assessment

1.3.1 In the world

The image quality assessment is usually done in several forms such as evaluation and correction of image radiation, evaluation and correction of image geometry, etc. In terms of methods, there are currently many evaluation methods. such as using targets to assess and using the cross-validation method.

Studies on image quality assessment in the world were performed from super-high-resolution image data such as Quickbirds, Worldview, or medium-resolution image data such as Landsat, SPOT, Sentinel-2, to less popular data as THEOS, GF all choose one of two parameters or both MTF and SNR parameters to

assess image quality with different algorithms such as slanted edge, Entropy, etc, with different targets such as test site, bridge, the building edge, etc.

1.3.2 In Vietnam

Although remote sensing image data has been applied in Vietnam for many years, the image quality assessment is performed still very limited. The reasons are the data is completely dependent on the supplier, and there is not enough information and raw data to conduct research, analysis and evaluation. Therefore, there are not many publications on image quality assessment.

Research on image quality often focuses on image products with high processing levels such as 3A and3B, processing techniques to enhance the quality of image products. The image at the lower levels has not been studied much. Regulations of the government also are at the level of uniformity in popularity, cloud coverage, and accuracy of geometry.

1.4 Conclusion of chapter 1

The indirect image quality assessment method is the most popular and widely applied method by manufacturers as well as researchers with different algorithms and approaches, depending on each type of satellite.

The SNR and MTF are used the most because these are easily defined parameters; there is a similarity between theoretical and actual values. There are many methods to determine SNR, MTF, and it is possible to use only test sites without special equipment that Vietnam currently does not have.

Research on the payload quality in the world has just stopped at comparing to design requirements, or changing or improving the

algorithm in the evaluation, but there is no link between these evaluation results and the needs of image users.

In Vietnam, the payload assessment is still very limited, and there are not many publications related to the quality of raw images.

CHAPTER 2. SCIENTIFIC BASIS AND METHODOLOGIES OF THE OPTICAL REMOTE SENSING IMAGES QUALITY ASSESSMENT

2.1 Payload and image quality

According to the principle, the main factors related to optical remote sensing image data quality are input signal, sensor characteristics and optical system quality.

2.1.1 Radiance image quality

The ability to distinguish the smallest change in spectral reflectance/emission between different objects on image data is called radiance resolution. This value depends on the parameters: signal-to-noise ratio (SNR), saturation radiation level and quantization bits.

2.1.2 Spatial image quality

The spatial characteristics of an image are the swath width and the spatial resolution. After through the optical system, the obtained image will be reduced in contrast, and the characteristic quantity for the degradation of contrast with spatial frequency is the modulation transfer function MTF.

2.2 Parameters to assess image quality

2.2.1 Parameters representing the radiance factors

The radiance performance of a payload is characterized by the following key parameters: signal-to-noise ratio, absolute radiance

correction, relative radiance correction, radiance stability, foreign components, linear response, polarization sensitivity.

2.2.2 Parameters representing the spatial factors

The spatial quality of a remote sensing satellite system depends on several aspects of the payload, which are expressed in modulation transfer function (MTF), ground sampling distance (GSD), aliasing effect.

2.2.3 Parameters suitable for Vietnam

a. Signal to noise ratio (SNR): The signal to noise ratio is used to evaluate the quality of signal reception systems. With an optical remote sensing system, the energy obtained is the radiance value from the object, and the noise is the energy level obtained on the image that does not correspond to the radiance level of the object being imaged.

b. Modulation Transfer Function (MTF): After through the optical system, the obtained image will be reduced in contrast, and the characteristic quantity for the degradation of contrast with spatial frequency is the modulation transfer function MTF. The MTF value of the payload is the product of many different component MTFs.

2.3 Signal to noise ration estimation methods

Estimation of SNR is based on factors: data, calculation method, and time of application of assessment results.

2.3.1 Data

a. Single scene: usually taking image with a uniform area or a near uniform area

b. Synthetic landscape: is constructed by the fusion of actual single images..

2.3.2 Calculation method

a. Local standard deviation: Divides the image into homogeneous cells, calculates the mean and standard deviation of each cell, and the standard deviation is considered as the noise value of the calculated cell. The mean of the standard deviation in the cell is considered the noise value of the image.

b. Spectral and Spatial Correlation: This method estimates band noise, exploits spectral correlations between data in a band and two adjacent bands, spatial correlations in that band.

c. Geostatistic: Geostatistical method is a technique based on the theory of area variables. This method requires a large enough data set, which is long-term accumulated.

2.4 Modulation transfer function estimation methods

2.4.1 Based on the test site method

Accurate MTF calculation method for optical payload based on analysis of known targets. These targets can be divided into 4 types of target: edge, pulse, impulse, and periodic.

2.4.2 Bi-resolution method

This is a method to estimate MTF with the principle based on pair of images of the same area with identical spectral bands and different spatial resolutions. This method requires preprocessing procedures such as geometry and radiance correction.

2.4.3 Based on specific onboard devices method

This method is suitable for satellite systems with specific equipment to estimate the MTF and it is designed from the beginning.

2.5 The method of assessing image quality is suitable for the conditions of Vietnam

2.5.1 Actual conditions of Vietnam

Vietnam has built a test site in Buon Ma Thuot city, Dak Lak province, operating since 2017. This test site is designed in two parts for calculating the MTF and SNR.

2.5.2 SNR estimation method

In the actual conditions of Vietnam, the most appropriate method is to use a single scene with local standard deviation method.

2.5.3 MTF estimation method

The MTF estimation method suitable for Vietnam is to use the edge target test site. In which, edge extraction is done by Canny method.

2.5.4 Canny edge extraction method

Because the quantization level increases, the linear algorithm for edge extraction does not guarantee accuracy. PhD student applies the edge highlighting advantage of gradient image to edge extraction by Canny method, including following steps: noise filtering, gradient calculation and gradient direction, non-maximum value removal and threshold filtering.

2.6 Conclusion of chapter 2

The payload performance is evaluated by two parameters MTF and SNR in the condition of not being able to contact directly, or without models simulating the operation of the device.

The proposed SNR estimation method suitable for Vietnam conditions is to use a single scene, calculated according to the local standard deviation.

The proposed MTF estimation method for Vietnam conditions is the method of using edge target test site, with edge extraction is performed by Canny method.

CHAPTER 3: PROPOSED PROCEDURES FOR QUALITY ASSESSMENT OF OPTICAL REMOTE SENSING IMAGES FOR VIETNAM

Based on published image quality assessment procedures, PhD. student proposes an overall image quality assessment process, satisfying both technically and practically.

The input data process is the image at level 0, after radiance correction, the level 1A data in the homogenous area will be used to assess through the SNR parameter. The assessment through the MTF was performed with level 1A data at the test site. Before providing, image quality assessment should be performed as required and MTF enhancement if necessary.

The output results of the processes are included in the calibration file to update the image-receiving system.

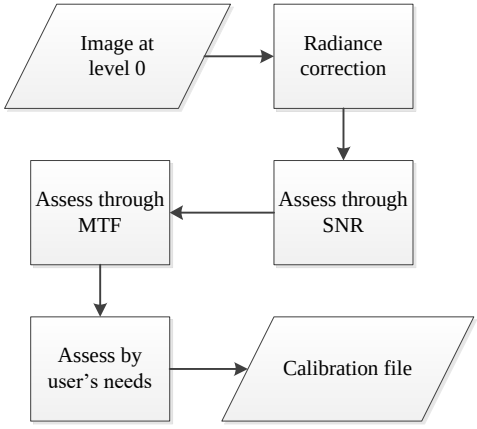

Fig. 3.1: Overall image quality assessment process

3.1 Radiance correction process

3.1.1 Dark signal correction (DS)

The image data used in the dark signal correction is level 0 image that captures areas considered to be absolutely black on the Earth's surface such as the ocean at night.

The dark signal correction process includes steps: Statistics of the radiance value of pixels, removing bad values, compare DS value, DS correction.

The result is the DS correction file, which is used to generate the calibration file. This file is updated directly to the satellite image acquisition system or to the image-receiving ground stations.

3.1.2 Pixel response non-uniform correction (PRNU)

The image data used in the PRNU correction is the level 0 image that captures areas considered to be time-invariant reflections on the Earth's surface such as desert areas.

PRNU correction procedure includes steps: Average value of image, filter, compare PRNU value, correct PRNU

The result is the PRNU correction file, which is used to generate the calibration file.

3.2 Process of image quality assessment through SNR

Level 1A image after radiance correction is used to calculate the SNR, the locations captured are homogenous areas.

After assessing the SNR, if it meets the requirements, the level 1A image will be produced to evaluate the next step, if not, it will not be used.

The process is shown below:

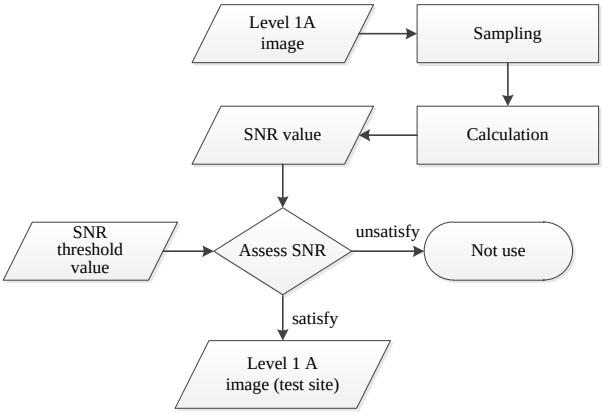

Fig 3.4 SNR assessment process

3.3 Process of image quality assessment MTF

The data used for the MTF calculation is the level 1A image, which captures the test site with the edge target.

The calculated MTF value is compared with the threshold. If it is lower than the threshold value, the image data is not used. If it is higher then the data is processed for image production.

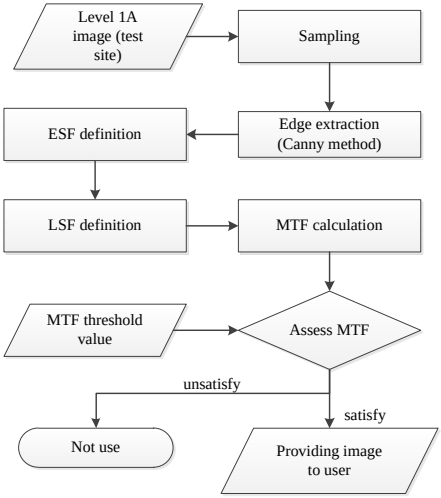

Fig 3.5. MTF assessment process

3.4 Process of image quality assessment by user's needs

Input data is the image that provides to the user, produced from the image receiving ground station.

The process of image quality assessment by user's needs is a new proposed sub-process in the image quality assessment process, including the following steps: Conformity assessment and MTF quality enhancement.

The output image meets the technical requirements of the payload as well as the user's criteria.

3.5 Test site for image quality assessment

3.5.1 The permanent test site

The permanent test site can be divided into the following kinds:

- LES: Land Equipment Site
- SES: Sea Equipment Site
- LNES: Land Non - Equipment Site
- SNES: Sea Non - Equipment Site

3.5.2 The temporary test site

Artificial temporary test sites are the most common standard reference targets, generally divided into the following categories:

- Black and white
- Greyscale

3.5.3 Criteria for selection of test site

- Terrain: altitude, topography, type of water surface, logistics
- Climate: Spatial homogeneity, surface reflectance, spectral variability, spectral and radiance invariance, magnetic field, cloud coverage, precipitation, aerosols, ozone absorption.

3.6 Conclusion of chapter 3

Level 0 image is used to correct the DS and PRNU. The result is two correction data files DS and PRNU, and they are combined into a calibration file.

The calculation and assessment of image quality through SNR and MTF parameters are described in detail in the assessment process. In which, edge extraction to calculate MTF is performed according to the Canny method.

After assessing the satisfactory MTF, the image data is compared with the user's needs, and in case of the requirements are not met, MTF enhancement needs to be performed.

The result of the correction and assessment process is a system calibration file that is updated to ensure the image quality is in accordance with the design and meets the needs of the user.

CHAPTER 4. EXPERIMENT: ASSESSING THE QUALITY OF VIETNAM'S REMOTE SENSING IMAGE VNREDSAT-1

4.1 Radiance correction

4.1.1 DS correction

a. DS assessment: A level 0 image was taken in the Atlantic ocean is used to assess the dark signal. The dark signal is evaluated at all bands of the VNREDSat-1 image, this value is still in the range below 0.25lsb below the allowable threshold (0,5lsb).

b. DS correction: Dark signal correction will be performed on all spectral bands, the image data after the correction has a much lower dark current value than the input image data, the maximum is 1.8.

4.1.2 PRNU correction

a. PRNU assessment: Level 0 image was taken in the Algerian and Libyan deserts is used. Analyzing the assessment results showed that from the previous period to this PRNU value does not exceed 0.01.

b. PRNU correction: The corrected image will be more uniform than the pre-corrected one. The stripes caused by the uneven response of the sensor have been corrected and the output image has better quality.

4.2 Assessment of VNREDSat-1 image quality through SNR parameter

In IOT phase, the VNREDSat-1 image is assessed for SNR with the target as the Salar de Uyuni salt lake in Bolivia that is equivalent to the radiance level in plot 1 on the test site in Buon Ma Thuot (reflectance value $\rho = 0.4$). The obtained results show that the conditions of the test site in Buon Ma Thuot completely meet the requirements and the SNR value is quite similar to IOT phase.

Table 4.4. Comparison result between experiment and design value

Band	***IOT***	***Experiment***		***Design***
		2017	***2018***	
Pan	142	148	147	>100

At the same noise level, regions with highly homogeneous objects express the noise most apparent. Regions with diverse and heterogeneous objects are harder to detect.

Ph.D Student proposes to divide the image quality according to the SNR value with two levels, good and bad, with the threshold being the design value. (SNR=100)

4.3 Assessment of VNREDSat-1 image quality through MTF parameter

4.3.1 Assessment of image quality through MTF parameter

During satellite operation, the MTF value will fluctuate vertically and horizontally with the satellite's flight direction. So, it is necessary to assess in both directions.

a. Comparison of the proposed MTF calculation method and the manufacturer's method.

Table 4.7. Comparing the MTF value calculated by the proposed method and the VNREDSat-1manufacturer's method

Date	**Method**	**MTF**	
		Along track	**Across track**
23/05/2013	Manufacturer	0,17	0,19
	Proposed	0,21	0,18
26/05/2013	Manufacturer	0,19	0,22
	Proposed	0,21	0,23

b. MTF calculation by using Buon Ma Thuot test site

Table 4.10. Along track MTF results

Date	***MTF***		
	Transition black to white	***Transition white to black***	***Mean value***
14/11/2017	0.21	0.20	0.21
02/11/2018	0.19	0.20	0.20

Table 4.13. Across track MTF results

Date	***MTF***		
	Transition black to white	***Transition white to black***	***Mean value***
14/11/2017	0.18	0.19	0.19

02/11/2018	0.24	0.20	0.22

Till 2018, after 5 years of operation according to the design life, the VNREDSat-1 satellite system still ensures image quality. VNREDSat-1 satellite uses the test site at Salon de Provence to evaluate image quality since launch. The calculation results show that the MTF value of the VNREDSat-1 payload is still above the required threshold.

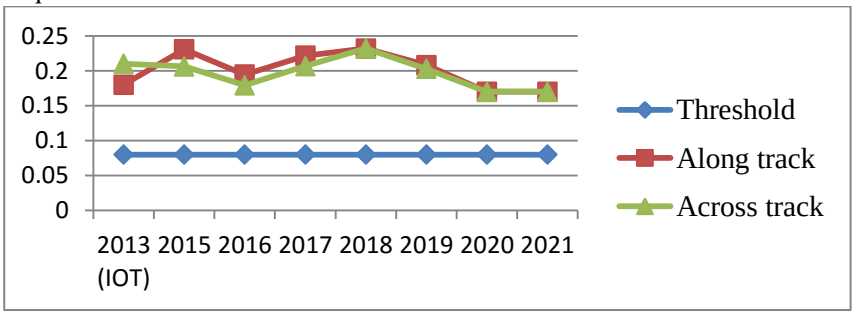

Fig 4.22. VNREDSat-1 MTF values after 8 years

Ph.D student proposes that the assessment period of the payload on optical remote sensing satellites is 2 times per year.

Table 4.14. Comparing the MTF value calculated by using the test site in Salon de Provence and Buon Ma Thuot

Date	**Test site**	**MTF**	
		Along track	**Across track**
2017	Buon Ma Thuot	0.21	0.19
	Salon de Provence	0.22	0.21
2018	Buon Ma Thuot	0.20	0.22
	Salon de Provence	0.23	0.23

The reason for the difference between the MTF results is the atmospheric conditions in the two test sites, it is having a certain influence on the results.

4.3.2 Proposed image quality level via MTF parameter

a. Vietnam's natural conditions affect image quality

Vietnam can be divided into two major climate zones: (1) The North (from Hai Van Pass to the North) has a tropical monsoon climate, with high humidity and four distinct seasons, (2) The South (from Hai Van Pass to the South) has a tropical climate is quite moderate, hot all year round, with two seasons.

b. Proposed image quality level

Due to the specific climatic conditions of Vietnam, the taken image in different areas also have differences. Regions with a lot of construction are quite clearly distinguished in the seasons of the year across the country.

In homogeneous areas such as fields or forests, although the contrast between objects is relatively low, in many cases objects still can be distinguished. In the spring time in the North, the image quality is worse.

Proposed image quality level via MTF parameter for applications that need to extract information from satellite images as shown in the table below.

Table 4.15. Proposed image quality level

No.	MTF value	Quality level	Suitable scale
1	< 0,15	Bad	Not use
2	0,15 – 0,2	Medium	≤ 1:50.000
3	> 0,2	Good	≤ 1:25.000

4.4 Conclusion of chapter 4

With the existing conditions of Vietnam, assessing the quality of remote sensing satellite images only needs to use two parameters SNR and MTF, and a set of images at the test sites.

The results of using the Canny edge extraction method in calculating the MTF to assess the spatial quality of optical remote sensing images are similar to the method used by the VNREDSat-1 satellite manufacturer. This method has better edge extraction accuracy than the linear method for high quantization image.

Experimental results have proved that the payload on VNREDSat-1 satellite still ensures the image quality compared to the designed requirements (MTF ≈ 0.2 is higher than the threshold of 0.08 and SNR ≈ 145, is higher than the threshold of 100).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the results obtained after conducting research and experimenting with Vietnam's optical remote sensing image quality assessment method, the Ph.D student has the following conclusions::

- In the conditions of Vietnam, the quality of optical remote sensing images is assessed based on only two parameters, the modulation transfer function MTF and the signal-to-noise ratio SNR. These are two parameters that represent spatial and radiance factors. For this assessment, it is necessary to collect a regular and appropriate data set to fully reflect the condition of the payload during the operation of the satellite system.
- The method of assessing image quality for SNR parameter is the single scene method, calculated by the local standard deviation method. For the MTF parameter, the slanted edge method with the

Canny edge extraction method replaces the linear algorithms, and the Canny method is suitable for the current conditions of Vietnam..

- The proposed optical remote sensing images quality assessment process includes both technical and practical factors. This is the first time that the optical remote sensing image quality assessment process has been proposed using the test sites in Vietnam, giving quantitative conclusions about the image quality. Moreover, the proposed process has added user needs, which is an element that has not been mentioned in previous assessment processes.

- The reliability and feasibility of the proposed method and process for assessing image quality have been proven through experimental results. The image quality of the VNREDSat-1 satellite system is guaranteed until the time it is evaluated with the value of the MTF parameters of 0.2 (compared to the threshold of 0.08) and the SNR of 145 (compared to the threshold of 100).

- The process proposes image quality levels corresponding to the different map scales for which the VNREDSat-1 data is used, they are: good (SNR > 100; MTF > 0,2 suitable scale 1:25.000 and smaller), medium (SNR > 100; 0,2 > MTF > 0,15 suitable scale 1:50.000 and smaller), bad (SNR > 100; 0,15 > MTF , not use). This quality level is applicable to data with specifications equivalent to VNREDSat-1; in other cases, more experiments are needed to give the most reasonable results.

- The test site in Buon Ma Thuot city, Dak Lak province meets the requirements to assess the quality of optical remote sensing images not only of Vietnam but also of other countries in the world. The difference between the assessment results using this test site and

other ones around the world is due to the difference in atmospheric conditions.

Recommendations

The proposed method of image quality assessment is not only applicable to the existing VNREDSat-1 satellite system but also to future optical remote sensing satellite systems in Vietnam. Moreover, this method can be applied to other optical remote sensing images in Vietnam if the input data and supporting parameters are sufficient.

The optical remote sensing image quality assessment process is applied at agencies that have image receiving ground stations such as the National Remote Sensing Department; operating and exploiting satellite systems agencies such as Space Technology Institute, Vietnam Space Center; other agencies and organizations.

LIST OF PUBLICATION

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