VISUAL AND STATISTICAL QUALITY ASSESSMENT AND IMPROVEMENT OF REMOTELY SENSED IMAGES

S.Mohammad Shahrokhy

Iran's Space Agency– Tehran – Iran
s_m_sh@hotmail.com

KEYWORDS: Atmospheric, Radiometric, Geometric, Quality, Diagnosis, Assessment, Improvement, Elimination

ABSTRACT:

Remotely sensed images are interpreted pixel by pixel, using spectral vector analysis methods. Most kind of noise and perturbation in pixel value or position cause misinterpretation. In this paper most common Radiometric, Atmospheric and Geometric defects of remotely sensed images are investigated along with the diagnosis and elimination methods on some high and medium resolution satellite images. Quality assessment is performed in both visual and statistical manner and also quality improvement is fulfilled in both Manual and Automatic ways. Many technical methods are used such as histogram transformation, mean, variance and median calculation of lines and bands, spatial filtering, template matching, rectifications using GCPs and brightness temperature and reflectance checking. Visual diagnosis of defects is often more precise but not appropriate for automatic procedures. Manual elimination of the defects is also more accurate however time consuming and user dependent.

1. INTRODUCTION

Reliable interpretation and results necessitate input data Quality Assessment (QA) and sometimes Quality Improvement (QI). On the other hand, in automatic procedures, image Quality should be checked to accept or reject the input or sometimes improve it to be able to cope with the expected duty.
Remote sensing image Quality generally has three aspects; Radiometric Quality, Atmospheric Quality and Geometric Quality. Radiometric Quality is affected by sensor characteristics and detector responses. Striping, Drop lines, Noise and Band missing are of this sort. Atmospheric Quality is dependent on the circumstances at the imaging time. Cloud cover and Haze are of this type. Geometric Quality is either dependent on sensor characteristics and also satellite situation such as attitude, position, velocity and perturbations. Earth's surface relief is another important factor affecting Geometric Quality of the images. Band to band Misregistration and image to map Misregistration are of geometric Quality elements (QE).
It is essential to note that each sensor has special Quality Assessment and Quality Improvement methods, thresholds and coefficients. So images of each sensor must be processed separately. In this research, TERRA-MODIS, NOAA-AVHRR, IRS-PAN and IRS-LISS III images are investigated.
Many works have been done on image Quality control (Barrett 1990, Nill & Bouzas 1992, Eskicioglu & Fisher 1995, Barrett 1995, Westen et al 1995, Taylor 1998, Avicibas and Sankur 2000) and generally, each company provides a complete report of its sensor images and products Quality e.g. EOS (Chu *et al* 2000 , Vermote *et al* 1997).

2. QE AND DEFECT DIAGNOSIS

2.1 Radiometric Quality Assessment

Radiometric Quality elements and recognition methods are briefly listed in Table 1.

Quality Defect	Visual Diagnosis	Statistical Diagnosis
Striping	Different overall brightness of adjacent lines	Significantly different variance and mean of adjacent lines
Drop Line	Null scan line	Zero variance of a line
Noise	Dark and bright points at the background	Radiometric anomalies
Band Missing	Lack of data in a band	Zero variance of a band

Table 1. Radiometric Quality defects and diagnosis methods

Striping is caused by different response of elements of a detector array to same amount of incoming EM energy. This phenomenon causes heterogeneity in overall brightness of adjacent lines (figure 1).

Figure 1. Image No.1 (MODIS) with stripes

Drop line occurs when a detector does not work properly for a short period (figure 2).

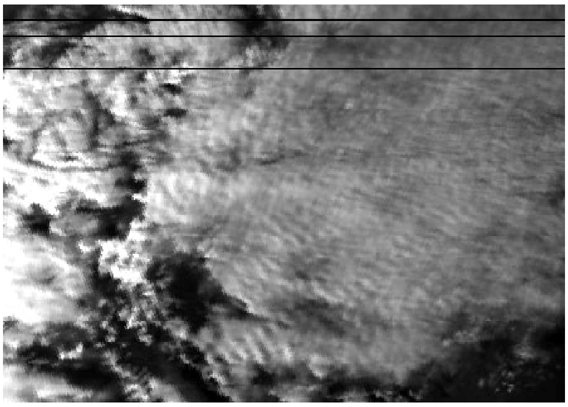

Figure 2. Image No. 2 (AVHRR) with drop lines

Noise appears when disturbing EM or MW energies are present or the sensor/detector is degraded (figure 3).

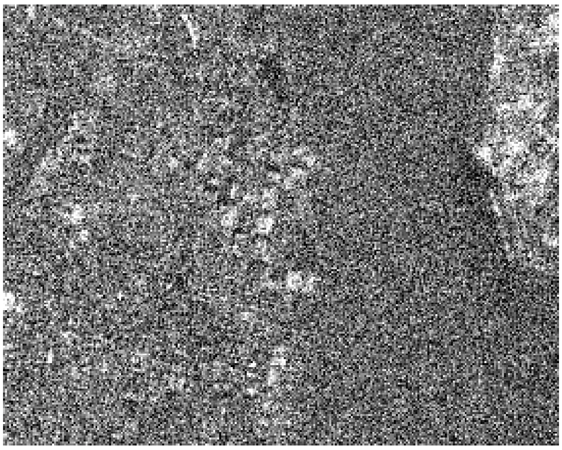

Figure 3. Image No.3 (PAN) noisy

Band missing is a serious problem and is caused by corruption of whole system of a band.

2.2 Atmospheric Quality Assessment

Table 2 contains Atmospheric problems and diagnosis methods.

Atmospheric Problem	Visual Diagnosis	Statistical Diagnosis
Cloud Cover	Cotton shaped white segments	High visible reflectance and low brightness temperature
Haze	Ambiguous and unusually bright image	Compressed and shifted histogram

Table 2. Atmospheric problems and diagnosis methods

In most of RS applications, absence of cloud is essential or at least it must be masked. Cloud could be recognized by its shape and color as well as its spectral and thermal characteristics (figure 4).

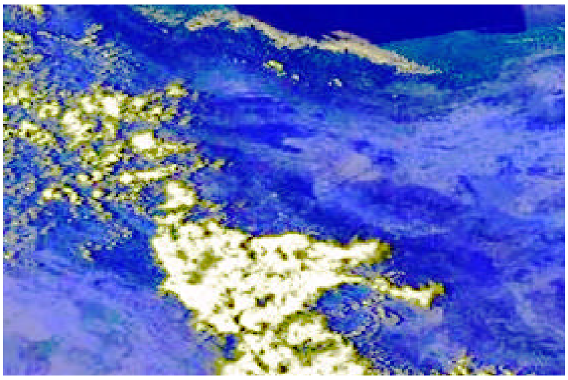

Figure 4. Image No. 4 (AVHRR) Cloudy

Another Atmospheric problem is haze that appears when there is considerable amount of dust, aerosols or water vapor within the traveling EM energy path (figure 5).

Figure 5. Image No.5 (LISSIII) hazy

2.3 Geometric Quality Assessment

Table 3 contains Geometric Quality defects and diagnosis methods.

Geometric Quality Element	Visual Diagnosis	Statistical Diagnosis
Band to band misregistration	Unable to recognize unless in significant cases	Different sharpness of the same edges
Image to map misregistration	Map overlay mismatch	High matching residuals

Table 3. Geometric Quality defects and diagnosis methods

When telescope assemblies of a sensor are not centralized to a ground point or if detector sets are not synchronized accurately, band to band misregistration appears and if the image is not rectified properly, image to map misregistration occurs (figure 6).

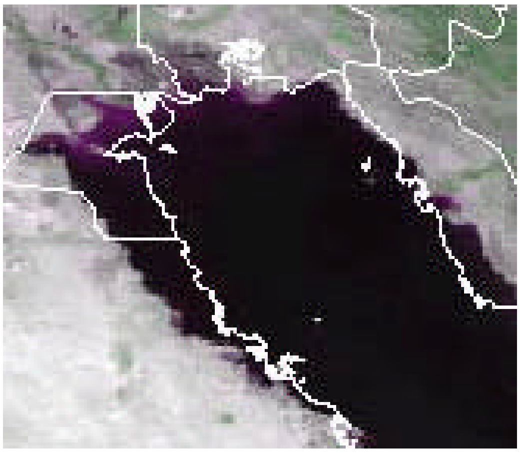

Figure 6. Image No.6 (MODIS) Image to map misregistration

3. PRACTICAL STUDY RESULTS

In a comparative study on some satellite images the following results were obtained:
a) TERRA-MODIS images have very high geometric Quality except one systematic error called BOW-TIE effect caused by multi detector scan line system that could be removed easily and accurately. Another error caused by multi detector scan line imaging system of MODIS is intense striping. MODIS bands systematically have a specific relative delay that causes a slight spatial misregistration of corresponding pixels.
b) NOAA-AVHRR images are of high radiometric Quality especially thermal channels, but drop lines were observed frequently.
c) IRS-PAN images despite their high resolution, have not appropriate geometric Quality because of misregistration of detector array. Also these images have intense periodic and random noise that should be removed and enhanced in several stages.
d) IRS-LISSIII images have relatively better Radiometric Quality although band missing is reported sometimes.

4. QI AND DEFECT ELIMINATION

Once the defect or the problem is recognized, the elimination or improvement process can be performed. But it should be noted that sometimes defect elimination could not be accomplished perfectly and also however in improvement process the desired element enhances but other elements may be destroyed. For example geometric correction imposes a radiometric blending because of resampling and also noise reduction blurs the image. So there should be an equilibrium point to balance the destructions (Watson 1993).

4.1 Radiometric Quality Improvement

A quick reference for radiometric Quality improvement could be found in Table 4.

Quality Defect	Manual Elimination	Automatic Elimination
Striping	Equalization of mean and variance of adjacent lines	Removing the related frequency Zone in spectrum
Drop Line	Replacement of an adjacent line	Replacement of mean of adjacent lines
Noise	Averaging , Spatial filters	Median and adaptive filters
Band Missing	-	Replacing a combination of the other bands

Table 4. Radiometric Quality defects and improvement methods

Regarding the cause of striping defect, the elimination must be performed in order to equalize the appearance of the adjacent lines (figure 7) (Richards & Jia 1999).

Figure 7. Image No.1 (MODIS) Destriped

Drop lines are simply loss of data and merely could be eliminated by replacing the other lines or a composition of them (figure 8).

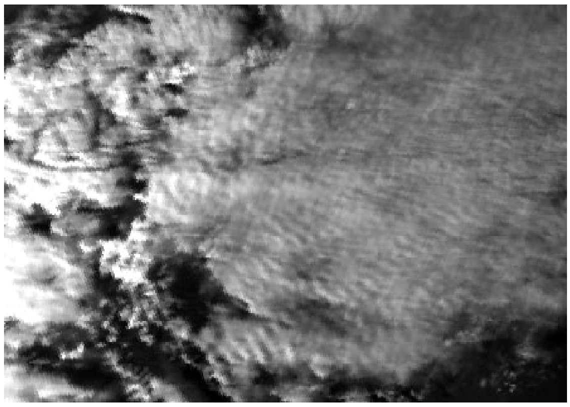

Figure 8. Image No.2 (AVHRR) after drop line removal

Periodic and random noise can be reduced by increasing the ratio of signal to noise (figure 9) (Abreu *et al* 1996, Hu et *al* 1997, Ishihara *et al* 1999).

Figure 9. Image No.3 (PAN) after noise removal

Fundamentally band missing problem could not be eliminated or improved because of significant loss of data but sometimes replacement of values obtained from the correlation equation to other bands can be useful however not appropriate for all of the features.

4.2 Atmospheric Quality Improvement

In table 5, removal methods of atmospheric effects are mentioned.

Atmospheric Problem	Manual Elimination	Statistical Elimination
Cloud Cover	Cloud masking by region growing	Cloud masking by clustering and thresholding
Haze	Conventional enhancements (Andrews 1976)	HMM correction and stretching

Table 5. Atmospheric problems and removal methods

Once cloud is recognized, a null or zero value is assigned to the corresponding pixels (figure 10).

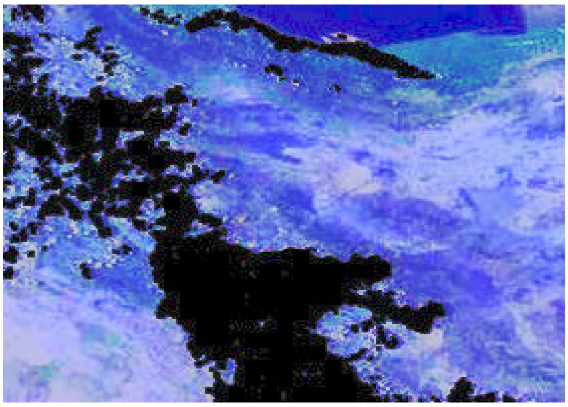

Figure 10. Image No.4 (AVHRR) Cloud masked

Since atmospheric haze directly affects the histogram of the image (shift and compression), histogram transformation techniques are employed to eliminate it (figure 11) (Mekler & Kaufman 1990).

Figure 11. Image No.5 (LISSIII) after haze removal

4.3 Geometric Quality Improvement

Geometric Quality improvement methods are listed in table 6.

Geometric QE	Manual Improvement	Automatic Improvement
Band to band misregistration	Conformal Transf. & Resampling	Sub pixel Edge matching (Canny 1986,Tao & Huan 1997)
Image to map misregistration	Rectification using Manually selected GCP's	Rectification using template matching technique

Table 6. Geometric Quality defects and improvement methods

Using sufficient and well distributed GCPs, the image can be rectified properly and be matched to the overlaid vector map (figure 12) (Buiten 1993).

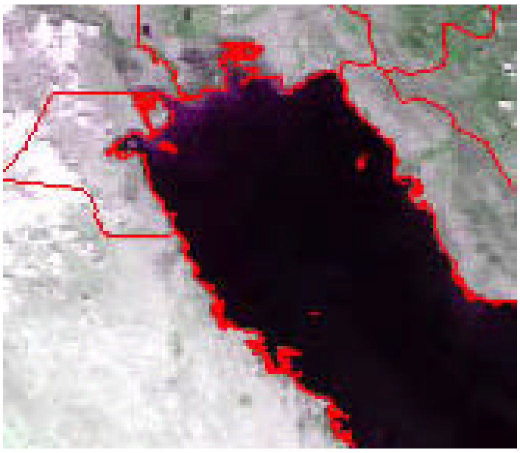

Figure 12. Image No.6 (MODIS) Image to map registration

5. CONCLUSIONS

Each sensor regarding its design specifications has special Radiometric and Geometric Quality status that directly influences the applications and user's demand.
Automatic Quality assessment and improvement procedures are not always possible and sometimes a simple manual stage needs much complicated automatic stages. But finally most of things that eye senses and recognizes could be modeled by programs with different accuracy and consequently different complexity levels.

REFERENCES

Abreu, E., Lightstone, M., Mitra, S.K., Arakawa, K., 1996, "A New Efficient Approach For The Removal Of Impulse Noise From Highly Corrupted Images", IEEE Trans. Image Processing, (5), No. 6, June , pp. 1012-1025. 9607

Andrews, H. C., 1976,"Monochrome Digital Image Enhancement," *Applied Optics*, Vol. 15, No. 2, pp. 495-503.

Andrews, H. C., And B. R. Hunt, 1977, "*Digital Image Restoration*, Prentice-Hall Signal Processing Series, A. V. Oppenheim, Ed.,, Prentice-Hall, Englewood Cli.S, NJ.

Avcibas, *I*, And B. Sankur, 2000, "Statistical Analysis Of Image Quality Measures", In *Proceedings EUSIPCO'2000: 10th European Signal Processing Conference*, pp. 2181-2184, 5-8 September, Tampere, Finland.

Avcibas, Ismail, 2001, "Image Quality Statistics And Their Use In Steganalysis And Compression", Phd Thesis , Bogazichi University.

Barrett, H. H., 1990, "Objective Assessment Of Image Quality: Effects Of Quantum Noise And Object Variability", *Journal Of Optical Society Of America*, Vol. A, No. 7, pp. 1261-1278.

Barrett, H. H., J. L. Denny, R. F. Wagner And K. J. Myers, 1995, "Objective Assessment Of Image Quality II: Fisher Information, Fourier-Crosstalk, And Figures Of Merit For Task Performance", *Journal Of Optical Society Of America*, Vol. A, No. 12, pp. 834-852.

Buiten, H.J., 1993, "Geometrical And Mapping Aspects Of Remote Sensing", Gordon And Breach Science Publishers , Reading , pp.297-321.

Canny, J., 1986, "A Computational Approach To Edge Detection", *IEEE Transactions On Pattern Analysis And Machine Intelligence*, Vol. 8, No. 6, pp. 679-698.

Chu, Allen, Kathy Strabala, Steve Platnick, Eric Moody, Michael King, Shana Mattoo, Rich Hucek, Bill Ridgway, 2000 "MODIS Atmosphere QA Plan", NASA, GSFC.

Eskicioglu, A. M. And P. S. Fisher, 1995, "Image Quality Measures And Their Performance", *IEEE Transactions On Communications*, 43(12), 2959-2965.

Hu, J., H. Yan And X. Hu, 1997, "Removal Of Impulse Noise In Highly Corrupted Digital Images Using A Relaxation Algorithm," In Optical Engineering 36(03), Proc SPIE, pp 849-856.

Ishihara, J., M. Meguro And N. Hamada, 1999, "Adaptive Weighted Median Filter Utilizing Impulsive Noise Detection," In Applications Of Digital Image Processing '99, Proc SPIE 3808, pp. 406-414.

Lubin, J., 1995, "A Visual Discrimination Model For Imaging Systems Design And Evaluation, In Vision Models For Target Detection And Recognition", (E. Peli, Ed.), pp. 245-283, Singapore: World Scientific .

Mekler Y. And Y. J. Kaufman, 1980, "The Effect Of Earth's Atmosphere On Contrast Reduction For A Nonuniform Surface Albedo And Two-Halves Field," *J. Geophys. Res.*, Vol. 85, pp.4067–4083.

Nill, N. B. And B. H. Bouzas, 1992, "Objective Image Quality Measure Derived From Digital Image Power Spectra", *Optical Engineering*, Vol. 31, No. 4, pp. 813-825.

Richards, J.A. And X. Jia, 1999, "Remote Sensing Digital Image Analysis – An Introduction", Third Edition, Springer Verlag, New York .

Tao, H. And T. Huang, 1997, "Color Image Edge Detection Using Cluster Analysis", *IEEE, International Conference On Image Processing*, pp. 834-836, California.

Taylor, Christopher C., 1998, "Image Quality Assessment Based On A Human Visual System Model", Phd Thesis , Purdue University.

Vermote E., N. Z. El Saleous, C. O. Justice, Y. J. Kaufman, J. L. Privette, L. Remer, J. C. Roger, And D. Tanre, 1997, "Atmospheric Correction Of Visible To Middle-Infrared EOS-MODIS Data Over Land Surfaces: Background, Operational Algorithm And Validation," J. Geophys. Res., Vol. 102, pp.17131–17142.

Watson, A. B. (Ed.), 1993, "*Digital Images And Human Vision"*, Cambridge, MA, MIT Press.

Westen, S. J. P. , R. L. Lagendijk, And J. Biemond, 1995, "Perceptual Image Quality Based On A Multiple Channel HVS Model," Proc. Of IEEE Int'l Conf. On Acoust., Speech And Sig. Proc., pp. 2351 - 2354.