Satellite Images Quality Improvement for Multilevel Data Processing

Ivan Prudyus, Leonid Lazko, Serhiy Semenov

Abstract - **In present paper there was done analysis of possible ways to improve quality of satellite images, which are being used for multilevel data processing, in order to increase object detection accuracy.**

Keywords - **Remote sensing, data fusion, pixel level fusion, feature level fusion, image processing.**

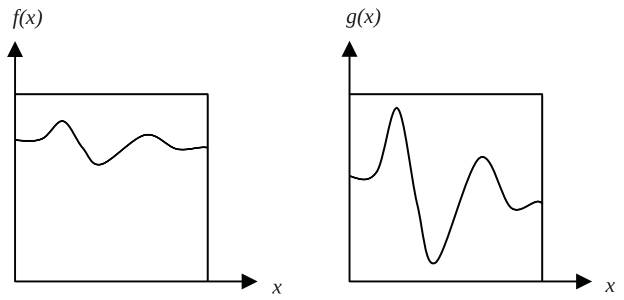
I. INTRODUCTION

In a multilevel fusion, having several sources of primary information, important role belongs to pixel level fusion [5,6,10], which is seriously affecting the efficiency of data processing on all next stages and processing result in general. In a case, when images of separate spectral channels are used as primary data for processing and its goal consists in provision of accurate object detection of a specific scene that is being described by these images, the main attention should be paid for quality improvement of each separate image that is being fused. As we're talking about detection, under concept of quality we should understand quality as a characteristic of an image and not the measure of image's proximity to some "standard". Thus, the target of such kind processing is obtaining "suitable for observation", "qualitative" image. Let's take a view of some possible ways of image quality improvement.

II. LINEAR CONTRAST INCREASE

As an input images for image processing were used spectral channels 1-6 of satellite Landsat 7 ETM +, after applying the first stage of processing, which includes correction of geometric distortions, calibration and re-discretization of data.

Images that are processed are often found as soft images [3], i.e., the brightness values are small compared with the mean value. The brightness doesn't change from black to white, but from gray to little more light gray. That is the real range of brightness appears much lower than allowable (brightness scale). The task of contrast enhancement is to "stretch" a range of image brightness on all scale [2,3,8] (Figure 1)



а) б)

Figure 1. Linear contrast enhancement of the image

Serhiy Semenov – Lviv Polytechnic National University,
S. Bandery str., 12, Lviv, 79013, UKRAINE,
E-mail: ideafix@ua.fm

This problem can be solved using pixel by pixel conversion – linear contrast enhancement:

$$g(n_1, n_2) = af(n_1, n_2) + b\,, \qquad (1)$$

where $f(n_1,n_2)$ – function of two discrete spatial variables, in other words - discrete image to be processed; a, b – constants; $g(n_1,n_2)$ – the output discrete image. Parameters of this transformation can be defined as follows: range $[f_{\min},f_{\max}]$ transforms into the range $[g_{\min},g_{\max}]$. So, there is the following system:

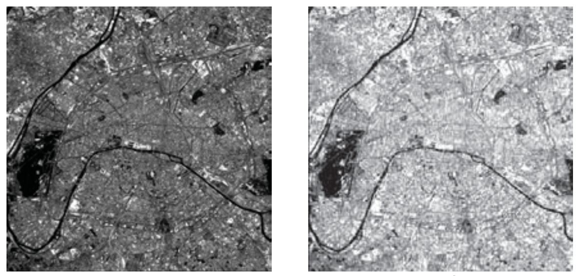
$$\begin{cases} g_{\min} = af_{\min} + b, \\ g_{\max} = af_{\max} + b, \end{cases} \qquad (2)$$

thus,

$$a = \frac{g_{\max} - g_{\min}}{f_{\max} - f_{\min}};\; b = \frac{g_{\min} f_{\max} - g_{\max} f_{\min}}{f_{\max} - f_{\min}}. \qquad (3)$$

Obviously, first we must evaluate $f_{\min}$, $f_{\max}$.

Further processing was carried out using values of $f_{\min}$=0, $f_{\max}$=0.8 and $g_{\min}$=0, $g_{\max}$=1 for input images.



а) б)

Рис.2. Example of linear contrast enhancement of 3rd channel's image: before (a) and after (b) the processing

III. SHARPNESS ENHANCEMENT

During the formation of satellite images due to inaccurate settings of the optical part of the system, non-zero area of the video sensor (CCD line) and other reasons frequency response of imaging system differ from the ideal. So, images are being affected by linear distortions. Typically, these distortions consist in reducing of rate of upper spatial frequencies of image spectrum. Visually they are perceived as misfocusing, deterioration of image sharpness, which is bad for small details observation [2,3].

Typical example of such an image is the image of thermal infrared channel №6 (Fig.3), because of inability to provide zero dark current of CCD line, which operates in the IR range, and applying the procedure of changing image resolution of this channel to fit the resolution of visible channels' images.

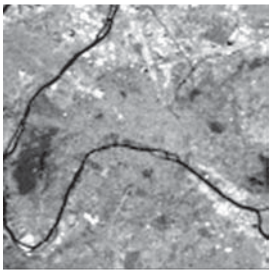


Figure 3. Image of thermal IR channel

Therefore, sharpness enhancement should consist in raising the level of high-frequency spectrum components of the image or, in other words, its high-frequency filtering.

It should be noticed that the task is not to reconstruct the image, i.e. return to the "original". Due to sharpness enhancement it sometimes needed to re-compensate distortions, i.e. to raise the level of high-frequency components of a spatial spectrum excessively.

Thus, sharpness enhancement consists in strengthening of high-frequency components of a spatial spectrum of image.

There are a lot of specific methods to increase sharpness (and their variations) [1,2,8]. Let's consider the method that is based on a spatial linear image processing by small "sliding window" [2,3,8]. This window moves across the image, and for each its position one sample of the output brightness field is being formed (usually it corresponds to a centre of the window). In this case the sharpness enhancement algorithm is being realized as two-dimensional filter with finite-impulse response (FIR). Size and shape of the window area is being specified by non-zero values of FIR-filter impulse response.

Let's apply a low-frequency filter to the image of the thermal channel. Smoothing will be implemented by averaging samples of brightness field within the window:

$$\overline{f}(n_1, n_2) = \sum_{(k_1,k_2)\in D}\sum a(k_1, k_2)\, f(n_1 - k_1, n_2 - k_2), \qquad (4)$$

where D – some finite region in space of arguments, that defines the window $((k_1, k_2) \in D)$. We see that written expression define two-dimensional convolution signal with impulse response $a(k_1, k_2)$ of FIR-filter.

At the same time, it's being assumed:

$$a(k_1, k_2) > 0\,. \qquad (5)$$

In addition, smoothing procedure should meet the following requirement: it must not change the average value (constant component) of image, so that next demand should be followed:

$$\sum_{(k_1,k_2)\in D}\sum a(k_1, k_2) = 1. \qquad (6)$$

Next, high-frequency image is being computed:

$$f'(n_1, n_2) = f(n_1, n_2) - \overline{f}(n_1, n_2) \qquad (7)$$

then, image with enhanced sharpness:

$$g(n_1, n_2) = f(n_1, n_2) - qf'(n_1, n_2), \qquad (8)$$

where q – gain factor of difference (high-frequency) signal ($q > 0$).

Thus, we get:

$$g(n_1, n_2) = \sum_{(k_1,k_2)\in D}\sum h(k_1, k_2)\, f(n_1 - k_1, n_2 - k_2), \qquad (9)$$

where $h(k_1, k_2)$ - impulse response of FIR-filter, that realize sharpness enhancement;

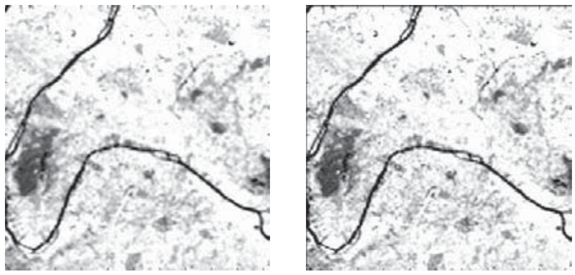
$$h(0,0) = 1 + q - qa(0,0), \qquad (10)$$

$$h(k_1, k_2) = -qa(k_1, k_2),\ (k_!, k_2) \in D,\ (k_1, k_2) \neq (0,0). \qquad (11)$$

To carry out filtering of channel 6 image centered window of 3x3 pixel size will be taken. At the same time samples of $h(k_1, k_2)$ will be set as so-called "mask" of the following from:

$$\frac{1}{(\alpha+1)}\begin{bmatrix} -\alpha & \alpha-1 & -\alpha \\ \alpha-1 & \alpha+5 & \alpha-1 \\ -\alpha & \alpha-1 & -\alpha \end{bmatrix} \qquad (12)$$

using the value of $\alpha = 0.2$.



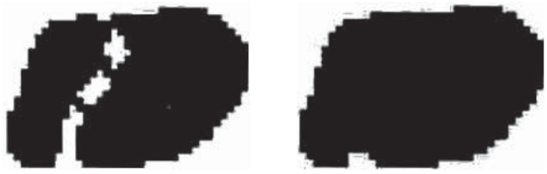
а) б)

Figure 4. Image of thermal IR channel: after contrast (a) and sharpness (б) enhancements

Results of this filtration are being reflected in objects boundary enhancement, improvement of discernibility of small details (that were fuzzy before) and "texture" improvement, i.e. small regular or random brightness fluctuations within areas without contours.

IV. PIXEL LEVEL RESULTS PROCESSING ON A FEATURE LEVEL

In order to improve the efficiency of processing on a feature level, on its start it was proposed to apply the procedure of objects "closure" [1,2,8], which consist in alternate application of erosion and jointing [2] procedures, in order to remove small-area parts of background inside object, such as "holes" (closed background areas inside objects). Operation of "closure" procedure is illustrated on Figure 5.



а) б)

Figure 5.: a) input image; б) image «closure»

V. CONCLUSION

As a result of application of linear contrast enhancement to images of separate channels the improvement of the probability of target missing, during detection of the river in separate channels, reaches 9-27%, depending on the channel; at the same time worsening or the false alarm probability makes up 5-28%. For groups of fused channels improvement of the probability of target missing is 12-17%, depending on the group of channels; at the same time worsening of the false alarm probability makes up only 2.8%.

Sharpness enhancement or, in other words, high-frequency filtering of channel 6 image improves the target missing probability in this channel on 24%, while false alarm probability increases on 19%. For groups of fused channels, which contain contrast-enhanced images of separate channels together with the filtered image of the 6-th channel, improvement of the probability of target missing reaches 14-25%, depending on the group of channels, at the same time worsening of the false alarm probability makes up 7-19%.

Application of "closure" procedure on a feature level provides improvement of false alarm probability in each group of fused channels on 2.8% without worsening the probability of target missing.

As a result of multi-level processing, using all above operations for image processing and detection of original object, it was achieved an improvement of the target missing probability on 43% and the false alarm probability on 7%.

REFERENCES

1. Haralick R.M., Shapiro L.G. Computer and Robot Vision. V. I. Addison-Wesley, 1992, 630 pp.
2. Гонсалес Р., Вудс Р., Эддинс С. Цифровая обработка изображений в среде MATLAB. Москва: Техносфера, 2006. - 616 с.
3. Методы компьютерной обработки изображений / Под ред. В.А. Сойфера. – 2-е изд., испр. – М.: ФИЗМАТЛИТ, 2003. – 784 с.
4. Прудиус И.Н., Лазько Л.В., Семёнов С.А. Детектирование объектов на уровне признаков с использованием коэффициента формы. – СВЧ-техника и телекоммуникационные технологии: Материалы 18-й междунар. конф., 8-12 сентября 2008 г. - Севастополь: Изд-во СевНТУ, 2008.
5. Прудиус И.Н., Лазько Л.В., Семёнов С.А., Многоуровневый метод комплексирования изображений. – Современные информационные и электронные технологии: Материалы 8-й междунар. конф., 21-25 мая 2007 г. – Одесса, 2007.
6. Прудиус И.Н., Лазько Л.В., Семёнов С.А., Помехоустойчивое комплексирование данных на пиксельном уровне. – Современные информационные и электронные технологии: Материалы 9-й междунар. конф., 19-23 мая 2008 г. – Одесса, 2008.
7. Прудиус І.Н., Лазько Л.В., Семенов С.О. Багаторівневе комплексування графічної інформації в системах дистанційного зондування. Вісник НУ «Львівська політехніка». Радіоелектроніка та телекомунікації. Львів, 2008.
8. Прэтт У. Цифровая обработка изображений. В 2 т. М.: Мир, 1982, 312с., 478с.
9. Семёнов С.А. Многоуровневое комплексирование информации в пассивных широкополосных спутниковых системах дистанционного зондирования. – Современные проблемы радиотехники и телекоммуникаций «РТ-2007»: Материалы 4-ой междунар. молодежной науч.-техн. конф., 16-21 апреля 2007 г. – Севастополь: Изд-во СевНТУ, 2007, с. 218.
10. Семёнов С.А. Помехоустойчивое комплексирование данных на пиксельном уровне с использованием сегментации. – Современные проблемы радиотехники и телекоммуникаций «РТ-2008»: Материалы 5-ой междунар. молодежной науч.-техн. конф., 21-25 апреля 2008 г. – Севастополь: Изд-во СевНТУ, 2008, с. 31.