Multispectral Imagery Fusion for Future Belarusian and Ukrainian Remote Sensing Satellites

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Abstract: *New techniques and algorithms for the integrated processing of multispectral imagery from future Belarusian and Ukrainian remote sensing satellites are described. Apply the developed techniques extends the interpretation facilities and classification validity of Sich-2 and BelKA-2 multispectral imagery owing to spatial and spectral resolution enhancement.*

***Keywords*:** Remote Sensing, Multispectral Imagery, Spectral Band, Data Fusion, Resolution Enhancement.

1. INTRODUCTION

It is known, that efficiency of the natural management, ecological and other tasks using remote sensing directly depends on imaging data quality. The high spatial and spectral resolution of imagery is the major factor of imaging data quality. The high spatial resolution opens capabilities to restore the ground details on the image better, and the high spectral permission allows to register the spectral features of objects precisely.

So, it is impossible to provide high performance level of both factors in same sensor out of fundamental physical limitations. Therefore, in practice, depending on a customer needs, it is exploit two different kinds of sensors. First one supports the high spatial resolution in limited number of spectral bands; other has a significant number of working spectral bands with the low spatial resolution.

The main idea of the current research is a fusion the imagery of same scene generated by different sensors with the unequal resolution to extract all spatial and spectral information and to synthesize secondary images with increased interpretation facilities.

Imagery from different sensors can essentially differ by geometric and radiometric performances. Therefore, it is required to elaborate computer processing of multispectral imagery for distortion rectifying, georeferencing, spatial resolution matching or enhancement, additional spectral bands synthesizing, interpretation, etc. The integrated approach for computer processing of multispectral imagery, based on data fusion methods and spectral libraries of natural objects is offered.

Original techniques and algorithms for integrated processing of multispectral imagery are improved and adapted for enhancement of interpretation facilities and classification validity of multispectral imagery from future Ukrainian (Sich-2) and Belarusian (BelKA-2) remote sensing satellites.

2. DATA

The launch of Ukrainian satellite Sich-2 is planned in fall of 2009. Same year the launch of Belarusian satellite BelKA-2 is scheduled.

The Sich-2 sun-synchronous orbit satellite is intended for natural resources control, land management, forests and waters monitoring, minerals prospecting, emergency control. Onboard sensors of Sich-2 satellite have four spectral bands – three visible and near infrared (VNIR) and one short-wave infrared (SWIR). The spatial resolution in all VNIR bands is equal 7.8 m at nadir, in SWIR band – 39.5 m. The panchromatic band for Sich-2 is not present.

Belarusian satellite BelKA-2 destination is the monitoring of natural resources and disasters, agriculture and land management, environment condition control, topographic mapping, mark of perspective area for minerals search. Onboard sensors of BelKA-2 satellite have five spectral bands – three visible and one near infrared, and one panchromatic band. The spatial resolution in the panchromatic band is 2.1 m, in spectral bands – 10.5 m at nadir.

Basic specifications of the future Ukrainian and Belarusian remote sensing satellites are given in Table 1.

Thus, lack of the high spatial resolution band is disadvantage of Ukrainian satellite Sich-2, but advantage is unified space resolution of VNIR spectral bands and also SWIR band presence. Contrariwise, the high resolution panchromatic band is advantage of Belarusian satellite BelKA-2, but disadvantage is the lower spatial resolution in spectral bands, than for Sich-2 ones. Obviously, that the Sich-2 and BelKA-2 satellites are complementary each for other by its capabilities.

The carried out analysis shows, that by the integrated (concurrent) processing of multispectral imagery, received from both satellites, it is possible to compensate the listed disadvantages and to synthesize secondary images with the enhanced spatial resolution and radiometric quality. Furthermore, due to engaging the spectral libraries of natural objects it is possible to increase essentially the interpretation facilities of multispectral imagery. It solves such actual fundamental problem, as valid classification of the multispectral imagery received from modern remote sensing satellites.

3. PREPROCESSING

The main entities of the integrated processing of multispectral imagery from the future Belarusian and Ukrainian remote sensing satellites are:

- automatic georeferencing the Earth observation data from Sich-2 and BelKA-2 satellites;
- preprocessing the multispectral imagery from Sich-2 and BelKA-2 satellites;
- signal-to-noise ratio amplification inside shaded land area on space imagery;
- synthesizing the images with the enhanced spatial resolution on the basis of joint processing of

multispectral imagery from Sich-2 and BelKA-2 satellites using the spectral libraries of natural objects;

- synthesizing the additional spectral images in visible and infrared spectral bands, missing in initial bandset, using the spectral libraries of natural objects.

Novelty of some foregoing entities is confirmed by patents [1, 2].

The registered signal E_i from scene object within the sensor spectral band with wavelengths λ_i up to $\lambda_i+\Delta\lambda_i$ is modulated by object spectral reflectance $\rho(\lambda)$ as:

$$E_j = \int_{\lambda_j}^{\lambda_j+\Delta\lambda_j} E_0(\lambda)\,\tau^2(\lambda)\,\rho(\lambda)\,d\lambda\,, \qquad (1)$$

where $E_0(\lambda)$ – spectral density of solar irradiation, $\tau(\lambda)$ – Earth's atmosphere spectral transparency.

The spectral distribution of solar irradiation with high accuracy coincides with thermal radiation of ideal blackbody with a wavelength maximum at a λ_0 = 0.47 µm and before the Earth's atmosphere is described jointly by Plank's and Wien's laws:

$$E_0(\lambda) = \frac{2\pi h c^2}{\lambda^5\left[\exp\left(\frac{h c b}{k\lambda\lambda_0}\right)-1\right]}\left(\frac{R_0}{D_0}\right)^2, \qquad (2)$$

where h = 6.626·10^{-34} W·s^2 – the Plank's constant, c = 2.998·10^5 km/s – the light velocity in vacuum, k = 1.38·10^{-23} W·s^2/K – the Boltzmann's constant, b = 2898 µm·K – the Wien's constant, R_0 = 6.96·10^7 km – the Sun radius, D_0 = 1.496·10^8 km – the Sun to Earth average distance.

The multispectral imagery resolution enhancement technique consists in the following [3]:

- sensor calibration for scene objects spectral signatures measurement by formula (1);
- objects spectral signatures classification inside remote sensing scene;
- spectral signatures calculation for the low resolution image subpixels which correspond to the high resolution image separate pixel;
- low resolution image subpixels correction using high resolution image classified pixels under low resolution image pixels non-deviation restriction:

$$E_j = \frac{1}{n_j}\sum_{i=1}^{n_j} E_{ji}\,, \qquad (3)$$

where n_j – the number of high resolution image pixels which correspond to the low resolution image single one.

Data processing flow is shown in Figure1.

Figure 2 illustrates the multispectral imagery spatial resolution enhancement.

Principle for the multispectral imagery additional spectral band synthesizing is the same as the spatial resolution enhancement [4]. It is possible to restore the radiometric value of a scene object in any spectral band if spectral library data is available for this object. So, the radiometric values in some additional spectral band can be calculated for all pixels of the source multispectral imagery and thus the additional spectral image will be synthesized. Described procedure repeats for all required additional spectral bands.

Figure 3 shows the additional spectral images in VNIR and SWIR bands synthesizing for MS-2-8 multispectral imagery.

4. DATA FUSION

In satellites launched after 1999, sensitivity range of the panchromatic image sensor is usually extended to cover nearest infrared range. It is made in order to increase resolution of the registered panchromatic image, but the former fusion methods cause significant color distortion.

In Fig.4 we present a scheme for fusion of multispectral data registered by Ukrainian and Belarusian satellites. Starting from original data we can produce new (artificial) multispectral image like new blue band B_S and new short-wave infrared S_S for Ukrainian satellite, also new pan-sharpened blue, green, red and near infrared images with resolution like in pan-sharpening band Pan_S.

We developed several variants of multispectral image fusion with minimal color composite distortion and resolution enhancement of the fused images up to than resolution of the given panchromatic image (see examples in Figure 5 and 6).

5. CONCLUSION

Experimental research of adaptation of our fusion methods for pan-sharpening of collection of imagery registered form Ukrainian and Belarusian satellites for the same terrain areas is very important for various applications.

New techniques and algorithms for the integrated processing of multispectral imagery with different spatial resolution are represented. Developed algorithms are based on data fusion method and give possibility to synthesizing enhanced images.

New algorithm for generating the additional spectral images in VNIR and SWIR bands is described. It is obviously shown that received with proposed technique images carry important addition information about scene.

We presented a technology for multispectral image processing and imagery fusion with minimization of color composite distortion and resolution increasing up to the resolution of a given panchromatic image. This was done in two stages: first, we apply super-resolution panchromatic image reconstruction using the original multispectral and panchromatic images; second, multispectral images are fused using the reconstructed panchromatic image.

Thanks to the fusion methods we properly reconstruct color and structural information and do not blur the edges on color bands.

6. REFERENCES

[1] M. Popov, S. Stankevich. Method for Spatial Resolution Enhancement of Multispectral Aerospace Imagery Based on Spectral Signatures Classification. *Ukrainian Patent* No 84877, 2008 (Ukrainian).

[2] M. Popov, S. Stankevich, A. Kozlova. Method for Spectral Resolution Enhancement of Multispectral Aerospace Imagery. *Ukrainian Patent* No 81195, 2007 (Ukrainian).

[3] M. Popov, S. Stankevich. Multispectral Imagery

Resolution Enhancement in Environmental Remote Sensing. *Proceedings of the International Advanced Research Workshop on Fuzziness and Uncertainty in GIS for Environmental Security and Protection*, Kiev, Ukraine, 2006, pp. 9-10.

[4] M. Popov, S. Stankevich. About Restoration of the Scanning Images Received Onboard a Sich-1M Space Vehicle by Inverse Filtering Method. *Proceedings of the 31st International Symposium on Remote Sensing of Environment*, Saint-Petersburg, Russia, 2005, pp. 488-490.

[5] Y. Monich, V. Starovoitov, Multispectral image enhancement by non-linear adaptive techniques, *Proceedings of 9th Pattern Recognition and Information Processing*, Minsk, Belarus, 2007, Vol. II, pp.18-22.

[6] V. Starovoitov, A. Makarau, I. Zakharov, D. Dovnar. Fusion of reconstructed multispectral images, *Proceedings of IEEE International Geoscience and Remote Sensing Symposium*, Barcelona, Spain, 2007.

Table 1. Future Belarusian and Ukrainian remote sensing satellites specifications

Satellite	Orbit altitude, km	Sensor	Band name	Spectral bands, μm	Spatial resolution, m	Ground swath, km
Sich-2	668	MS-2-8	G_S R_S N_S	0.50-0.59 0.61-0.68 0.79-0.89	7.8	46.6
		SSIR	S_S	N 1.55-1.7	39.5	55.3
BelKA-2	495	PSS	Pan_B	0.54-0.78	2.1	20.4
		MSR	B_B G_B R_B N_B	0.53-0.61 0.62-0.70 0.67-0.72 0.74-0.87	10.5	18.9

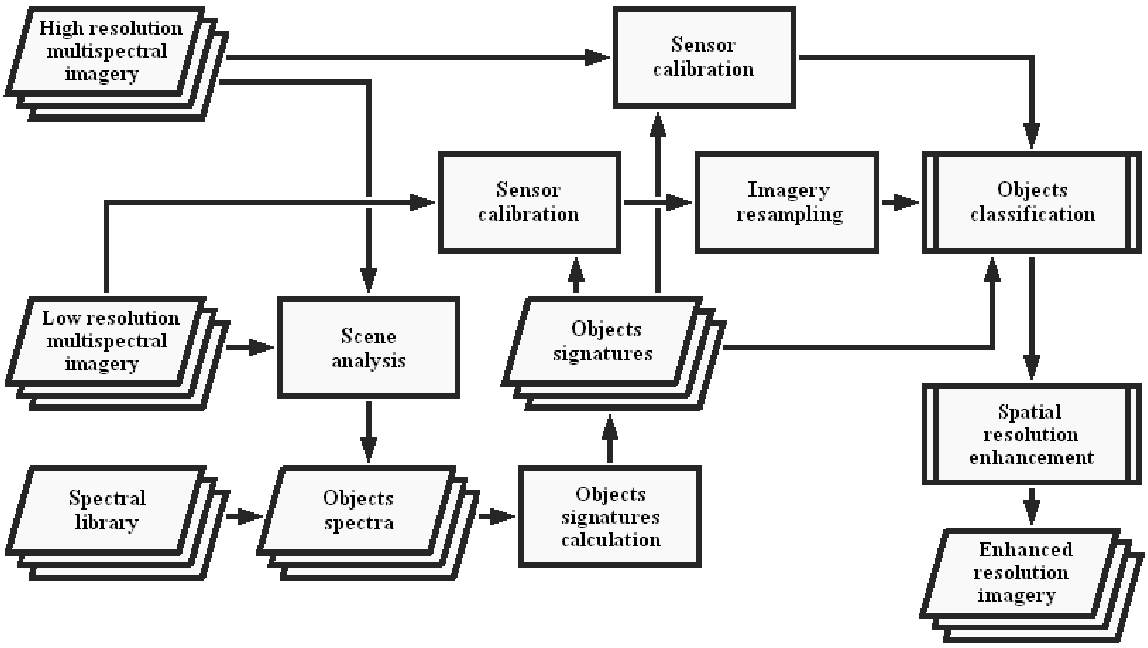
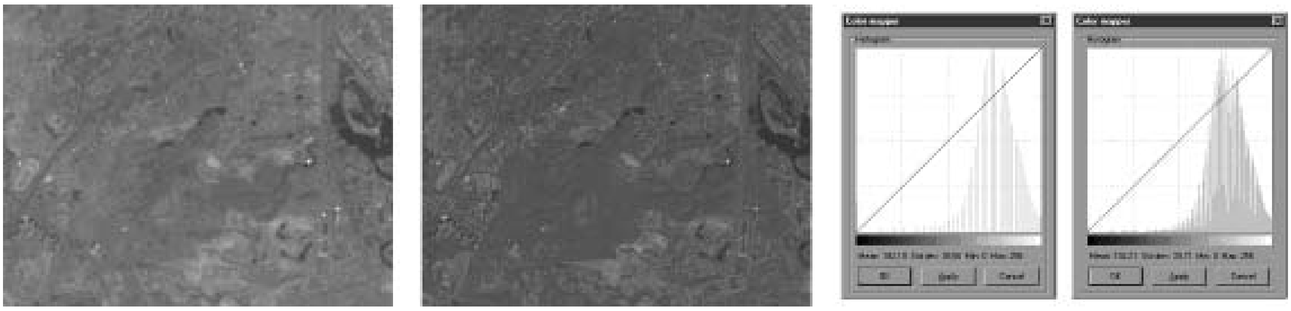


Fig. 1 – Multispectral imagery spatial resolution enhancement on the basis of spectral signatures classification.



a b c

Fig. 2 – ASTER multispectral imagery fragment resolution enhancement
a – SWIR band (1.6-1.7 μm) half resolution image, b – enhanced resolution image, c – histogram change.

a b c d e

Fig. 3 – MS-2-8 multispectral imagery fragment additional spectral bands synthesizing
b, c, d – source MS-2-8- spectral bands: green (0.50-0.59 μm), red (0.61-0.68 μm), near infrared (0.79-0.89 μm)
a, e – synthesized additional spectral bands: blue (0.40-0.49 μm) and SWIR (2.0-2.4 μm).

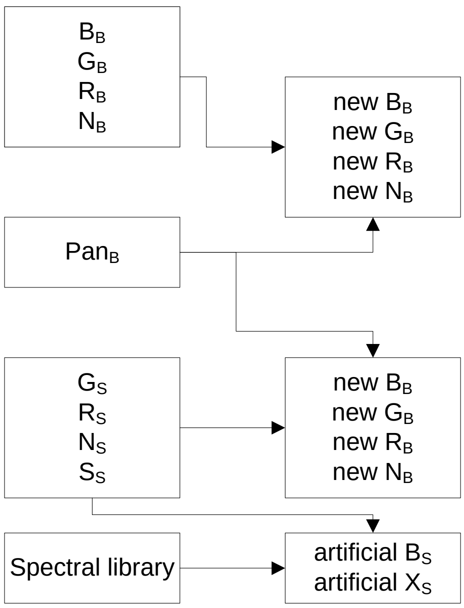
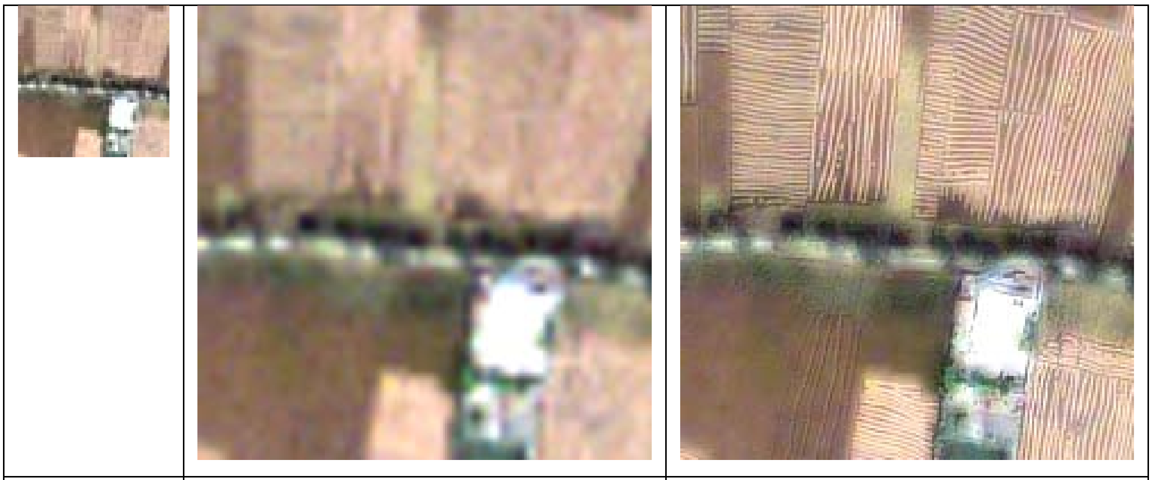
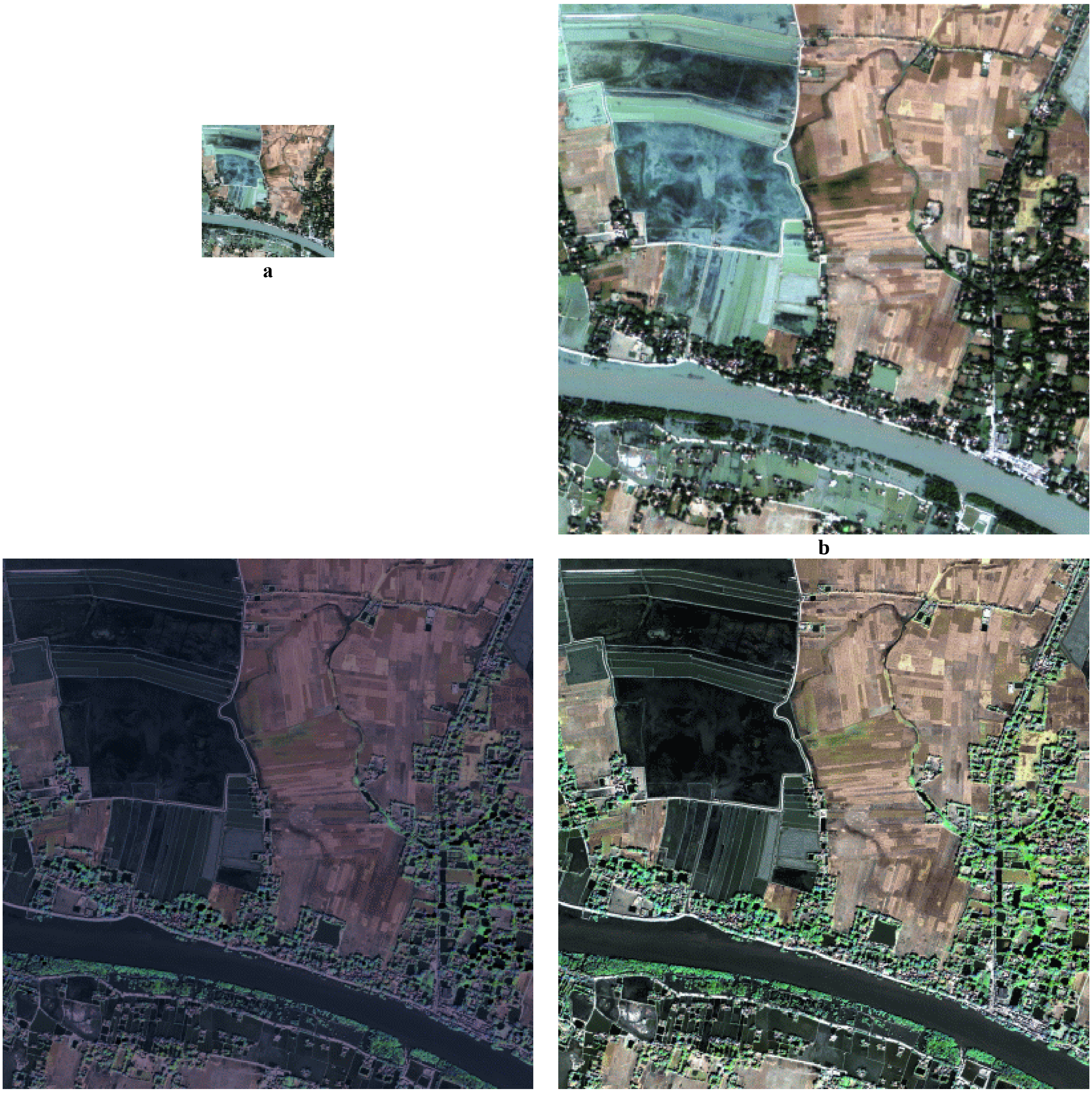


Fig. 4 – Multispectral imagery fusion scheme



a	b	c

Fig. 5 – a – an example of original multispectral imagery in natural colors (R, G, B), b – four times scaled original (bad details), c – a fused image (good detail representation).



a b c d

Fig. 6 – a – Original multispectral imagery in natural colors (Quickbird), b – four time pan-sharpening by our approach based on global regression (maximal original color preservation), c – Brovey pan-sharpening (big color distortion), d – pan-sharpening via HSV color space (small color distortion).