RESEARCH METHODS FOR IMPROVING SATELLITE IMAGES BASED ON PAN-SHARPENING

Oleksandr Dorozhynskyy, Radomir Obroslak, Yurii Stusyak

Summary

The authors of the article consider five classic methods to improve images with pan sharpening and it present their mathematical models and technological schemes, the estimation of their positive effects both on color distortion and fragmentation in spatial resolution. Results of impact methods were observed and compared in two software products: Erdas Imagine 10.0 and ArcGIS 10.2. For comparison were used satellite images with ultrahigh spatial resolution and high spatial resolution.

1. Introduction

Space information or information that is obtained by space means of remote sensing (RS), widely and effectively used by many countries. Today, by using space information, successfully resolved the problem of search of minerals and energy, estimating agricultural and forestry potential of regions and countries, performed monitoring of emergencies and so on [Аристов 2009].

Given the fact that data from sensors mounted on satellites have different spatial, spectral, temporal and other resolution, pressing question becomes of remote sensing of the merger in order to integrate the characteristics for their improvement and further analysis, for example in GIS.

The information contained in the image, resulting from the merger, are more complete and accurate and higher quality first, leading to a clearer understanding of the properties of the selected object.

2. Methods of image fusion

All the variety of methods of "image fusion" adopted to classify by types of transformations as follows [Бабков and Титаренко 2011] (Figure 1):
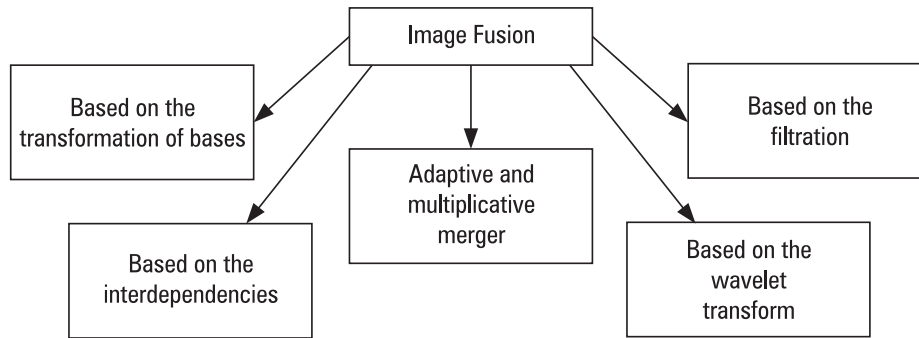
Source: authors' study

___

Fig. 1. Classification of image fusion techniques

Among the hundreds of different methods of image fusion most popular and effective are:

- IHS (Intensity – Hue – Saturation / Intensity – Hue – Saturation),
- PCA (Principal Component Analysis – analysis of the main component of the image),
- arithmetic combination and fusion based on wavelet – transformation,
- method merger Gram-Schmidt,
- convert Brovey.

2.1. IHS pan-sharpening technique

IHS (Intensity-Hue-Saturation) is the most common image fusion technique for remote sensing applications and is used in commercial pan-sharpening software. This technique converts a color image from *RGB* space to the IHS color space. Here the *I* (intensity) band is replaced by the panchromatic image. Before fusing the images, the multispectral and the panchromatic image are histogram matched. The image is converted to IHS color space using the following linear transformation [Padwick et al. 2010]:

$$\begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} = \begin{bmatrix} \dfrac{1}{3} & \dfrac{1}{3} & \dfrac{1}{3} \\ \dfrac{-\sqrt{2}}{6} & \dfrac{-\sqrt{2}}{6} & \dfrac{2\sqrt{2}}{6} \\ \dfrac{1}{\sqrt{2}} & \dfrac{1}{\sqrt{2}} & 0 \end{bmatrix} = \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

Therefore, the entire fusion process can be expressed mathematically as:

$$\begin{bmatrix} F(R) \\ F(G) \\ F(B) \end{bmatrix} = \begin{bmatrix} \dfrac{1}{3} & \dfrac{1}{3} & \dfrac{1}{3} \\ \dfrac{-\sqrt{2}}{6} & \dfrac{-\sqrt{2}}{6} & \dfrac{2\sqrt{2}}{6} \\ \dfrac{1}{\sqrt{2}} & \dfrac{1}{\sqrt{2}} & 0 \end{bmatrix} = \begin{bmatrix} Pan \\ v1 \\ v2 \end{bmatrix} \qquad 2)$$

This process is equivalent to:

$$\begin{bmatrix} F(R) \\ F(G) \\ F(B) \end{bmatrix} = \begin{bmatrix} R + Pan - 1 \\ G + Pan - 1 \\ B + Pan - 1 \end{bmatrix} \qquad (3)$$
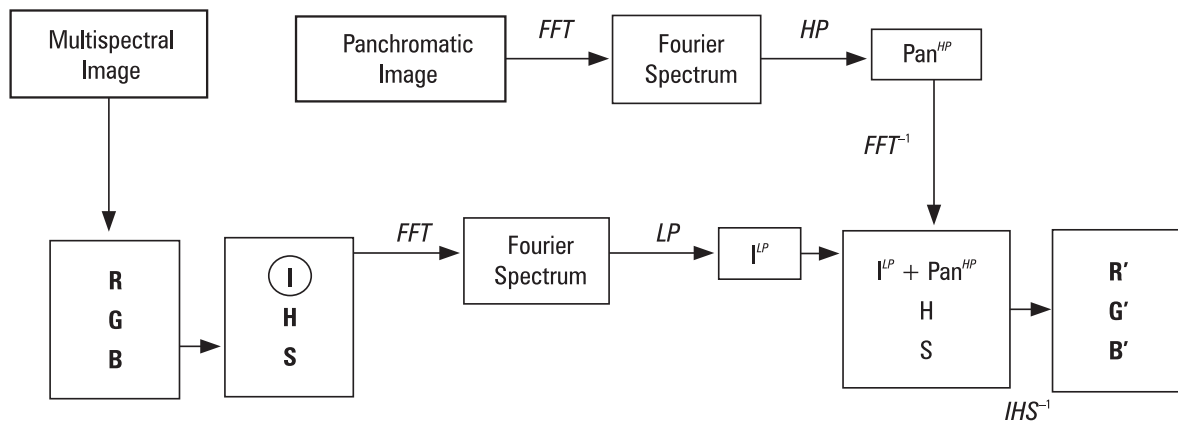

Fig. 2. Scheme implementation of IHS image fusion method

2.2. PCA method PCA transformation (conversion data using PCA matrix) converts the multispectral bands linked to a new set of uncorrelated components [Rose 2009].
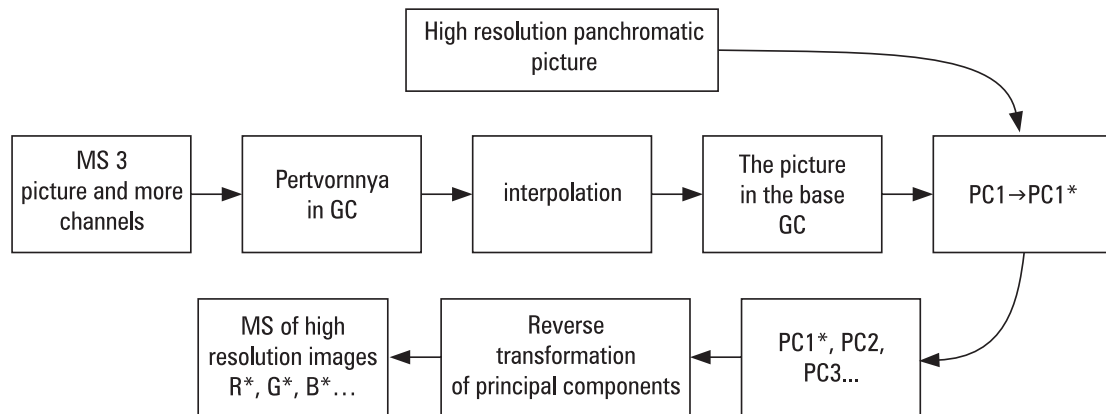
$$\begin{bmatrix} PC1 \\ PC2 \\ PC3 \end{bmatrix} = W_{pc} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (4)$$

where:
    PCi – matrix and the second main components,
    W_{pc} – matrix transformation,
R, G, B – matrix brightness of pixels in the output spectral channels.

Source: authors' study

Fig. 3. Scheme of merger by PCI

2.3. Wavelet

The wavelet fusion method is based on the wavelet decomposition of images into different components based on their local frequency content. We perform the Discrete Wavelet Transforms (DWT) on the multispectral and panchromatic images to extract the low frequency data from the multispectral image and the high frequency data from the panchromatic image. These components are combined to create the Fused Wavelet Coefficient Map. The inverse wavelet transformation is performed on the fused map to create the final Pan-Sharpened image. Below is a visual representation of the wavelet method [Strait et al. 2008].
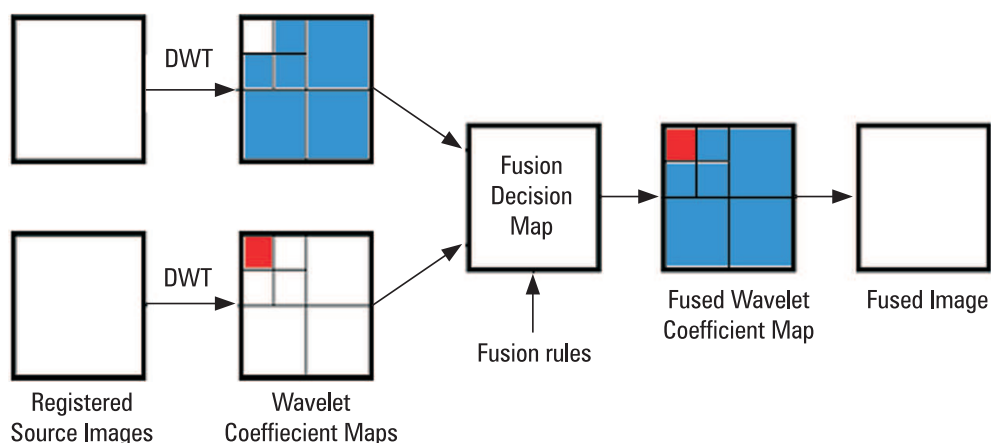
Source: authors' study

Fig. 4. Scheme Wavelet-transformation

2.4. Convert Brovey

This conversion uses the method in which the brightness of each pixel multispectral image is multiplied by the ratio of the brightness of the corresponding pixel panchromatic image brightness to the sum of all areas multispectral image [El-Mezouar et al. 2012].

When converting Brovey, basic equation uses red, green, blue (RGB) and the panchromatic channel to calculate the new red, green and blue channels. example:

$$Red\_out = Red\_in / [(blue\_in + green\_in + red\_in) \cdot Pan]$$

2.5. Method merger Gram-Schmidt

Method of fusion Gram-Schmidt algorithm based on the total for vector orthogonalization – orthogonalization Gram-Schmidt. This algorithm gets vectors as input (e.g. 3 vector in three dimensions) that are not perpendicular, then returns them so that They then are perpendicular (orthogonal). In the case of images, each channel (panchromatic, red, green, blue and infrared) corresponds to the vector with multiple dimensions (dimensions = pixels) [Qian Du et al. 2005].
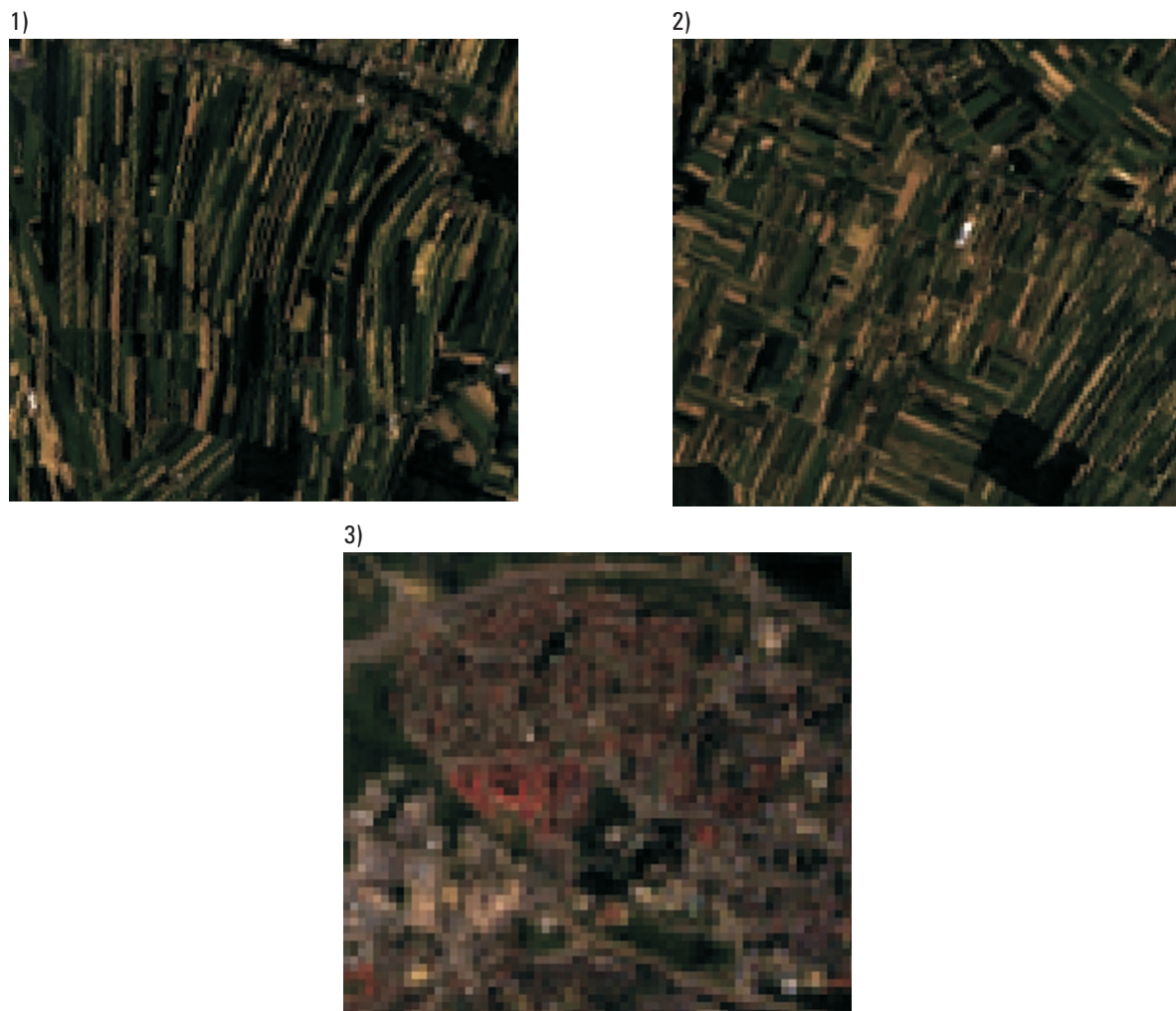
3. Processing of images

3.1. Intput data

The initial data for images served two survey systems such as Landsat 8, QuickBird. Photos of QuickBird satellite of images belong to ultra-high resolution 0.4–0.9 m and Landsat 8 – a relatively high 15–30 m.
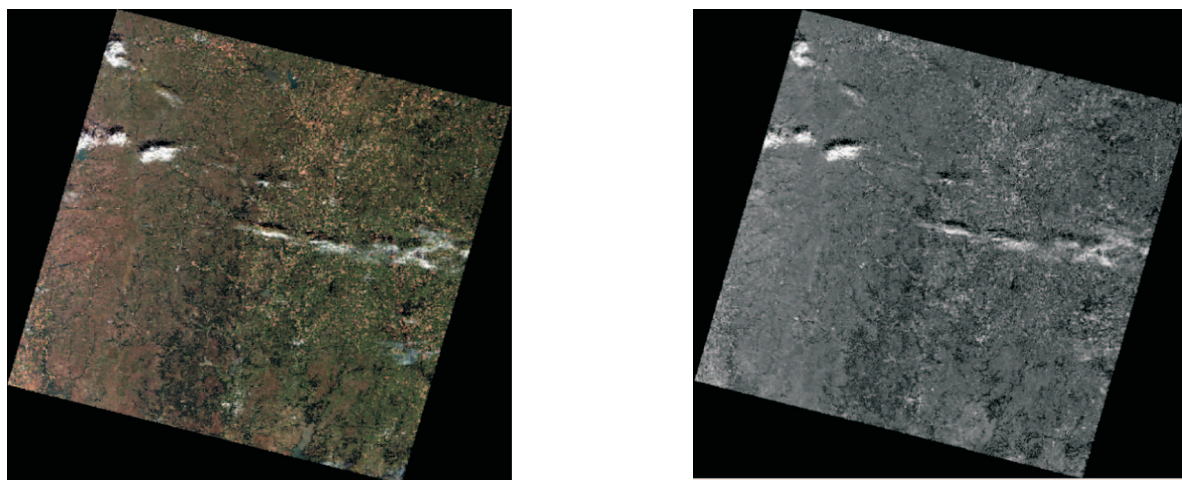

Source: authors' study

Fig. 5. Satellite images of the satellite QuickBird, left to MS – 2.4 m, and the right PAN – 0.6 m

Source: authors' study

Fig. 6. Multispectral satellite images Landsat 8 to Poland, from left to right: 1) Jaroszewice area, 2) Chodel area, 3) disttrict of Lublin
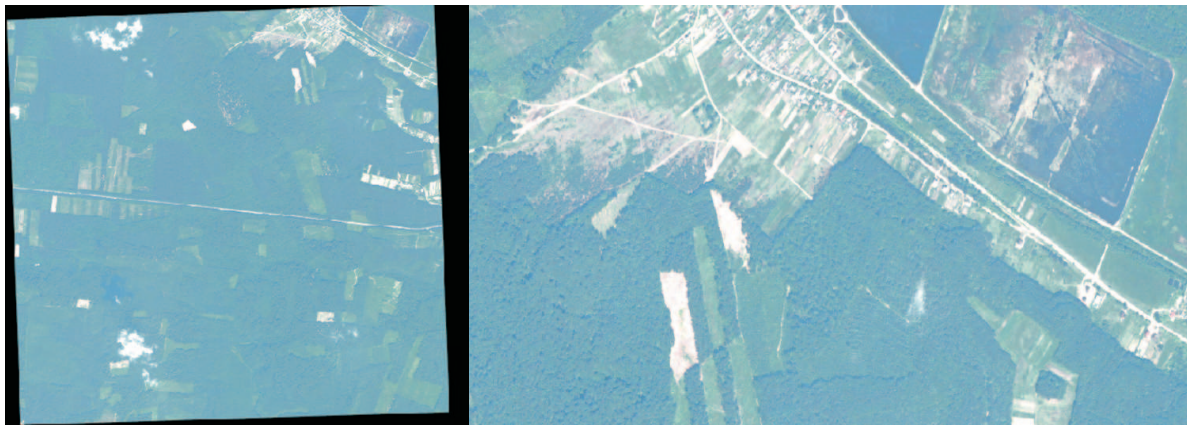

Source: authors' study

Fig. 7. Satellite images of the satellite Landsat 8, left to MS – 30 m, and the right PAN – 15 m

3.2. Application Pan Sharpening in ArcGIS 10.2

Fusion with panchromatic channel is radiometric transformation that is available through the user interface or by using geo instrument processing.

In ArcGIS software product offered five ways to association data to create an image with increased spatial resolution: Brovey transformation, the transformation model by IHS, transformation fusion of Esri, the arithmetic mean by transformation and fusion spectral method Gram-Schmidt.

Each of these methods uses its own model of increasing fragmentation in the processing of color and some of them (Gram-Schmidt) allow you to use a weighing factor for the inclusion of a fourth channel data (such as near infrared channel). When you add weighing and turn on the infrared component, the visual quality color output improves.
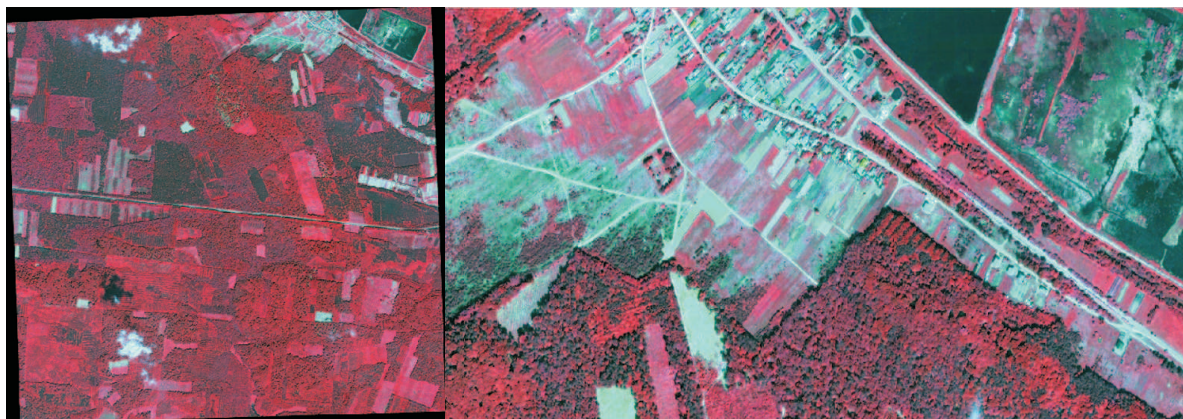

Source: authors' study

Fig. 8. Result of the fusion by IHS method
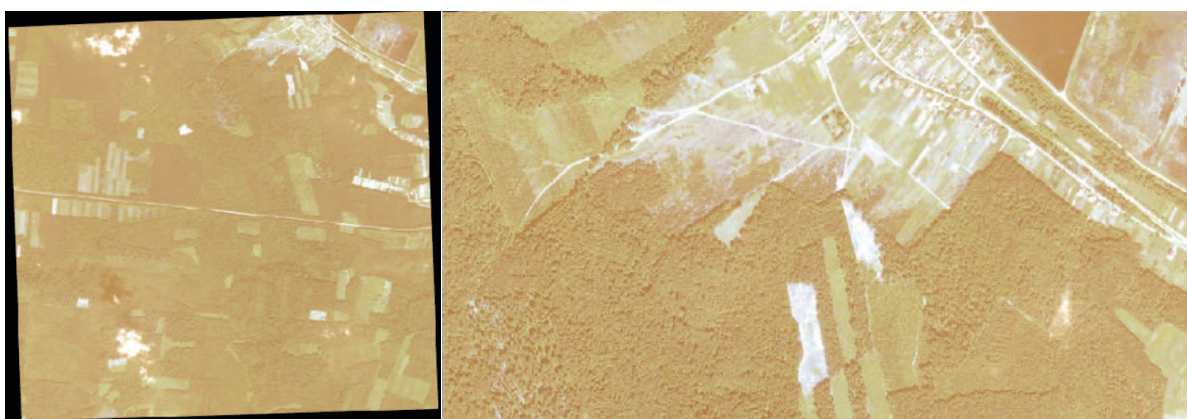
Source: authors' study

Fig. 9. Result of the fusion by Brovey method

Fig. 10. Results of the fusion by Gram-Schmidt method (with the addition of the infrared channel)

When applying methods for greater efficiency and improved raw materials, were taken into account weight coefficients that are designed specifically for each channel. Weights for multispectral channels depend on the overlay spectral sensitivity curves for multispectral channels with panchromatic channel. Weights is relative, and can be selected when used. Multispectral channel with the greatest overlap with the panchromatic channel should receive the greatest weight. Multispectral channel that does not intersect with the panchromatic channel should get a weight that is equal to 0.

For the QuickBird satellite channels weight coefficients will be the following values (the order: red, green, blue, infrared):

- QuickBird – 0.85, 0.7, 0.35, 1.0.

Method IHS gave good results in the problem of color distortion, because the colors are synthesized very close to "natural", but on the image, we can see the so-called smoke background image on the floors, which complicates the clear object recognition. Clearly one can see large objects and boundaries of land, well recognized roads and contours of vegetation.

Method Brovey got good spatial resolution, but appeared color distortion, which are in a similar smoke background image on the floors, as well as providing a green hue across the image plane.

Method Gram-Schmidt – application received at best clarity and object recognition (thanks weight coefficients), but also the largest color distortion which explains the addition of the 4th near infrared channel.

Working with images obtained from satellites Landsat 8, found some set of channels that are best suited for displaying certain types of objects, namely coastlines of water bodies, vegetation, soils. For display on effectively synthesized image smaller structures used eighth panchromatic channel with a higher resolution – 15 m.

To improve the resolution and objects on the ground applied technology Sharping. The technology provides for the 8th channel 30% transparency and pixel size multispectral channels, which transforming, must lead to a pixel size of 8th channel.

In progress alternate overlay 8th (30% transparency) channel, a separate layer for each channel and so on three different channels. Received three image files in grayscale color as a basis for synthesis of color image system RGB. After the construction of three channels into one RGB-color image we get color scene areas with spatial resolution of 15 m.

All received images were synthesized by the method of IHS, because it gives the best results.

Source: authors' study

Fig. 11. Fusion previously imposed channels – 5_6_2, water and coastal line
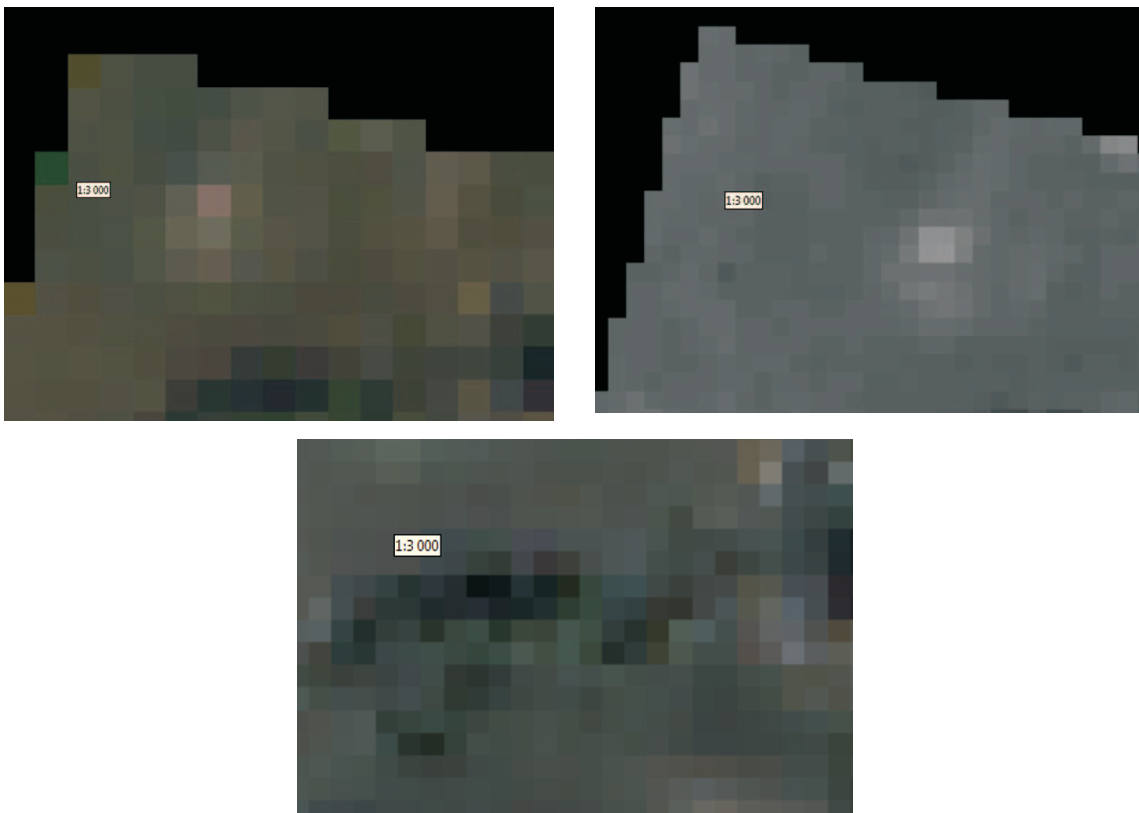

Source: authors' study

**Fig. 12.** Fusion previously imposed channels – 7_4_2, soil

Source: authors' study

Fig. 13. Fusion previously imposed channels – 7_2_4, vegetation

To visually assess the accuracy of synthesized inbox images, need to match the size of pixels that can be done easiest by increasing the so-called "Zoom". Figures 13 and 14 present pixel size images before and after synthesis.

Source: authors' study

Fig. 14. Zoom (1 : 3000) for images Landst 8, top and down – MS picture, PAN picture and a synthesized picture
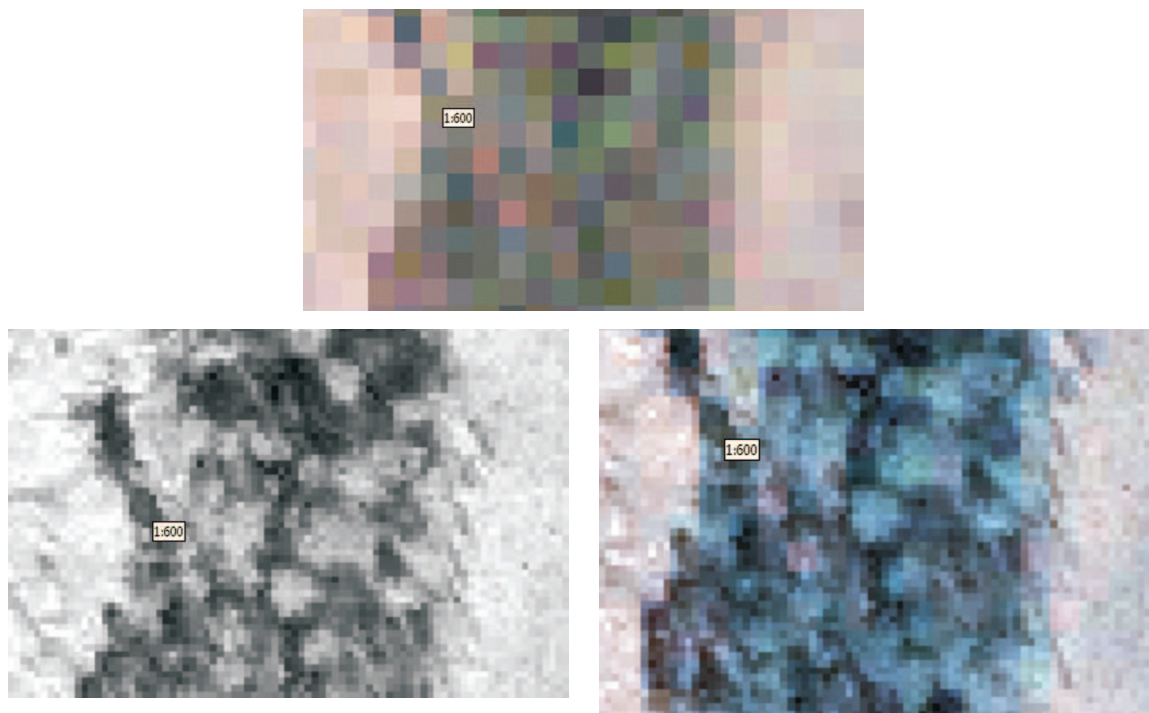
Source: authors' study

Fig. 15. Zoom (1 : 600) on the images QuickBird, top and down – MS picture, PAN picture and a synthesized picture

As seen from submitted images all the synthesized images really got spatial resolution of panchromatic image.

4. Application Pan Sharpening in Erdas Imagine 10.0

It was chosen three test areas Jaroszewice, Chodel and Lublin, which are characterized by varying coverage and land use. The test area is Jaroszewice agricultural area of narrow and elongated plots. Chodel is also the area but the agricultural parcel characterized by lower surfaces and are not as extended as in the case of a Jaroszewice. Finally, the third area is the central part of Lublin on building a diverse and with different proportions of urban green areas.

In all cases, the assessment have been subjected to satellite images recorded 3 June 2015 year with a deck of Landsat 8. MS multispectral images have a resolution of 30 m surface, and the image resolution panchromatic Sciences 15m. For the analysis methods were used [Garzelli and Nencini 2007]: Modified IHS Resolution Merge, Merge and Wavelet Resolution Color Space Hyperspherical Resolution Merge implemented in the program Erdas Imagine. In Figures 1–3 the results of combining images MS and PAN are presented. In each figure, the image a) is a composition formed from the RGB channels 2,3, and 4, the image b) is the result of applying the method Modified IHS Resolution Merge, picture c) generated by Wavelet Resolution Merge, and image d) is a result of the use of the method Hyperspherical Color Space Resolution Merge.

Analyzing the images obtained for objects Jaroszewice and Chodel (Figures 16 and 17) it should be noted that the best results in a visual sense gave the method Modified IHS Resolution Merge. On the images generated by this method are well visible individual land and roads. Images of inferior quality were obtained using a method Hyperspherical Resolution Color Space Merge. The weakest quality characterized by images obtained using methods Wavelet Resolution Merge.

In assessing the object images obtained Lublin should be stated that their quality is low (Figure 18). Undoubtedly, the cause of the smaller size of the objects appearing in these photos. However, one can easily see the road, built-up areas and urban greenery. As in the two previous objects so here the best visual effect it afforded the method of Modified IHS Resolution Merge.
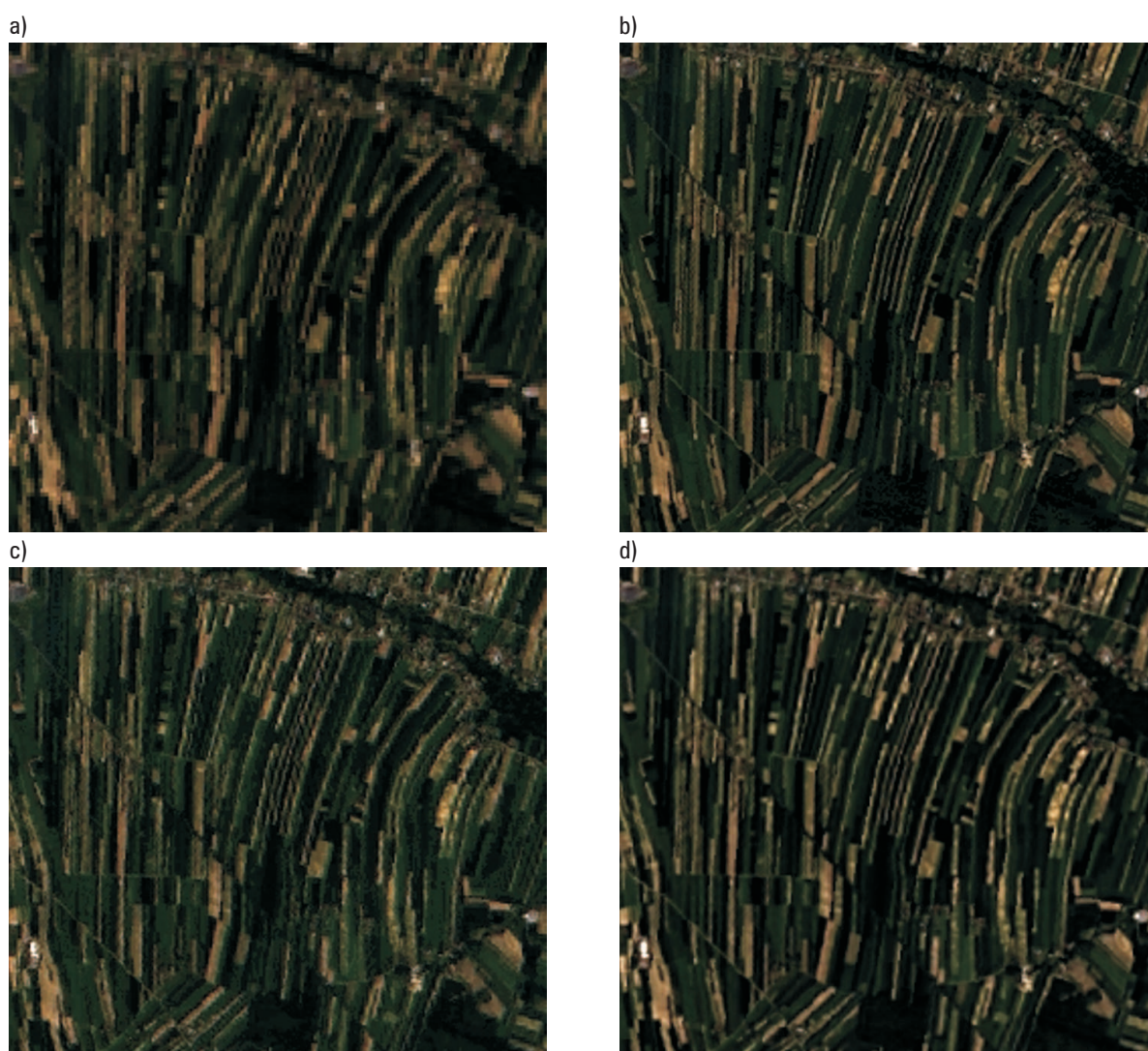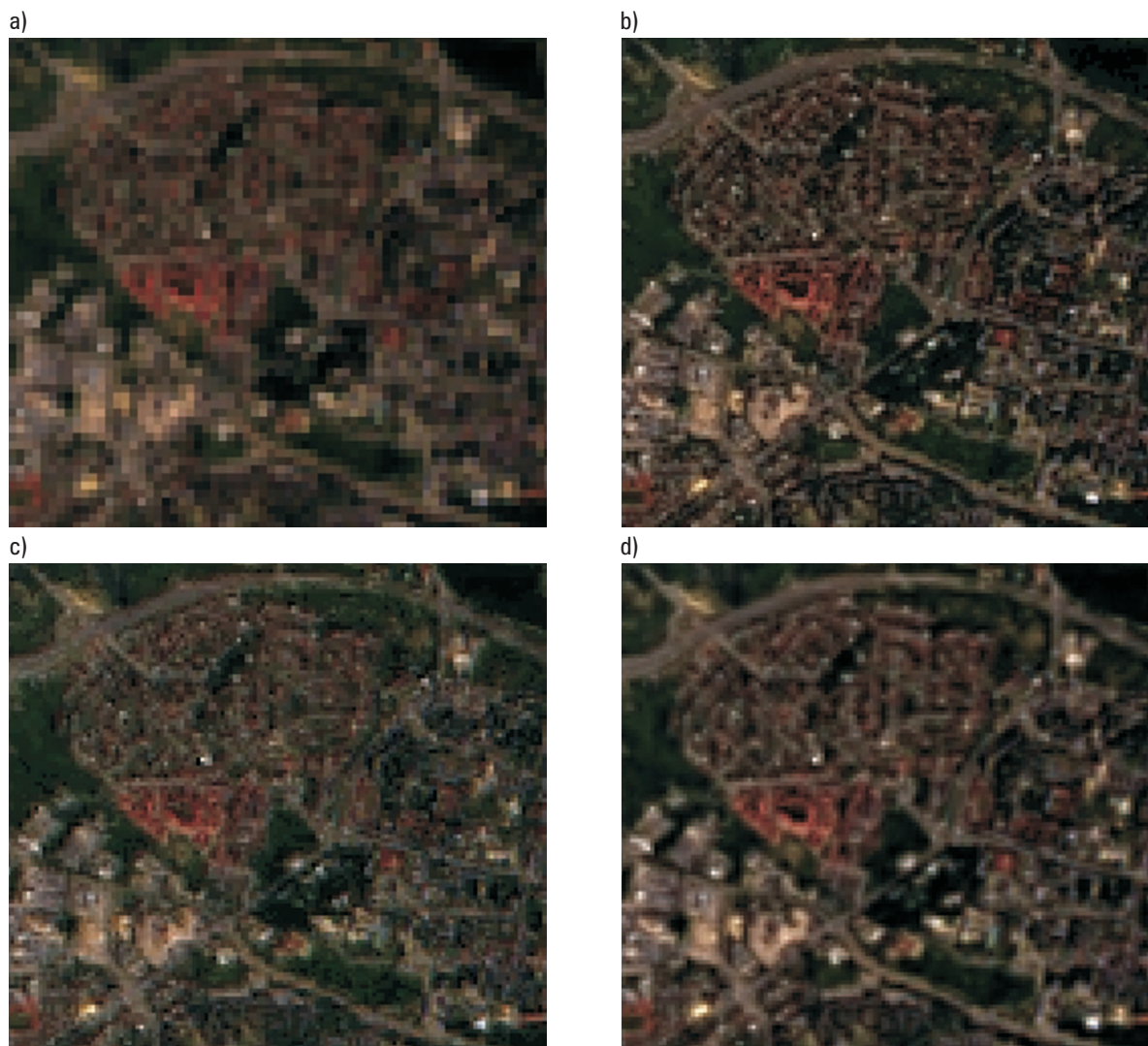

Source: authors' study

Fig. 16. The compositions of the RGB color object Jaroszewice: a) picture of MS, b) the image obtained after application of Modified IHS Resolution Merge, c) picture of the applied Wavelenth Resolution Merge, d) the image obtained after application of HCS Resolution Merge
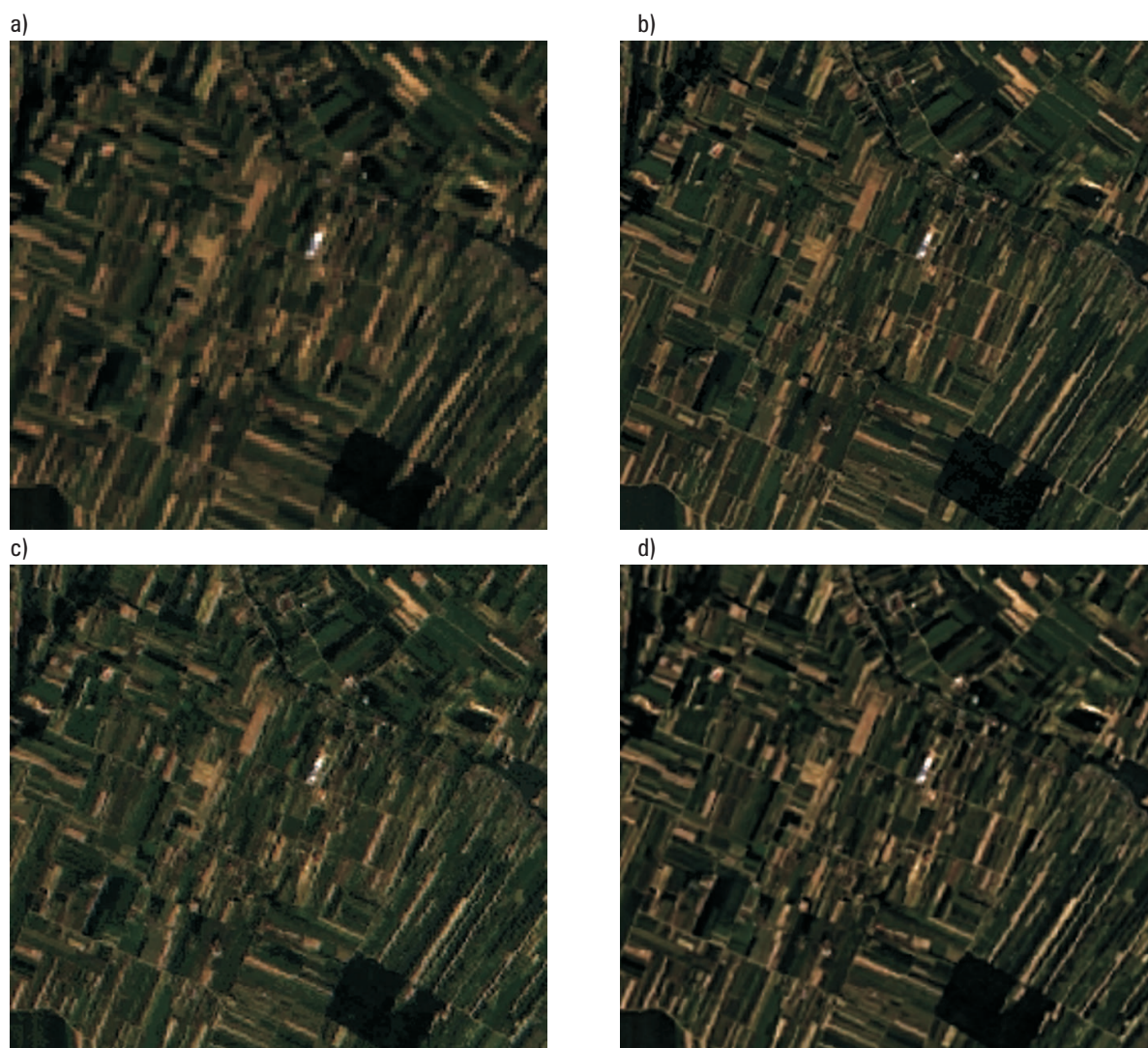
Source: authors' study

Fig. 17. The compositions of the RGB colour object Chodel: a) picture of MS, b) the image obtained after application of Modified IHS Resolution Merge, c) picture of the applied Wavelenth Resolution Merge, d) the image obtained after application of HCS Resolution Merge

Source: authors' study

Fig. 18. The compositions of the RGB colour object Lublin: a) picture of MS, b) the image obtained after application of Modified IHS Resolution Merge c) picture of the applied Wavelenth Resolution Merge, d) the image obtained after application of HCS Resolution Merge

5. Conclusions

After analyzing the classical methods of merging in two software products Erdas Imagine 10.0 and ArcGIS 10.2. It is obvious that the most significant problem unification and improvement of images – are colour distortion. For satellite data the main cause of substantial colour distortions in the resulting image is an extension of wavelengths panchromatic images. Wavelength range panchromatic channel extended in new satellites, from visible to near infrared region of the spectrum. This difference significantly changes the value of gray levels panchromatic images. So traditional methods merger,

which are well suited for fusion panchromatic images with other multispectral data (satellite to 1999) can not get quality results at the confluence of satellite images from the new satellite [Yao and Zhang 2008].

Another common problem is that the quality of fusion often depends on the experience of the operator and input data. For achievement a good result important: pre-processing of data and experience of the operator that performs this processing.

Still have not found a single universal automated solutions for obtaining high-quality results for different sets of fusion data from different satellites [Yun 2004].

References

Аристов М. 2009. Космический снимок или аеросьемка для картографирования в крупних масштабах. В Фокусе, 05, 11, 11–20.

Бабков В.С., Титаренко К.К. 2011. Слияние мультиспектральных изображений в задаче обработки спутниковых снимков. УДК 004, 932, 1–5.

Padwick C., Deskevich M., Pacifici F., Smallwood S. 2010. WorldView-2 pan-sharpening. AS-PRS 2010 Annual Conference San Diego, California, April 26–30.

Rose G. 2009. Pan sharpening. Photogra. Engin. Remote Sens., September, 17, 2, 18–27.

Strait M., Rahmani S., Markurjev D. 2008. Evaluation of pan-sharpening methods. UCLA Department of Mathematics, August.

El-Mezouar M.C., Taleb N., Kpalma K., Ronsin J. 2012. A new evaluation protocol for image pan-sharpening methods, ICCT, 15, 144–148.

Qian Du, Oguz Gungor, Jie Shan. 2005. Performance evaluation for pan-sharpening techniques. IEEE, 5, 4264–4266.

Yun Zhang. 2004. Understanding image fusion. Photogram. Engin. Remote Sens., June, 657–661.

Yao Wan-qiang, Zhang Chun-sheng. 2008. Multi-spectral image fusion method based on wavelet transformation. I. Arch. Photogram. Remote Sens. Spat. Infor. Sci., 37, B7, 1261–1266.

Garzelli A. Nencini F. 2007. A genetic approach to Pan-sharpening of multispectral images. New Develop. Chall. Remote Sens., 91–100.

Prof. dr hab. inż. Oleksandr Dorozhynskyy
Uniwersytet Przyrodniczy w Lublinie
Katedra Inżynierii Kształtowania Środowiska i Geodezji
20-069 Lublin, ul. Leszczyńskiego 7
e-mail: adorozhynskyy@hotmail.com

Radomir Obroslak
Uniwersytet Przyrodniczy w Lublinie
20-950 Lublin, ul. Akademicka 13
e-mail: radomir.obroslak@up.lublin.pl

Yurii Stusyak
Lviv Polytechnic National University
Department of Photogrammetry and Geoinformatics
Ukraine, 79013 Lviv, str. S. Bandery, 12
e-mail: Stusyaky@gmail.com