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Spatial Quality of Manually Geocoded Multispectral and Multiresolution Mosaics

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Abstract: *The digital airborne multisensor and multiresolution system for collection of information (images) about mine suspected area was created, within European commission project Airborne Minefield Area Reduction (ARC, EC IST-2000-25300, <http://www.arc.vub.ac.be>) to gain a better perspective in mine suspected areas (MSP) in the Republic of Croatia. The system consists of a matrix camera (visible and near infrared range of electromagnetic spectrum, 0.4-1.1 μm), thermal (thermal range of electromagnetic spectrum, 8-14 μm) and a hyperspectral linear scanner. Because of a specific purpose and seeking object on the scene, the flights for collecting the images took place at heights from 130 m to 900 m above the ground. The result of a small relative flight height and large MSPs was a large number of images which cover MSPs. Therefore, the need for merging images in largest parts, for a better perspective in whole MSPs and the interaction of detected object influences on the scene appeared. The mentioned system did not dispose of the module for automatic mosaicking and geocoding, so mosaicking and after that geocoding were done manually. This process made the classification of the scene (better distinguishing of objects on the scene) and fusion of multispectral and multiresolution images after that possible. Classification and image fusion can be even done by manually mosaicking and geocoding. This article demonstrated this claim.*

Key words: *manual mosaicking, manual geocoding, geometric analysis, multisensor and multiresolution images*

1. Introduction

Operative multi-sensor airborne acquisition system is in intensive operational use in Croatia for remote sensing of minefields (Bajić, 2003; Krtalić 2006). The system consists of two digital cameras: DuncanTech MS3100 (URL1) and Thermovision THV 1000 (AGEMA, 1992) and hyperspectral line scanner Imspector V9. DuncanTech MS3100 is a digital matrix camera (sensor resolution 1392x1040 pixels) for acquisition in three visible channels (V: 0.4-0.5 μm , 0.5-0.6 μm , 0.6-0.7 μm) and near infrared (NIR: 0.7-1.0 μm) – VNIR. It produces images in the central projection. The second sensor, Thermovision THV 1000, is a thermal line scan camera which collects data in the long wave thermal infrared (TIR: 8-14 μm) area. An image is developed by continually scanning of the terrain with a sensor which consists of 5 parallel elements (data are collected with 5 parallel line elements at the same time). In this article, we will consider the quality of manually geocoded VNIR and TIR mosaics.

The flights for collecting the images for the purpose of humanitarian demining in Croatia took place at height of 130 m to 900 m above the ground. Because of small flight height, the small surface of each image and a large number of images, orientation in space became more difficult. This problem can be solved by mosaicking the selected VNIR (RGB format – G, R, IR) and TIR images of the area and geocoding the whole mosaic. However, these processes generate new problems, such as additional geometric and radiometric distortion of images made by interpolation in mosaicking and geocoding (Krtalić, 2006). Mosaicking can also be done automatically

Prostorna kvaliteta ručno geokodiranih višespektralnih i višesenzorskih mozaika

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Sažetak: Nastojanjem dobivanja boljeg uvida u minsko sumnjivo područje (MSP) u Republici Hrvatskoj, u okviru projekta Europske komisije Airborne Minefield Area Reduction (ARC, EC IST-2000-25300, <http://www.arc.vub.ac.be>) formiran je digitalni zrakoplovni višesenzorski i višerazlučivi sustav za prikupljanje informacija (snimki) o minsko sumnjivoj površini. Sustav se sastoji od matične kamere (vidljivi i blisko infracrveni dio elektromagnetskog spektra, 0.4-1.1 μm), termalnog (termalni dio elektromagnetskog spektra, 8-12 μm) i hiperspektralnog linijskog skenera. Zbog specifične namjene sustava i objekata koje je trebalo otkriti na sceni, snimanja su provedena sa relativnih visina leta platforme (helikopter) od 130 do 900 m. Kako su relativne visine leta bile male, a MSP velika, broj snimki bio je također velik i pojavila se potreba za spajanjem snimki u veće cjeline kako bi se dobio uvid u cjelinu područja i interakciju utjecaja detektiranih objekata na sceni. Sustav nije raspolagao s modulom za automatsko mozaiciranje i geokodiranje pa se u tu svrhu prišlo ručnoj izradi mozaika, a nakon toga ručnom geokodiranju. Ti su postupci zatim omogućili klasifikaciju scene, kako bi se scena što bolje raščlanila i fuziju višesenzorskih i višerazlučivih slika kako bi se što više informacija moglo iz nje dobiti. U ovom radu pokazano je da je moguće provesti spomenute procese i uz pomoć ručnog mozaiciranja i geokodiranja.

Gljučne riječi: ručno mozaiciranje, ručno geokodiranje, geometrijska analiza, višesenzorske i višerazlučive snimke

1. Uvod

U Hrvatskoj je u intenzivnoj operativnoj uporabi višesenzorski sustav za zrakoplovno daljinsko istraživanje minski sumnjivih površina (Bajić, 2003, Krtalić, 2006). Sustav se sastoji od dvije digitalne kamere: DuncanTech MS3100 (URL1) i Thermovision THV 1000 (AGEMA, 1992), te hiperspektralnog linijskog skenera Imspector V9. DuncanTech MS3100 je digitalna matična kamera (rezolucija senzora je 1392'1040 piksela) koja stvara odvojene zapise na osnovi refleksije svjetlosti u tri vidljiva kanala (V: 0.4-0.5 μm (plavi – B), 0.5-0.6 μm (zeleni – G), 0.6-0.7 μm (crveni – R)) i jednom bliskom infracrvenom (NIR: 0.7-1.0 μm) – VNIR. Snimke nastaju pravilima centralne projekcije. Drugi senzor, Thermovision THV 1000 je termalni linijski skener koji podatke o terenu prikuplja u dugovalnom termalnom području (TIR: 8-12 μm). Snimka nastaje kontinuiranim skeniranjem terena senzorom koji se sastoji od 5 paralelnih elemenata (podaci se prikupljaju istodobno na sensor koji se sastoji od 5 paralelnih linijskih elemenata). Ovaj se rad bavi kvalitetom ručnog geokodiranja VNIR i TIR mozaika.

Za potrebe humanitarnog razminiranja u Hrvatskoj je prikupljanje snimki obavljeno s relativnih visina leta od 130 do 900 m. Zbog male visine leta i površine terena koja se preslikava na senzor, odnosno velikog broja snimki (kanala), pojavljuju se poteškoće pri orijentaciji snimki u prostoru. Taj se problem može riješiti mozaiciranjem izabranih VNIR (RGB formata – G, R, IR) i TIR snimki terena i geokodiranjem gotovih mozaika. Pri tome treba imati na umu da ti postupci unose nove probleme kao što su geometrijske i radiometrijske deformacije slika

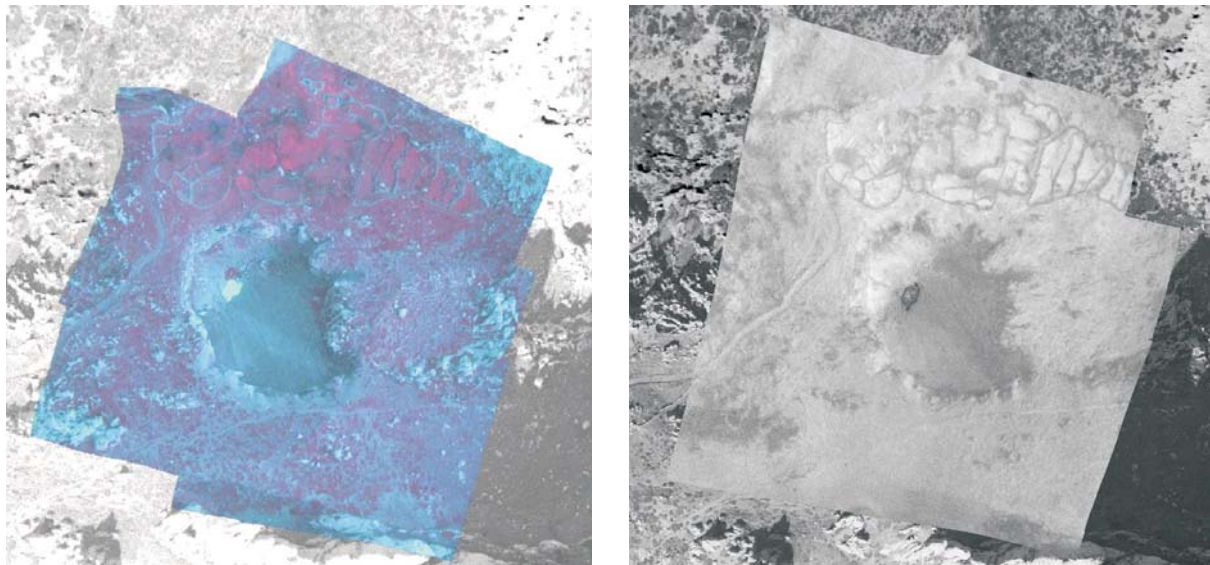


Fig. 1. Geocoded mosaics over DOF: VNIR mosaic (left), TIR mosaic (right). Part of mountain Velebit (Tulove grede) with large height differences (about 300 m between lowest and highest point) (Krtalić and Fiedler, 2003)

Slika 1. Geokodirani blok mozaici prikazani preko DOF-a: VNIR mozaik (lijevo), TIR mozaik (desno). Dio Velebita (Tulove grede) s velikim visinskim razlikama (oko 300 m između najniže i najviše točke) (Krtalić i Fiedler, 2003)

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by means of GPS and inertial navigation data collected during airborne acquisition. But, this system does not have this option. Further, orthophoto images and mosaics can also be produced by using photogrammetric methods. This article has to show what we can expect from manually made and geocoded mosaics of VNIR images instead of automatically made mosaics. Manually mosaicking and geocoding make sense in cases when the automatic process is inaccessible (lack of IMU and GPS) and the acquisition area is small. Therefore, for the practical use of mosaic it is necessary to know what can we expect from it with respect to geometric improvement.

Because of a fact that an airborne remote sensing acquisition system produced multisensor and multiresolution images, the need for a combination of different data about the same terrain showed up. Therefore, for better and more complete perspective in the scene, classification and image fusion are carried out.

2. Principles of Classification and Image Fusion

Image classification is the process of assigning pixels to specific features (objects, class) on the basis of their spectral characteristics (Richards, 1986). The aim of classification is to classify all pixels from every input channel (images) to a new image. Pixels in this new image are assigned to classes according to features or scenes (objects) typed by interpreter (MicrolImages Inc., 2001). Classification can be made on a pixel or an object base. The best possible registration of every item of input data (images) is needed for both cases.

Data fusion means the process of extraction and combination of same or different type of information spontaneously adopted in several domains before this was expressed as data fusion. This approach is based upon the exploitation of the synergy offered by the information originating from various sources. Here, data is a generic term and is equivalent to information, so the term data fusion can be replaced with the term – information fusion. A combination of additional independent and/or redundant data usually results in an improvement of the results (Wald, 2002). The input data for image fusion was considered in this article.

3. Mosaicking and Geocoding

The first step after airborne acquisition of VNIR images was mosaicking along the strip (Fig. 3) and after that mosaicking between strips (Fig. 1 and 4). Images collected with matrix camera originate by the rules of central projection. The central projection adversely affects the geometry of images because during scene projection it distorted the image (Kraus, 2006). Mosaicking was done by registration of as many as possible identical points on overlap of two neighbour images. This process additionally distorted the projected content of scene. Namely, interpolation took place on the overlap between registered points and extrapolation on the rest of the image, according to the same points. TIR images have an additional source of deformation and that is the way of collecting data (line scanning).

After mosaicking, the mosaics were geocoded on a geodetic base (digital orthophoto (DOF) 1:5000, 0.5 m



Fig. 2. Image of the terrain (Velebit, Tulove grede) taken from the ground

Slika 2. Slika terena (Velebit, Tulove grede) snimljena sa zemljišta

nastalih mozaiciranjem i geokodiranjem (Krtalić, 2006). Mozaicirati se može automatski pomoću modula koji za tu svrhu koristi GPS i inercijalno-navigacijske podatke prikupljene prilikom snimanja, ali on nije postojao za opisani višesenzorski sustav. Nadalje, mozaik i ortofotoslike mogu se izraditi fotogrametrijskim metodama. Ovaj rad želi pokazati što se može očekivati od ručno geokodiranog VNIR i TIR mozaika. Ručni način mozaiciranja i geokodiranja ima smisla u slučajevima kada ne postoji spomenuti modul za automatski proces (GPS, IMU) i kada se radi o manjim površinama. Zato je za praktičnu upotrebu ručno geokodiranih mozaika neophodno znati što se od njih može očekivati u smislu geometrijske kvalitete.

Kako zračni sustav za zrakoplovno daljinsko istraživanje daje višesenzorske i višerazlučive snimke javlja se i potreba za kombiniranjem raznovrsnih podataka o istom terenu, odnosno klasifikacijom i fuzijom snimki, kako bi se stekao bolji i potpuniji uvid u snimanu scenu.

2. Principi klasifikacije i fuzija slika

Klasifikacija je metoda s pomoću koje se značajke pojedinih obilježja (objekta, klasa) mogu pridružiti pikselima na osnovi njihovih spektralnih karakteristika (Richards, 1986). Cilj klasifikacije je razvrstati sve piksele iz svih ulaznih kanala (slika) u novu sliku, tako da u novonastaloj raspodijeli klasa budu pikseli koje interpretator pridružuje tipovima značajki (objekata) na površini ili tipovima snimane scene (Microlmages Inc., 2001). Klasifikacija se može provoditi na razini piksela ili područja. U oba slučaja potrebno je što točnije registrirati ulazne slike.

Fuzija podataka označava postupak izdvajanja i kombiniranja informacija istog ili različitog tipa, koji je spontano prihvaćen u nekoliko znanstvenih domena prije nego je označen izrazom fuzija podataka. Postupak se bazira na sinergiji informacija koje potječu iz različitih izvora. Podatak je u ovom slučaju opći izraz i ekvivalent informaciji, pa se izraz fuzija podataka može zamijeniti i

izrazom fuzija informacija. Kombinacija dodatnih neovisnih i/ili zalihih podataka obično rezultira poboljšanjem rezultata (Wald, 2002). U ovom se radu razmatraju ulazni podaci za fuziju slika.

3. Mozaiciranje i geokodiranje

Prvi korak nakon prikupljanja VNIR i TIR snimki bila je izrada mozaika od tih snimki po nizovima (slika 3), a zatim su se nastali mozaici nizova spajali u blok mozaik (slika 1 i 4). Snimke prikupljene matričnom kamerom nastaju posredstvom centralne projekcije. Centralna projekcija je nepovoljna jer u prikaz (snimku) uvodi geometrijske deformacije pri projiciranju sadržaja scene (Kraus, 2006). Mozaiciranje je provedeno registriranjem što većeg broja identičnih točaka na preklopu dviju susjednih slika. Time se dodatno deformira preslikani geometrijski sadržaj scene. Naime, na preklopu priključne snimke provodi se interpolacija između registriranih točaka, a na ostalom dijelu – ekstrapolacija na osnovu registriranih točaka na preklopu. Za TIR snimke, uz sve navedeno, dodatni izvor deformacija je i način snimanja (linijsko skeniranje).

Nakon mozaiciranja, mozaici su geokodirani na osnovi dostupnih geodetskih osnova (digitalni ortofoto DOF, 1:5000, 0,5 m piksel). DOF je prikaz terena nastao po principima ortogonalne projekcije. Dakle, geokodiranje je postupak kojim se uklanjaju/smanjuju geometrijske deformacije na mozaiku.

Treba naglasiti i činjenicu da oba terena imaju veliku dinamiku promjene objekata na sceni (ima puno detalja koji su manji od prostorne rezolucije referentne podloge – DOF-a) što također ima utjecaja na otkrivanje detalja na referentnoj podlozi, a samim time i na točnost geokodiranja.

Procesi mozaiciranja, geokodiranja i geometrijske analize kvalitete rezultata tih postupaka predstavljeni su preko geokodiranih mozaika dvaju različitih vrsta terena,



Fig. 3. Six VNIR strip mosaics which are mosaicked into one block mosaic Pristeg (Vrankovići)

Slika 3. Šest mozaika nizova koji su spojeni u blok mozaik Pristeg (Vrankovići)

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pixel). DOF is presentation of the terrain in an orthogonal projection. So, geocoding is a process which removes/decreases geometrical distortion on the mosaic.

Both types of terrain considered in this work have large spatial frequency on the scene (the scenes are full of details which are smaller than the resolution of the reference image – DOF). That fact also has impact on the detection of details on the reference image and geocoding accuracy.

Mosaicking, geocoding and geometric analysis of the quality of results of these processes are introduced by geocoded mosaics of two different types of terrain: one represents mountainous terrain (with big differences in heights – Velebit, Tulove grede) and the other a flat terrain (Pristeg – Vrankovići).

3.1. The Velebit Region

The first mosaics are small VNIR and TIR mosaics (both consist of 5 images in two strips – Fig. 1a and 1b) of mountainous terrain (Velebit, Tulove grede – Fig. 2). Geocoding the VNIR mosaic was done on 232, and TIR mosaic on 96 common points. The calculated spatial resolution of VNIR mosaics is 0.15 m, and of TIR mosaic 0.5 m (Krtalić and Fiedler, 2003).

3.2. The Pristeg Region

The third mosaic is a huge VNIR mosaic of a part of the Pristeg region (Vrankovići). Mosaicking of 106 VNIR images was done. 106 VNIR images (airborne acquisition from 600 m above the ground) collected in six strips were chosen for the purpose of mosaicking. VNIR

images are RGB images created from infrared (IR), red (R) and green (G) channels (false colour). The first step was also mosaicking along the strip (Fig. 3) and after that mosaicking between strips was carried out. Manually made mosaics have better colour balance between strips than automatically made mosaics. After mosaicking, the mosaic was geocoded manually by means of the software package DESCARTES with *Thin Plate Spline* (URL2) transformation according to 87 common points on DOF (1:5000) of the same area. The spatial resolution on DOF is 0.5 m. The calculated spatial resolution of the VNIR mosaic is 0.15 m.

4. Geometric Analysis of Geocoded Mosaics

The quality of geocoding was checked on 52 control points of the Velebit mosaic (Krtalić and Fiedler, 2003) and 55 control points on the Pristeg block mosaic according to position of the same points in reference DOF image. The mean deviations (Feil, 1989) of points on both axes and position, related to DOF are given in Table 1.

One can see that mean deviations of the TIR mosaic of the Velebit region and the VNIR mosaic of the Pristeg region are significant higher than the VNIR mosaic of the Velebit region. This is a consequence of significantly smaller number of images in one strip and whole mosaics (Velebit region – 5 images, Pristeg region – 106 images), and number of common points for geocoding (difficulty in finding common points on VNIR and TIR images of the Velebit region).

The recommended accuracy of registration multispectral and multiresolution images for classification and image fusion on a pixel basis is one pixel (Hall, Llinas, 2001). In such cases, reference images are DOF images with resolution of 0.5 m. Therefore, registration accuracy of VNIR mosaics through the axes is 1 to 1.5 pixel, and 1 to 2 pixels in position (Table 1). On the other hand, registration accuracy of the TIR mosaic is 2 pixels through the axes and 3 pixel in position (Table 1).

Table 1. The mean deviations on axes and position of control points

	m_y	m_x	m_p
Velebit (VNIR)	$\pm 0,60$ m	$\pm 0,40$ m	$\pm 0,70$ m
Velebit (TIR)	$\pm 0,90$ m	$\pm 1,10$ m	$\pm 1,50$ m
Pristeg (VNIR)	$\pm 0,66$ m	$\pm 0,70$ m	$\pm 0,96$ m

jednog planinskog (s velikim visinskim razlikama – Velebit, Tulove grede) i drugog ravničarskog (Pristeg – Vrankovići).

3.1. Područje Velebit

Prvi mozaici su mali VNIR i TIR mozaici (po 5 snimki u dva niza – slike 1a i 1b) dijela planinskog terena (Velebit, Tulove grede – slika 2). Geokodiranje VNIR mozaika izvršeno je na 232 zajedničke točke, a TIR mozaika na 96 zajedničkih točaka. Proračunana vrijednost prostorne rezolucije piksela na VNIR mozaiku je 0,15 m, a na TIR mozaiku 0,5 m (Krtalić i Fiedler, 2003).

3.2. Područje Pristeg

Treći mozaik je veliki VNIR mozaik dijela područja Pristeg (Vrankovići). Mozaicirano je 106 VNIR snimki, prikupljenih u 6 nizova sa 600 m visine iznad zemljišta. VNIR snimke su RGB slike nastale kombinacijom zelenog, crvenog i infracrvenog kanala (pseudokolor). Prvi korak u izradi mozaika i ovdje je bilo mozaiciranje uzduž nizova (slika 3), a zatim su ti nizovi spojeni u blok mozaik (slika 4). Nastali mozaik geokodiran je ručno u programskom paketu *Descartes* transformacijom *Thin Plate Spline* (URL2) na osnovi 87 identičnih točaka s DOF-a (1:5000) istog područja. Prostorna razlučivost DOF-a je 0,5 m, a proračunana prostorna razlučivost VNIR mozaika je 0,15 m.

4. Geometrijska analiza geokodiranih mozaika

Kvaliteta geokodiranja provjerena je na 52 točke Velebitskog (Krtalić i Fiedler, 2003), odnosno 55 točaka blok mozaika Pristega, u odnosu na položaje istih točaka na referentnom DOF-u. Srednje pogreške (Feil, 1989) po osima i položaju na tim točkama dane su u tablici 1. Vidi se da su srednje pogreške TIR mozaika velebitskog područja i VNIR mozaika područja Vrankovići bitno veće

Tablica 1. Srednje pogreške kontrolnih točaka po osima i položaju

	m_y	m_x	m_p
Velebit (VNIR)	$\pm 0,60$ m	$\pm 0,40$ m	$\pm 0,70$ m
Velebit (TIR)	$\pm 0,90$ m	$\pm 1,10$ m	$\pm 1,50$ m
Pristeg (VNIR)	$\pm 0,66$ m	$\pm 0,70$ m	$\pm 0,96$ m

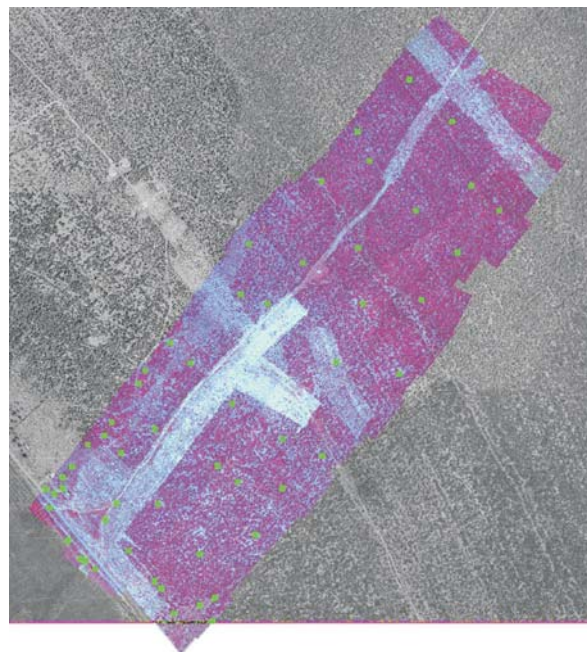


Fig. 4. Geocoded block mosaic (colour image) over DOF image (panchromatic image). Part of the Pristeg region (Vrankovići) with 55 control points (green spots)

Slika 4. Geokodirani blok mozaik (prikaz u boji) na osnovi DOF-a (pankromatski prikaz). Dio Pristega (Vrankovići) s označenih 55 kontrolnih točaka (zelene točke)

od VNIR mozaika velebitskog područja. To se može pripisati znatno manjem broju snimki unutar jednog niza i cijelog mozaika, te bitno većem broju zajedničkih točaka na osnovi kojih se geokodiralo u odnosu na VNIR mozaik područja Vrankovići i teškoći pri pronalaženju zajedničkih detalja na DOF-u i TIR mozaiku velebitskog područja.

Preporučljiva točnost registracije višespektralnih i višerazlučivih snimki za provođenje klasifikacije i fuzije slika na razini piksela je jedan piksel (Hall i Llinas, 2001). U našim slučajevima referentne slike su DOF-ovi prostorne razlučivosti 0,5 m. Prema tome, točnost registracije VNIR geokodiranih mozaika je 1 do 1,5 piksel po X-u i Y-u, odnosno 1 do 2 piksela po položaju (tablica 1). Točnost registracije TIR geokodiranih mozaika je 2 piksela po X-u i Y-u, odnosno 3 piksela po položaju (tablica 1).

Prilikom geometrijskih transformacija VNIR snimki one se ne preuzorkuju kako bi se sačuvala njihova prostorna razlučivost (čitljivost – 0,15 m) koja je bolja od razlučivosti DOF-a (0,5 m). U tom slučaju DOF i VNIR mozaik nemaju istu veličinu piksela, pa DOF ne može ući u postupak fuzije slika bez prethodnog preuzorkovanja na veličinu piksela VNIR mozaika. Prilikom mozaiciranja i geokodiranja VNIR slika za radiometrijsku transformaciju je upotrijebljena je metoda najbližeg susjeda (Castelman, 1996) kako bi se u što većoj mjeri sačuvala izvorne spektralne informacije VNIR snimki.

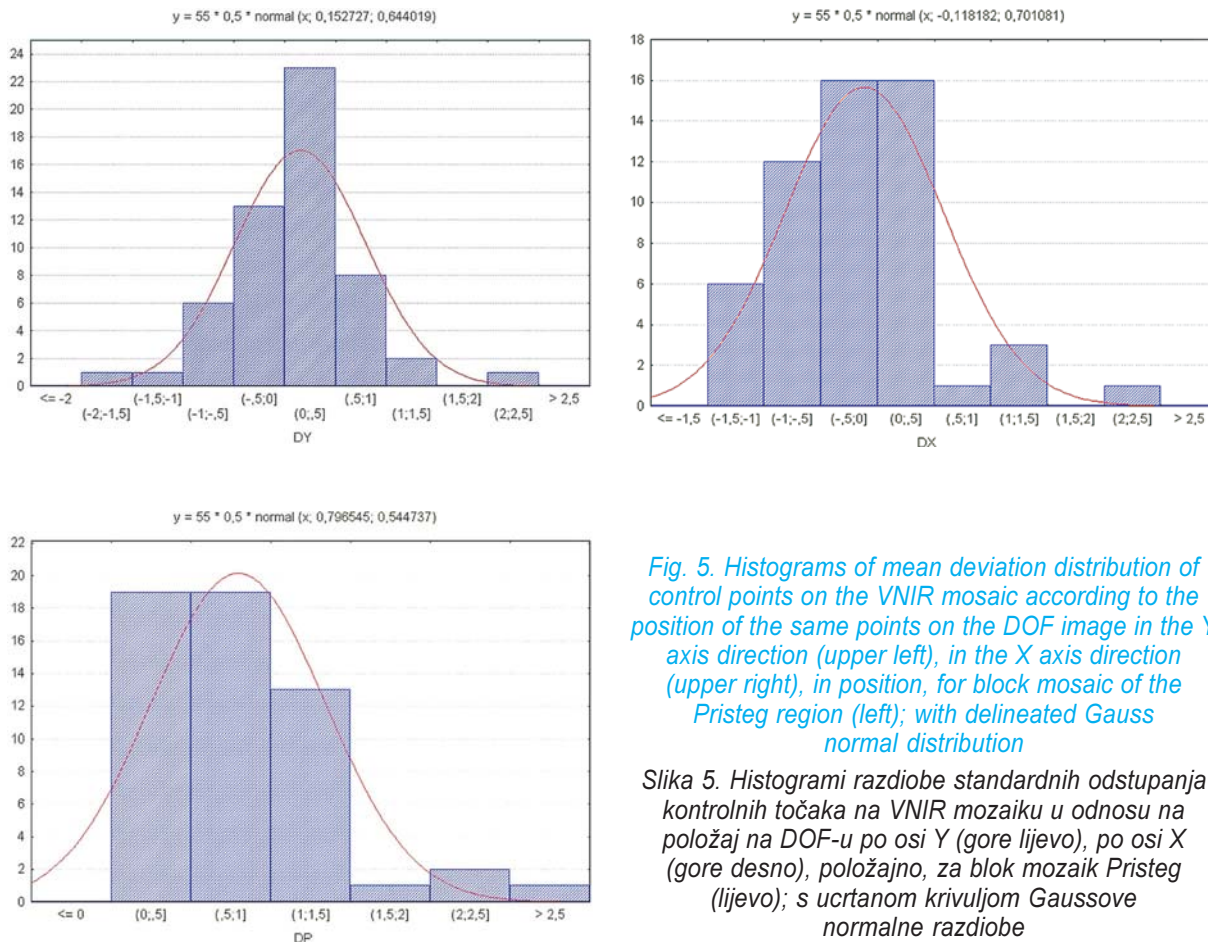


Fig. 5. Histograms of mean deviation distribution of control points on the VNIR mosaic according to the position of the same points on the DOF image in the Y axis direction (upper left), in the X axis direction (upper right), in position, for block mosaic of the Pristeg region (left); with delineated Gauss normal distribution

Slika 5. Histogrami razdiobe standardnih odstupanja kontrolnih točaka na VNIR mozaiku u odnosu na položaj na DOF-u po osi Y (gore lijevo), po osi X (gore desno), položajno, za blok mozaik Pristeg (lijevo); s ucrtanom krivuljom Gaussove normalne razdiobe

Geometrical transformation of VNIR images was done without resampling in order to preserve the spatial resolution of VNIR images (0.15 m). In this case, VNIR and DOF images do not have the same spatial resolutions (pixel size), so DOF image can not be an input image for image fusion without resampling on pixel size of the VNIR mosaic. The nearest neighbour transformation (Castelman, 1996) was used for radiometric transformation during mosaicking and geocoding. This type of transformation preserved the original spectral characteristics of VNIR images as much as possible.

5. Conclusion

VNIR and TIR mosaics gave a better perspective of the whole scene and relationships of objects on the scene. It is very important for interpretation of a mine scene. Also, this is an example for showing a difference between geocoding and georectification (Kasser and Yves, 2002). So, this paper proves that if the model of terrain does not exist, manual geocoding can satisfyingly reduce geometrical deformations on mosaic which aroused by central projection of images, during line scanning and mosaicking. Also, it is possible to carry out a good classification and image fusion with these mosaics (Krtalić, 2006). The

problem is in the fact that the reference image for registration has worse spatial resolution than the mosaic itself.

The registration accuracy, according to reference image (DOF), is less than recommend and the Table 1 shows that. However, in this case that should not a big problem because the RGB VNIR mosaic was produced and geocoded, and its components (G, R and IR channels) stayed in tight relationship. These single channels were created by sun reflection from the scene (terrain). Furthermore, the DOF was created from the same reflection but its information about scene was saved in one channel and without information from infrared range of spectrum (only visible range). So, the common source of information is the visible range of spectrum, but VNIR data has better spatial resolution and additional data about the scene – infrared data. All that leads to the conclusion that is not necessary to conduct classification with the DOF image. Also, the DOF image can contain some unwanted artefact like shadows (on the Velebit region – Fig. 1) and that can spoil the result of classification.

The TIR mosaic has the largest mean error (Table 1) but its value lies in the fact that it gives different information about the same scene which can not be obtained from VNIR images. That information can be very useful in the classification and image fusion process (Krtalić, 2006).

5. Zaključak

Mozaiciranjem odabranih VNIR i TIR snimki snimljene scene dobije se bolji uvid u cjelinu scene, odnosno međusobne odnose objekata na sceni što je bitno za interpretaciju minske scene. Na prikazanom se primjeru može pokazati i razlika između geokodiranja i georeferenciranja (Kasser i Yves, 2002). U ovom je radu pokazano da ukoliko ne postoji odgovarajući model terena, tada se geometrijske deformacije koje su nastale centralnom projekcijom, linijskim skeniranjem i izradom mozaika mogu korigirati u zadovoljavajućoj mjeri i ručnim geokodiranjem. To pokazuju tablica 1 i slika 5. Moguće je provesti i kvalitetnu klasifikaciju i fuziju takvih snimki (Krtalić, 2006). Nepovoljna je činjenica da referentni prikaz (DOF), na osnovi kojeg se geokodira mozaik, ima lošiju prostornu razlučivost od samog mozaika.

Tablica 1 pokazuje da je točnost registriranja u odnosu na referentnu podlogu (DOF) manja od preporučene. Međutim, to u opisanom slučaju ne mora biti presudno jer je izrađen i geokodiran trokanalni (RGB) VNIR mozaik,

čije su komponente (G, R i IR kanali) ostale u čvrstom položajnom odnosu, a nastale su digitalnim zapisom refleksije vidljivog i bliskog infracrvenog dijela elektromagnetskog zračenja. Nadalje, DOF je nastao od jednokanalnih pankromatskih aerofotogrametrijskih snimki koje nose informacije refleksije scene samo iz vidljivog dijela elektromagnetskog zračenja. Iz navedenoga slijedi da je presjek skupova VNIR i DOF informacija vidljivi dio elektromagnetskog zračenja. VNIR skup podataka, uz znatno bolju prostornu razlučivost, sadržava još i informacije o sceni u NIR dijelu elektromagnetskog zračenja. To navodi na zaključak kako nije nužno u klasifikaciju uvoditi DOF jer se na njemu mogu nalaziti i neki smetajući elementi kao što su npr. sjene na DOF-u velebitskog područja (slika 1).

TIR mozaik ima najveću srednju pogrešku (tablica 1), ali njegova je vrijednost u činjenici da daje drugačiji uvid u scenu, odnosno informacije koje se ne mogu dobiti iz snimki nastale na temelju refleksije vidljivog elektromagnetskog spektra. Te se informacije mogu iskoristiti u procesima klasifikacije i fuzije slika (Krtalić, 2006).

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