CONSIDERATION ABOUT THE COSTS OF ORTHOPHOTOPLANS IN ROMANIA

CONSIDERATII DESPRE COSTUL ORTOFOTOPLANURILOR IN ROMANIA

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Abstract: Today, many uses for geospatial mapping products require current planimetric feature data. Analysis and design from geospatial data sets generally require a known positional accuracy of features. The collection and updating of planimetric features in a data set can be costly. Many end users are also not accustomed to viewing and analyzing vector-based mapping data sets. They prefer to view planimetric features as a photo image. An orthophoto map would show the arch as an easily identifiable unique image feature. The cost to collect and update planimetric features can be significant. Costs can sometimes be minimized by the production of a photo-based digital map set that is spatially accurate throughout. Many GIS data sets make use of photo-based image data for these purposes. The Internet offers orthophotograph tutorials which may aid managers interested in the basic study of the subject.

Rezumat: In prezent, diversi utilizatori ai produselor cartografice geospatiale cer date actuale exacte ale unor portiuni de teren. Analiza terenului si desenarea lui pe un plan sau harta necesita o precizie cunoscuta de pozitionare a acestuia. Colectarea si actualizarea reprezentarilor topografice planimetrice in cadrul unor seturi de date poate fi costisitoare. Multi utilizatori de date geografice sunt familiarizati sa vizualizeze sis a analizeze seturi intregi de date de analiza cartografice in format vector. Ei prefera sa vada reprezentarile planimetrice ale terenului ca o imagine potografica. Dar, o harta ortofoto va arata de pilda un arc din reprezentarea vectoriala precum o reprezentare unica usor de identificat a respectivei imagini (a arcului). Costul pentru colectarea si actualizarea reprezentarilor planimetrice ale terneului poate fi semnificativ. Costurile pot fi uneori minimalizate de productia unor seturi de harti digitale bazate pe niste fotografii precis determinate. Multe seturi de date GIS utilizeaza date ale unor imagini bazate pe fotografii in studiul de baza al unui subiect. Internetul ofera informatii complete cu privire la "Orthophotography" ~ Ortofotografie (un domeniu de cercetare nou aparut) informatii care pot fi deosebi de utile pentru unii manageri de firme de cadastru si nu numai.

Keywords: *orthophotograph, ortophoto, image scanning, Digital Elevation Model, orthophotoplan*
Cuvinte cheie: *ortofotografie, ortofotgrafie, scanarea imaginii, Model Digital al Altitudinii, ortofotoplan*

INTRODUCTION

This discussion centers on panchromatic (black and white) aerial photography as being the minimum requirement for producing digital ortho-photography for compilation of a base map and associated spatial data layers. Use of color or infrared digital ortho-photography is considered an enhancement upon this minimum standard. *A pixel* is defined as a picture element. It is the smallest bit of information stored for a digital picture. A pixel can be visualized when an image is over-zoomed, resulting in a blocky grid-like appearance. These "blocks" are pixels. *Resolution* is the minimum sampling rate used to output image data such

that a defined area on the earth's surface is represented by one pixel in the digital image. A 1-foot pixel image means that a pixel in the image represents 1 square foot on the ground. *A pixel's panchromatic value* represents the average reflectance for that surface area. The range of reflectance values, also known as the gray scale, for panchromatic images is 0-256. The *aerial photography* used to create digital ortho-photos must have adequate horizontal and vertical controls to obtain the desired minimum pixel size (image resolution) referenced to true ground location. Simply scanning aerial photographs without proper ground controls to remove distortion will not yield accurate digital ortho-photos. *A digital elevation model* must be created and utilized as part of the production process for digital ortho-photograpy. The accuracy of the digital elevation model will depend on the number of spot elevations that are collected during field surveys. The amount and frequency of spot elevations are determined by the accuracy requirements of the digital orthophotography. The spot elevation data can then be used in some GIS environments to create digital elevation models to derive automated elevation contours and elevation slope layers A *properly* produced digital ortho-photo image has all distortion removed such that one can measure length and area on the image (using the image's scale factor to convert measurement units), and obtain accurate results. *The two prime factors* that impact the required level of resolution obtained are land use density and land cost. *Land use density* is a factor as the level of detail takes on greater importance in more developed areas. In urban areas greater resolution is required to be able to visually differentiate geographic features because of their proximity to one another. The cost of aerial photography and associated ground controls goes up with the level of desired resolution. However, the cost for acquiring and storing digital mages is decreasing. In addition, data compression technology is making storage and manipulation of digital data images more efficient and cost effective. Some municipalities and counties rely primarily on digital ortho-photo images as their land base, augmented with limited compilation (digitizing) of only key land base features. This can reduce the overall cost of establishing a working land base for a municipality, when compared with compiling all land base features as was previously done prior to the advent of digital ortho-photography.

MATERIAL AND METHODS
a. Orthophotos

Orthophotographs are photographic images constructed from vertical or nearvertical aerial photographs. The processes used to generate orthophotos remove the effects of terrain relief displacement and tilt of the aircraft. When properly generated, these digital images have a predictable constant positional accuracy throughout the entire image (see Figure 1).
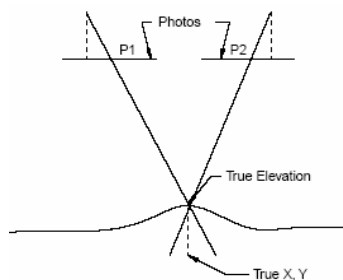

Figure 1: The effects of relief and how it is corrected for orthophotos.

A digital orthophoto image is a raw digital aerial photo image rectified to a suitable DEM of the same area. Software merges the digital image with the DEM and aligns the image orthogonally.

Currently, scanning technology and software allow end users to generate products that may appear as orthorectified images at very little cost. However, the techniques used to generate many of these products will not produce a positional accurate digital image. The employment of such products may be justified for some projects, but should never be confused with or considered as a digital orthophoto. Nondigital orthophoto products are generally considered to be digital image enlargements or semi-rectified digital images.

b. Digital orthophoto image production

Figure 2 illustrates a flow diagram of orthophoto production.

b.1. General

Many end users of digital orthophotos today have very robust hardware and sophisticated software to view and manipulate orthophoto images. They require the ability to view selected image features and perform analysis such as relative distance, area, or even change analysis. In order to meet these demands, proper design of an orthophoto is imperative. Design should consider the following factors:

1. Expected uses of the orthophotos and smallest features to be viewed and studied
2. Accuracy requirements (relative and feature)
3. Anticipated equipment with which the orthophotos will be viewed
4. The equipment, data, and processes used to generate the orthophotos

The end user and project manager should consider and be prepared to relay the information in Items 1, 2, and 3 to the photogrammetric technician. The photogrammetry technician should then design the orthophoto data collection and production around the equipment and processes necessary to meet these requirements (Item 4).
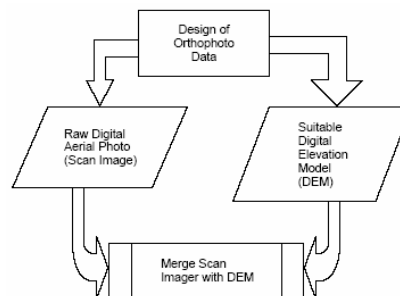

Figure 2: Flow diagram of orthophoto production.

b.2. Design parameters

Design parameters for an orthophoto are generally tied to the expected final accuracy. Suitable imagery and ground control are the basic elemental data that determines the final orthophoto reliability which involves both the accuracy of distances and areas within the orthophoto as well as the relative accuracy of features with respect to their true location on the earth. Distance and area accuracy are based on the pixel size. Relative feature precision is based on the accuracy of the DEM used in the rectification process. The relative accuracy cannot be more precise than the reliability of the DEM.

b.2.1. Imagery and Ground Control

Proper selection of imagery scale and ground control as stated above is critical to the reliability of the final orthophoto. Imagery either can be from existing sources (aerial photography or satellite/airborne imagery) or can be obtained specifically for the project. The key is the suitability of the imagery to meet the intended uses of the orthophotos. Some items to consider are as follows:
- Scale of the imagery
- Type of imagery required (i.e., black and white, natural color, and color infrared)
- Clarity of the imagery (i.e., cloud cover, vegetation cover, seasonal requirements)
- Timeliness of the imagery
- What is the format of the imagery and how effectively can it be introduced into the orthophoto generation process

Table 1:

Recommended digital orthophoto enlargement factors for photo negative scale.

Class	Enlargement
1	4–7 times
2	6–8 times
3	7–10 times

A frequently accepted accuracy standard for photogrammetric mapping and orthophotos is the national standards. Imagery design for orthophotos can therefore be tied to the Class 1, 2, and 3 horizontal accuracy requirements and an expected ground pixel size (resolution). Generally, the pixel size is based on the scale of the photonegative. For example, if the smallest feature that the end user must be able to see in an orthophoto is a typical sewer manhole (approximately 0.609m in diameter), then the imagery must be of a horizontal scale capable of viewing the feature and the pixel resolution should be approximately 0.609 m.

Photogrammetric equipment today allows for suitable orthophotos to be generated from photography at photo negative scales that are smaller than the intended final orthophoto scale. Table 1 lists recommended digital orthophoto enlargement factors for photo negative scale.

b.2.2 Image scanning

Imagery for digital orthophotos may be converted to a digital image with a specific pixel resolution. Obviously, existing digital imagery that is suitable for an orthophoto image does not require this process. The scanners are capable of scanning processed aerial film at very high resolutions (7μm) if required. High-resolution scanners also have the capability of scanning black and white, natural color, and color infrared film. The end user must be mindful of the fact that color digital images require three times the data storage space. This fact can affect performance and utility of the final products and should be taken into consideration during the design of an orthophoto project. Each pixel consists of a radiometric value plus an XY coordinate set. Radiometric gray scale of a single picture element may fall between reflectance values 0–255. Zero is no reflectance (black), and 255 is full reflectance (white). Both quality and economy must be factored into the selection of the pixel size. Proper flight altitude and scan rate must be designed for the orthophoto design horizontal scale. Reducing pixel size greatly increases database magnitude, which affects storage capacity and processing time.

Table 2.

Recommended Approximate Pixel Sizes for Selected Digital Orthophotograph Map Plot Scales

Final Map Plot Scale	Approximate Ground Pixel Resolution Required to Meet ASPRS Accuracy Standards
1:500	0.0625 m
1 in. = 50ft	0.25 ft
1:1000	0.125 m
1 in. = 100 ft	0.5 ft
1:1500	0.250 m
1:2000	0.375 m
1 in. = 200 ft	1.0 ft
1:2500	0.5 m
1 in. = 400 ft	2.0 ft
1 in. = 500 ft	2.5 ft
1 in. = 1000 ft	5.0 ft

Table 3.

*Digital Orthophoto File Size Based on a Neat Double (7.2*6.3 in.) Model for Black and White Uncompressed Images*

Scan sample rate	7.5 μm	15 μm	22.5 μm	30 μm
	3386 dpi	1693 dpi	1128 dpi	846 dpi
File size	496 Mb	124 Mb	55 Mb	31 Mb

A single aerial photograph may require as much as 100 megabytes of memory, depending on the pixel resolution. Contrarily, smaller pixels may assure greater accuracy.

After the data are scanned, histograms can be developed with which to adjust radiometric contrast in the formation of a more pleasing overall image tone.

Table 2 can be of assistance in determining the ground pixel resolution of a standard digital image, and Table 3 affirms the expected file size for a black and white digital orthophoto when scanned at various scan sample rates.

b.2.3. Ground control

Ground control is required to rectify (georeference) the imagery to its true geographical position on the earth's surface. Simple rectification (rubber sheeting) is not suitable. Generally, a process known as differential rectification is used. Differential rectification is a phased procedure which uses several XYZ ground control points to georeference an aerial photograph to the earth, thereby creating a truly orthogonal image which can provide accurate measurements throughout its bounds. The exact location and number of ground points required are based upon the scale and accuracy of the final orthophoto as well as the negative scale and number of photo images required to cover the entire project area. Selecting the ground control points is generally not a task for the project manager and should be decided by the photogrammetric technician designing the project based upon his/her experience and equipment.

b.2.4. Digital elevation model

A suitable DEM must be obtained to provide a vertical datum for an orthophoto. Some projects may allow inclusion of a DEM for the project area that was developed from other imagery. This may be the case when the ground in the project area has not changed significantly between the time the imagery was collected for the DEM and the new orthophoto imagery collection date. However, most large-scale orthophoto projects require a DEM to be developed from the new imagery. This will insure and improve the accuracy of the image rectification.

A DEM for orthophoto rectification does not have to be as dense or as detailed as a terrain model for contour generation. Most projects will only require a coarse grid of points along with breaklines to define areas of abrupt change (i.e., edges of roads, streams, etc.). The density and spacing of the DEM points and breaklines are dependent largely upon the accuracy requirements, the horizontal scale of the final orthophoto, and the character of the land.

b.2.5. Data merge and radiometric correction

The final phase of the orthophoto process is the merger of the digital image and the DEM along with corrections in pixel intensity throughout the image. Software, used to merge the digital raster image with the DEM, makes adjustments in the horizontal location of pixels based upon their proximity to DEM points. This process removes the errors due to displacement and produces an image that is orthogonally accurate. The final step adjusts the intensity of selected groups of pixels in the orthophoto to ensure that seams between mosaicked images are minimized and/or to bring out features of interest or minimize aberrations.

b.2.6. Tiling and Formatting

The conclusive orthophoto image is finally broken into smaller areas that are more convenient to handle by the end user. This process is generally known as tiling or sheeting. Formatting may also be an important task in preparing an orthophoto for submittal to the end user. The final software format and any compression formats should be considered in the design of the orthophoto. Many large orthophoto projects quite often require data to be submitted in the original resolution (i.e., 1-ft pixel resolution) and also resampled and submitted with a 3-ft pixel resolution for quick viewing and locating specific areas of concern. Refer to Figure 3 for an example of this situation.
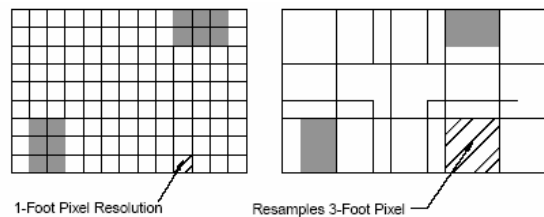

1-Foot Pixel Resolution   Resamples 3-Foot Pixel

Figure 3 An example of an area at 1-ft pixel resolution resample to 3 ft.

c. Orthophoto cost

The cost of orthophoto generation varies widely and is largely dependent upon the scale and accuracy requirements and the availability of source data. Obviously, projects that require the development of new photography and DEM data will be the most labor intensive and costly. However, in many cases suitable orthophotos can be generated from existing imagery and DEM data. The project manager simply needs to ensure that the data will meet the project accuracy and feature needs.

The National Agency of Cadastre and Land Registration (NACLD) is an agency that generates both large- and small scale orthophotos of various parts of our land. The National Agency of Cadastre and Land Registration is created, by reorganizing the National Office of Cadastre, Geodesy and Cartography and by taking over the land registration activity from the Ministry of Justice.

RESULTS AND DISCUSSIONS

The realization of national ortophoto coverage is a program of NACLD, the complete project was supported from Agency Budget (60%) and from World Bank Program.(40%). The level of coverage with orthophotoplans was 35% between 1995 and 2004, and 12% in 2005.The propose fly in 2005 was 52% (See Figure 4).
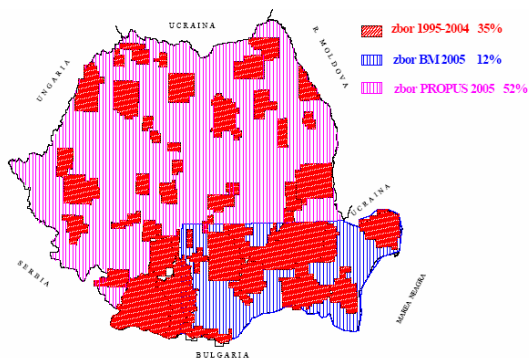

Figure 4: Romanian orthophotoplans coverage

An example of color orthophotoplans for Romania Country is given in Figure 4.

Figure 5: A fragment from an orthophotoplan

In our country exist othophoto at scale 1:1000, 1:2000 si 1:5000. The requirements for these orthophotos are showed in follow tables (Table 4 and Table 5):

Table 4.

Orthophotoplans at scale 1:5000

Intended output scale	1:5000
	Data acquisition
Camera	Analogue: ZEISS, LEICA f=150 mm
	Digital IMU, DMC f=120 mm
Photo scale	1:25000, 1:36000
Film	Color negative
Overlaps	Stereo, 60% forward overlap, 30% sidelap
Navigation	GPS navigation, using dGPS permanent station
Direction of flight	East-West
Area	98% of national area surface
Acquisition period	may-september 2003-2005
	Digital ortophoto
Ground resolution	50 cm
Accuracy	± 1.5 m
Spectrale band	True color (RGB)
Dataformat	24-bit TIF/TFW, ECW
Coordinate system	Dealul Piscului 1970/Stereo 70
Tiling system	2.5 km x 2.5 km
Tile name	SW corner coordinate in thousands (e.g. 350_450)
Show coverage	www.ancpi.ro Maps and Plans, Ortofotoplan coverage
Tile dimension	75 Mb/6.25 km²
Mosaic	ECW
Media deliverables	CD, DVD, external HDD, depending on datavolume
	Miscellaneous
Public authority responsable	NACLR
Copyright	NACLR
User right	End User Licence Agreement (Term & Conditions)
Show images	www.ancpi.ro Server Images
Availablity	by order

Purchase procedure	Cartographic products request form
	§ FNG fng@ancpi.ro, TEL/FAX: 4021 224 39 67
	   1A Expozitiei blvd., Bucharest, Romania
	   www.ancpi.ro, Maps and Plans
	§ County offices

Special requests	tile name or area of interest (DXF/SHP file)
Price	80 lei/ortofoto; 2 lei/km² - mosaic

Table 5.

Orthophotoplans at scale 1:2000 and 1:1000

Intended output scale	1:2000	1:1000
	Data acquisition	**Data acquisition**
Camera	Analogue: ZEISS, LEICA f=150 mm	Analogue: ZEISS, LEICA f=150 mm
	Digital IMU, DMC f=120 mm	Digital IMU, DMC f=120 mm, Vexcel UltraCam X
Photo scale	1:12000, 1:11000	1:25000, 1:6000
Film	Color negative/digital images	Color negative/digital images
Overlaps	Stereo, 60% forward overlap, 30% sidelap	Stereo, 60% forward overlap, 30% sidelap
Navigation	GPS navigation, using dGPS permanent station	GPS navigation, using dGPS permanent station
Direction of flight	East-West	East-West
Area	1.3% of national area surface	0.6% of national area surface
Acquisition period	may-september 2003-2005	may-september 2003-2005, april 2008
Digital ortophoto	**Digital ortophoto**	**Digital ortophoto**
Ground resolution	20 cm	15 cm, 20 cm
Accuracy	± 0.6 m	± 0.3 m
Spectrale band	True color (RGB)	True color (RGB)
Dataformat	24-bit TIF/TFW, ECW	24-bit TIF/TFW, ECW
Coordinate system	Dealul Piscului 1970/Stereo 70	Dealul Piscului 1970/Stereo 70
Tiling system	1 km x 1 km	0.5 km x 0.5 km; 1.8km x 1 km
Tile name	SW corner coordinate in thousands (e.g. 350_450)	SW corner coordinate in thousands (e.g. 350_450), custom
Show coverage	www.ancpi.ro Maps and Plans, Ortofotoplan coverage	www.ancpi.ro Maps and Plans, Ortofotoplan coverage
Tile dimension	75 Mb/km²	75 Mb/km²
Mosaic	ECW	ECW
Media deliverables	CD, DVD, external HDD, depending on datavolume	CD, DVD, external HDD, depending on datavolume
Miscellaneous	**Miscellaneous**	**Miscellaneous**
Public authority responsable	NACLR	NACLR
Copyright	NACLR	NACLR
User right	End User Licence Agreement (Term & Conditions)	End User Licence Agreement (Term & Conditions)
Show images	not yet available	not yet available
Availablity	by order	by order

Purchase procedure	Cartographic products request form
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	   1A Expozitiei blvd., Bucharest, Romania
	   www.ancpi.ro, Maps and Plans
	§ County offices
		Cartographic products request form
		§ FNG fng@ancpi.ro, TEL/FAX: 4021 224 39 67
		   1A Expozitiei blvd., Bucharest, Romania
		   www.ancpi.ro, Maps and Plans
		§ County offices

Special requests	tile name or area of interest (DXF/SHP file)	tile name or area of interest (DXF/SHP file)
Price	100 lei/km²	600 lei/km²

CONCLUSION

In Romania the cost of digital orthophotos is a reasonable price. The price for an othophotoplan at scale 1:1000 is 600 lei/ meter square and the price for an othophotoplan at scale 1:2000 is 100 lei/ meter square. For an othophotoplan at scale 1:5000 the price is 80 lei/ orthophoto. The strategy of NACLD in Cartography Sector include: the realization of orthophotoplans at scale 1:5000 for entire territory of Romania and the realization of orthophotoplans at scale 1:1000 and 1:2000 for other counties and cities from our country, to constitute a digital cartographic base, like an important part from a GIS.

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