CONSIDERATIONS ON THE STEREOSCOPIC PROCESSING OF DIGITAL AIR IMAGES WITH THE STEREO ANALYST SOFT

Pop Nicolae, Teodor Toderaş, Laura Cristina Luca*
*Faculty of Horticulture, University of Agricultural Sciences and Veterinary Medicine, 3-5 Mănăştur Street, Cluj-Napoca, 400372, Cluj, Romania; *Corresponding author: laura_c_luca@yahoo.com*

Abstract: The article contains some considerations regarding the stereoscopic processing of aerial digital images with the Stereo Analyst software. The particularities of the stereoscopic processing process are highlighted by a photogrammetric software and some particular aspects of a case study performed on several stereoscopic hooks of an area in the South-West part of Sibiu are presented. Also, some conclusions are presented on how to verify the accuracy of the stereoscopic model and the stereoscopic operation of stereograms.

Keywords: digital image, digital stereogram, stereoscopic model, 3D vectoring, cartographic database

INTRODUCTION

In various specialized papers, such as the ones in design and construction, hydrology, landscaping, etc., it is necessary to use the topographical plans.

The most efficient method of updating them is the photogrammetric method, which consists in the realization with specialized software of the stereoscopic model of the exploited area and the updating of the cartographic database of the correspondent topographic plan by 3D vectoring on such a virtual model, brought to and oriented in the geodetic coordinate system.

The informational content of the topographical plans must be permanently updated, due to the economic and social dynamics that take place permanently throughout Romania.

The most up-to-date and complete source of data on the represented territory on the topographical planes is digital aerial photographs that can be retrieved at the time of the update and can be successfully used in the process of updating or making and editing graphic content of the topographic plan.

The development and improvement of the technology for obtaining and recording digital stereoscopic images and their processing equipment has led to the possibility of obtaining very fast digital stereoscopic images of the terrain at a high resolution which ensures the necessary mapping accuracy. Today, for recording aerial images, are frequently used digital photogrammetric cameras, which are equipped with digital optical sensors with high-resolution and that are highly performant.

The stereoscopic processing of aerial digital images involves the realization with the help of *stereograms* of a virtual *stereoscopic model* (named stereomodel) of the recorded terrain, made even on a determined scale, in a photogrammetric coordinate system, which is then brought in and absolutely oriented in the geodetic coordinate system, or directly in the geodetic coordinate system (which is the Stereo Analyst software case) and spatial vectorization of the topographic details on this stereoscopic model.

The realization of such a stereoscopic digital model is based on the principle of stereoscopic vision (binocular vision) in order to perceive the objects in space and is realized with a specialized photogrammetric software.

The stereoscopic processing of digital aerial images eliminates the errors produced in the planimetric position of the vectorized topographic details, caused by the differences in the level of recorded terrain. For this reason, in the process of updating the topographic plans and the cartographic database, stereoscopic processing of digital photograms is indicated, because most of the Romanian territory is hilly and mountainous.

Therefore, updating topographical digital plans requires updating the geographic database from which they are generated.

MATERIAL AND METHOD

In order to update the cartographic database and the topographic plan respectively, digital stereograms were used as materials, and as a work method photogrammetric method of stereoscopic exploitation of stereogram photograms' was used.

Materials used. In order to analyze the efficiency of using the Stereo Analyst software in stereoscopic processing, a case study was carried out on an area in the South-West of Sibiu. Thus, for the case study, digital images were used as the source of photogrammetric digital images from the two tapes of photograms (photograms 102-129, 102-130, 102-131 from tape 4 and photograms 102-288, 102-289, 102-290 from tape 5) of the digital photogrammetric block, with a 60% longitudinal coverage covering the territory of the city.

Stereoscopic method of upgrading the topographic plan. For stereoscopic processing, the ***Stereo Analyst*** module from the ***Erdas Imagine 9.2*** software was used, a modern and high-performance workpiece, designed to create a stereoscopic model that can be viewed on the principle of *anaglyphs* of combining complementary colors. The software is equipped with powerful measurement and vectoring tools.

For the stereoscopic processing the following work subtopics were performed:

- selecting and opening digital stereogram images in the software window;
- adjusting image resolution and monitor resolution, as well as image contrast
- creation of the stereoscopic model;
- verifying the precision of creating the stereoscopic model;
- exploitation of the stereoscopic model (vectorization of the planimetric details on the stereoscopic model and registration in the cartographic database).

Preparation, selection and opening the images of the stereogram. The first step in creating the stereoscopic model is to select and open the stereogram images in the software window, from the folder where they were stored. Files with the stereogram images must be recorded in **.img** or **.tiff** format or in one of the formats recognized by Stereo Analyst.

First select the left image of the stereogram and open it using the **Open** option on the software toolbar, and the image from the right of the stereogram is selected and opened from the **File** menu by selecting **Open** > **Add a Second image for Stereo**. The images opened in the software window are applied the resolution and contrast adjustment process and also the resolution of the monitor will be adjusted in order to match that of the images.

Creating the stereoscopic model. In order to create the stereoscopic model (DSM – Digital Stereo Model), open its creation window from the Creare Stereo Model icon on the toolbar, to configure and enter the parameters of the photogrammetric camera used, of the inner and relative orientation of the elements of stereogram photogram and of the photogrammetric marker points coordinates (necessary for the absolute orientation of the stereomodel), as well as the connecting points.

In the **common** window, the values of the common parameters of the stereogram (the units of measure for coordinates and angles and the value of the average height of the photo shooting) are entered and then the cartographic projection is selected. If the cartographic projection is not found in the list of implemented projections, then it must be configured in the configuration window (Projection Choser), entering its parameters, and will be recorded in the list.

In the **Frame 1** window, enter the left photogram parameters of the stereogram as follows: in the ***Interior*** window, the values of the interior orientation elements are entered, and in the ***Exterior*** window the values of the external orientation elements are entered.

In the Frame 2 window, enter the parameters of the right-hand photogram of the stereogram as follows: in ***Interior*** window the values of the inner orientation elements are entered and in the ***Exterior*** window are entered the values of the external orientation elements.

The interior and exterior orientation parameters of stereogram photograms are extracted from the photogrammetry parameters file, delivered with the photogrammetric flight, and are used in the relative orientation of the stereogram photograms. Rigorous orientation of the stereogram photograms is based on the binding points that are usually selected in standard positions, on the double coverage of stereogram images. The parallaxes are then adjusted in the standard points.

After entering all the parameters of the stereogram images, **Apply** is used to create the block file with the recorded stereogram parameters, the result of the operations being a stereoscopic model (DSM) created, which can be displayed in the stereoscopic digital workspace of the software and can be viewed with anaglyph glasses.

It should be noted that since the known geodetic coordinates of the stereograms of the stereogram picture frames are introduced in Frame 1 and 2 windows, Exterior, the Stereo Analyst software creates the stereoscopical absolutely oriented model in the geodetic coordinate system.

Updating the cartographic database. To update the cartographic database of the topographic plan, was spatially vectorized (3D) the stereomodel, the contour of the planimetric topographic details (buildings, streets, sidewalks, boundaries, etc.) modified and recorded in the cartographic database.

The topographic plan thus updated can be displayed on the monitor or printed on one of the standard scales.

RESULTS AND DISCUSSIONS

Following stereoscopic processing of the case study images, good both planimetric and altimetric results were obtained. Coordinate values of digitized 3D points on the stereoscopic model achieved are situated within the tolerances imposed by the working instructions, at the geodetic field measurement points.

The precision of making the stereoscopic model depends on the punctuation accuracy on the stereogram images of the connection points, on the basis of which the relative orientation of the stereogram images is achieved and also the absolute orientation, due to the introduction of the geodetic coordinates of the perspectives centers of the images.

Making the stereoscopic digital model. The first operation of the stereoscopic modeling algorithm was to introduce the common parameters of the stereogram images in the **common** window of the software (the coordinate and angles measurement units and the average height of the photo shooting height), after which they were selected the parameters of the cartographic projection Stereo 70, in which was created the stereoscopic model that was used in the mapping of the case study area.

Parameters of the inner orientation of the stereogram images inserted into the **Frame** 1 and 2 window, **Interior**, were used by the software to perform the orientation of stereogram images in the reference index coordinate system (fiduciary markings).

The outside orientation parameters of the stereogram images entered in **Frame** 1 and 2, **Exterior**, were used by the software to perform the relative (reciprocal) orientation of stereogram images. Since the geodetic coordinates (x, y, z) of the perspective centers are also introduced here, the absolute orientation of the stereomodel in the coordinate system of the selected cartographic projection was carried out simultaneously with the relative orientation. A geodetically oriented stereoscopic model was thus obtained.

Verifying the accuracy of the stereoscopic model. The determination of the precision of the digital stereoscopic model is made: for the ***planimetry*** based on the *RMSE* mean square errors, m_x, m_y, m_p (relations 1) and for the ***altitudes*** based on calculations of the mean square error m_Z and of the standard deviation σ_z (relations 2).

$$m_X = \sqrt{\frac{\sum_{i=1}^{n}\left(X_{MS} - X_{REF}\right)^2}{n}}\ ;\quad m_Y = \sqrt{\frac{\sum_{i=1}^{n}\left(Y_{MS} - Y_{REF}\right)^2}{n}}\ ;\quad m_P = \sqrt{m_X^2 + m_Y^2} \qquad (1)$$

$$m_Z = \sqrt{\frac{\sum_{i=1}^{n}\left(Z_{MS} - Z_{REF}\right)^2}{n}}\ ;\quad \sigma_Z = \sqrt{\frac{\sum\left[\left(Z_{MS} - Z_{REF}\right) - ME\right]^2}{n-1}} \qquad (2)$$

where: m_x, m_y, m_z - are the mean square determination errors for *X, Y, Z* coordinates;
m_p - is the point position planimetric error;
σ_z - standard deviation;
X_{MS}, Y_{MS} - are the coordinates of the point read on the stereoscopic model made;
X_{REF}, Y_{REF} - are the geodetic coordinates of the point;
Z_{MS} – is the quota of the point read on the stereoscopic model achieved;
Z_{REF} - is the geodetic quota of the point;
ME - is the arithmetic mean of altitude deviations;
n - number of control points used.

The mean square error (*RMSE*), labeled m_x, m_y, m_z, measures the dispersion of error distribution and determines the overall accuracy of the stereoscopic model achieved (indicates its overall precision).

To verify the accuracy of the stereogram digital stereoscopic model, a number of 25 points was chosen. These points are identifiable on the stereogram photograms and on the realized stereoscopic model, with geodetic coordinates (X, Y, Z), which are topographically determined in the field in the case study area. The calculation of the precision of the stereoscopic model was made on the basis of the measurements made at the test points with geodetic coordinates determined.

For this purpose, the *Stereo Pair Choser* window was opened from the button, located on the toolbar of the *Stereo Analyst* software window and was selected the stereogram of the stereoscopic model (Fig. 1) from this table's window.

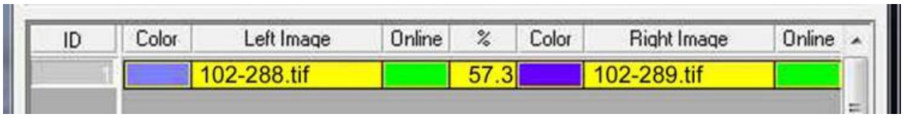

Fig. 1. Stereo Pair Choser window with the selected stereogram

Then, from the button located on the toolbar of the Stereo Analyst software window, was opened the Position Tools window, which is located at the bottom of the Stereo Analyst software window.

For determining the discrepancies between the coordinates measured on the stereomodel and the geodetic coordinates of each test point, the *Position Tools* window was used, in which the following operations were performed [according to the Stereo Analyst Software User's Guide]:

- was verified that *Enable Update* is unchecked;

- were entered the X, Y, Z values of the test point in the *Position Tools* window by double-clicking in the *coordinate* box and were written the corresponding geodetic coordinates, then was typed ENTER from the keyboard. The software positions the reticle of the positioning tool on the stereoscopic model in the position of the defined geodetic coordinate. Because of the planimetric residual errors, the position of the position tool reticle does not coincide with the position of the test point model;

- then, through the adjustment operation, was brought into coincidence with the reticule, by shifting, the image of the model with the test point;

- has been checked the *Enable Update* option in the *Position Tools* window, which has the effect of activating the stereoscopic measurement cursor;

- the new position of the test point that is coincident with the reticle has been punctuated with the stereoscopic cursor, in the Position Tools window, the X, Y coordinates of the cursor position being recorded. Differences in X and Y represent residual errors (discordances) between the two positions (measured and geodetic, respectively the reference one);

- in order to determine the altitude error, was pointed the stereoscopic cursor on the test point of the model by running the mouse wheel and the new Z value (the difference representing the residual discordance on Z) was recorded in the *Position Tools* window.

By checking all the test points in this way, the values of the discrepancies (between the coordinates measured on the stereoscopic model and the geodesic coordinates) were obtained at the 25 test points, from which the average square error and the standard deviation of the stereoscopic model , with relations (1) and (2) were determined.

Thus, following the measurements on the stereogram of the stereogram (102-288 and 102-289) and the calculations, the following values were obtained for the ***planimetry***: m_x = ±0,0876 m; m_y = ±0,0847 m; m_p = ±0,1218 m. For ***altimetry*** we obtained the values: m_z = ±0,1375 m m and the standard deviation σ = ±0,00412 m.

3D vectorization on the stereoscopic model and updating the topographic plan

The first operation was to create the cartographic database of layers for vectorized topographic details for updating purpose.

Space spatial digitization (3D) was then performed on the stereoscopic model, selecting for this purpose the spatial cursor (floating cursor) in the icon .

Then point-to-point all the topographic details that were the subject of updating the digital topographic plan were vectorized, permanently maintaining the spatial cursor in contact with the virtual terrain of the stereoscopic model.

The coordinates of the points of the vector entities resulting from the digitization are in the coordinate system of the cartographic projection *Stereo 1970* selected and refer to the vertical point of the digital stereoscopic model.

The vector entities collected by vectoring from the stereoscopic model were recorded in layers established prior to digitization.

CONCLUSIONS

The stereoscopic processing of digital photograms is a modern, efficient and accurate method of updating topographic plans due to the fact that it can be done with specialized photogrammetric software.

Digital photograms are the most up-to-date sources of information from which topographic details can be extracted and can be obtained with photogrammetric cameras at high resolutions that ensure the required photogrammetric precision.

In the process of digital stereoscopic processing, great importance must be given to the contrast and resolution of digital images, as these parameters can negatively or positively influence the quality and accuracy of the vectoring of the topographic details.

The computation and relative orientation of the stereogram images depends on the choice and accuracy of identifying and scoring on the stereogram images of the connection points and the photogrammetric reference points in order to measure their coordinates.

As can be seen from the above, although the technological process of stereoscopic processing of digital photograms is complex, the Stereo Analyst software, through its performance, makes this method very effective and rigorous in mapping hill and mountain areas.

The accuracy of vectorization on the stereoscopic image depends on the resolution of stereogram imaging and scoring accuracy on the stereoscopic pattern.

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