INTEGRATING REMOTELY SENSED DATA FOR RURAL ENVIRONMENTAL STUDIES

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***Abstract**: The paper deals with the integration of remotely sensed data gained from different sources having different resolution, date. It is important to join these data sources with their attribute data (resolution, location, spectral channels, etc.). For this purpose the meta-database is suitable tool. In this paper we examine the aspects of data integration and as an example we demonstrate the complexity of this problem by a simple rural environmental analysis.*

***Keywords:** Remote sensing, GIS, metadata, integration, environmental analysis*

1. Introduction

The need for data integration

In case of complex studies (for example examination of rural environmental conditions) a joint examination of data from several sources for several dates (principle of multiplicity) means a practical and important task. During the integration we seek for answers for our certain problems. Among others these can be the typical questions in data integration:

- Is the degree of change detectable?
- What new analytical capabilities do spectral, spatial, and other attribute data provide together?
- What new information does the raster resolution change or contrary do we lose information?
- Does combining 2D and 3D data help to solve a specific problem?
- With what trade-offs is integration possible?

Here is the list of type of data we typically try to integrate [1], [2]:

- By data format
  - Raster data (image) [14]
  - Vector data (map)
  - Attribute data (records, tables) [6]
- According to spatial characteristics
  - Points
  - 2D data
  - 3D data (DTM, DSM) [10], [14]
  - nD data (e.g. DTM+ time)
- According to physical characteristics
  - Spectral, radiometric data [6]
  - Geometric data
  - Thematic data [7],[8], [9], [12], [13]

Before integrating the data, it is necessary to know the properties that characterize the data (metadata). Without metadata, data integration will be incomplete or inaccurate. Obtaining metadata afterwards can run into serious hurdles if you don't think about it in advance. (E.g. we do not know the projection or the digital terrain model from which the orthophoto was created.

2. Data integration process

The data integration process can be divided into well-defines steps. These steps form an algorithm similar to algorithms used in programing. Here is a typical list we foloow usually:

- Setting up the desired goal, selecting the necessary data sources and data types
- Collection of data from different data sources
- Entering and editing metadata
- Data integration
  - In a database (GIS approach). The original data are stored, their transformation and integration takes place only during the given analysis task.
  - We transform all data sources into a common platform, e.g. raster (one projection, same raster size, conversion of vectors to raster format, interpolation of height data to raster, etc.)

During the data integration process, we should handle the errors [3]. For this we should know exactly the error sources and examine carefully all the available data. The possible errors can be grouped as follows:

- Positional, geometrical factors (scale, projection, etc.)
- Sensor defects
- Defects of carrying platforms
- Ground Control Point (GCP) errors
- Error sources in external conditions (e.g. refraction)
- Measurement and transformation errors
- Errors made during the data conversion (re-sampling errors, raster size reduction, etc.)

In order to handle the problems, we should consider the following aspects:

- By converting the data, usually we lose or falsify information.
- Handling data in a common projection may be more inaccurate than the positional accuracy of each data source in its own projection (external-internal accuracy dilemma).
- The amount of data can increase greatly and unnecessarily. (e.g. converting vector files to raster format.)
- The different accuracy factors of each data source are difficult to manage together. The least accurate data source can degrade the accuracy of multiple data sources.

After collecting the necessary data, we will need a suitable software for handling and processing. Answering the question "What software should I use?", we choose typically from this set:

- GIS based software (eg ArcGIS). We use this if we also want to build a database and a data warehouse.

- Target-oriented software, typically it is an image processing or an image classification software with extended functionality (e.g. Erdas, Envi, eCognition, etc.) [4]. We use this kind of software when we are really transforming data sources along a common logic for integration.
- Development environments (Matlab, IDL, etc.). We use this when we are looking for custom solutions.

It doesn't matter which software we choose, there common tasks and rules we should follow. Here is an incomplete list of tasks we typically looking for in an application:

- Raster vector transformation and manipulation
- Geometric corrections (georeferencing, image-map transformations)
- Radiometric corrections
- Image enhancement and conversion (e.g. contrast enhancement, filtering, histogram transformations, FT, indexes for image classification, texture statistics, etc.)
- Image classification, extraction of thematic information
- 3D data management, conversion (DEM, DTM)
- Change detection
- Accuracy assessment
- Database management, attachment of attribute data

3. Example of data integration

Let's take an example for data integration. We have aerial images from two different years (2005 and 2011) taken with RC20 frame cameras having 8 fiducial marks. The images were taken at different conditions. Table I summarizes the main characteristics of used images.

Table I. Main data of used images

Year	2005	2011
Number of images	2	3
Avg, Flight height[m]	5080	1530
Avg, Image scale	33 000	10 000
Scanning resolution [mm]	0.021	0.014
Avg. GSD [m]	0.70	0.14

The task was to produce a point cloud of a stone quarry and to compare the change of mining area based on the DTM and orthophoto. The whole orientation and evaluation process was carried out in Agisoft Metashape software. The photogrammetric process consisted of the following steps:

- Add photos
- Setup the camera (input focal length, pixel size)
- Detect and measure fiducial marks in all images
- Input of photo coordinates of fiducial marks
- Input of coordinates of projection centers gained from the approximate GPS data recorded during the flight
- Input of coordinates of control points
- Measurement of control points in all photos

- Align photos (measurement of tie points and calculation of exterior orientation elements)
- Build dense point cloud
- Build meshed model
- Build textured model
- Build DEM
- Build orthomosaic
- Export DEM as XYZ list of points
- Export orthophoto mosaic in GEOTIFF format

Figure 1 shows the user interface with the completed project based on images of 2005.

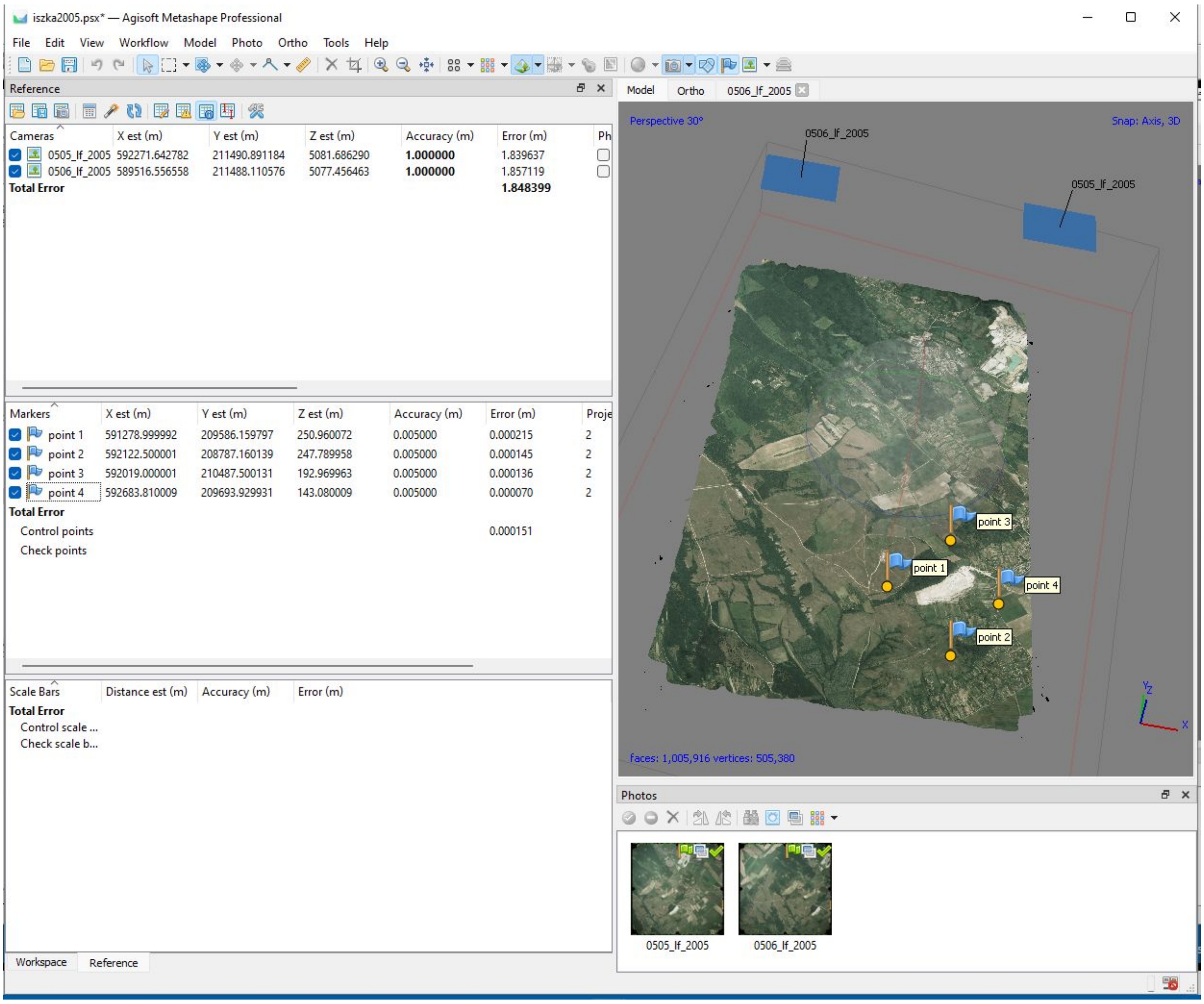

Fig. 1. Completed model for project 2005

Four control point were used around the quarry for absolute orientation of images. The covered area of the DEM and the produced orthophoto is 1.76 km². Fig. 2 and 3 show the DEM and the orthophoto. The exported DEM resolution is 1m, the pixel size of the produced orthophoto is 0.5 m.

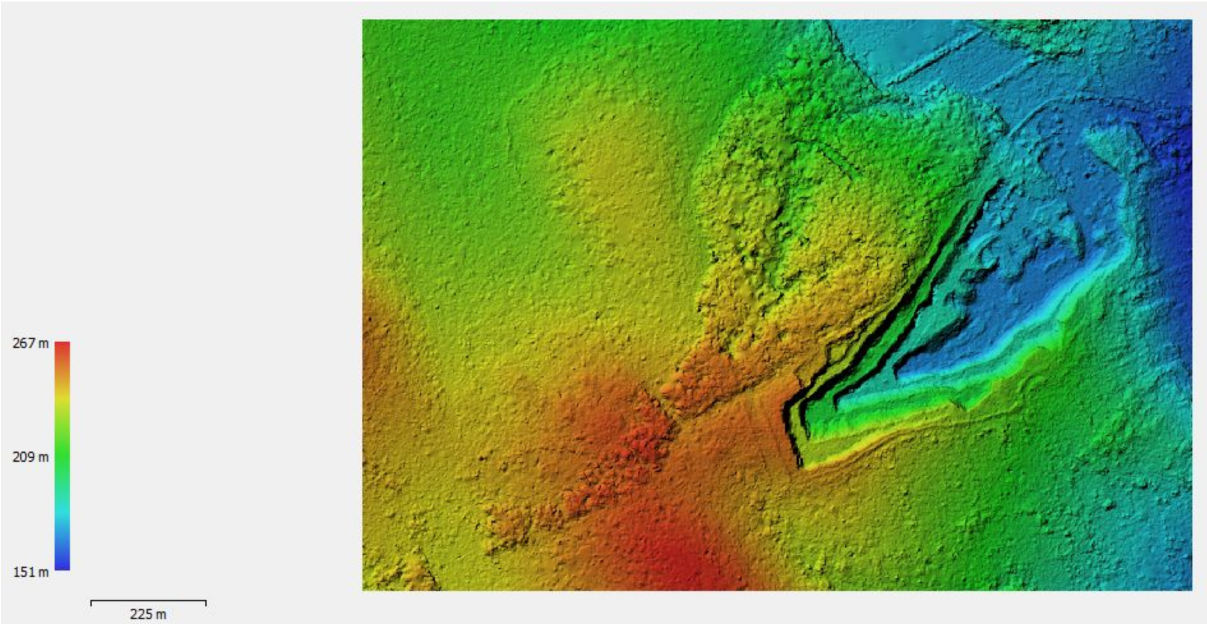

Fig. 2. Completed DEM for the year of 2005

Fig. 3. Completed DEM for the year of 2005

The same task was completed for images of 2011. Here three images were aligned and processed. Fig, 4 shows the user interface with the completes project 2011. Here we hade 5 control points in the target area.

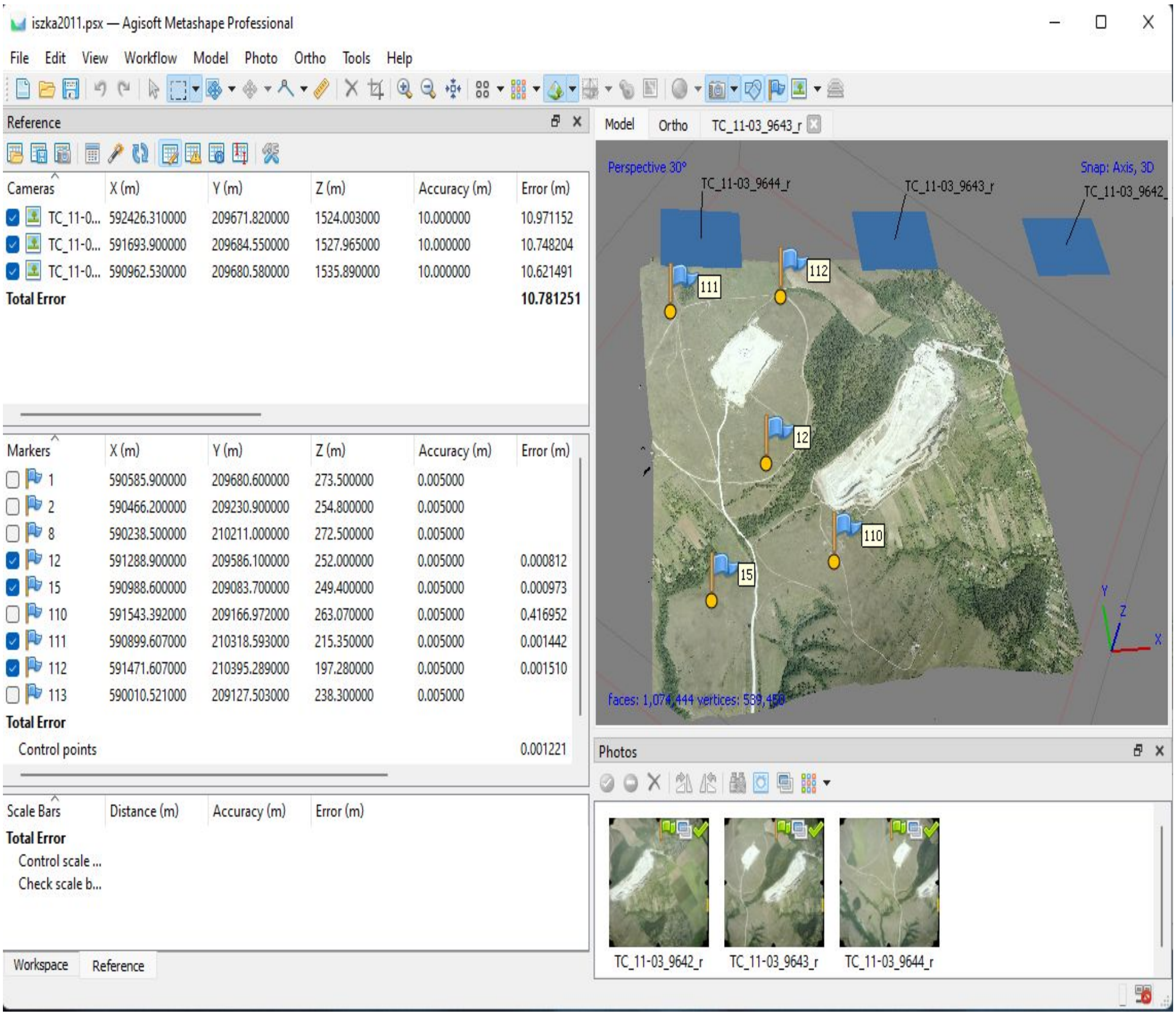

Fig. 4. Completed model for project 2005

Because of the higher image resolution, we decided to produce the DEM with 0.5 m grid size and the orthophoto was resampled with 0.25 m pixel size. Fig 5 and 6. show the final results.

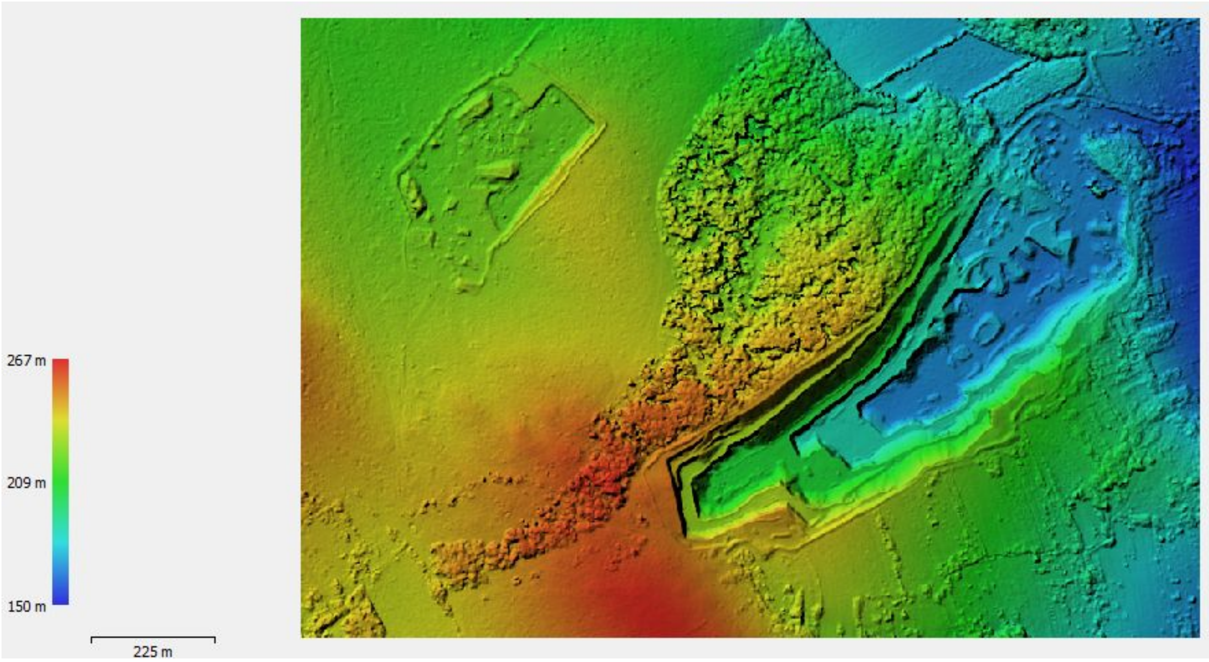

Fig. 5. Completed DEM for the year of 2011


Fig. 6. Completed DEM for the year of 2011

Examining visually the orthophotos we cannot notice big differences in quality and details. Although the scale and resolution of images are very different (see Table I). Considering the original pixels sizes and the exterior orientation accuracy, we had to make a decision which common resolution to choose for the integration of two different datasets.

Comparing visually the DEMs we can notice differences, the DEM of 2011 has a smother terrain, the DEM of 2005 has small disturbances in height especially in forest areas, probably it is because of the larger image resolution (Fig. 7 and 8).

The expansion of the mine territory has a great effect on environmental issues. The United Nations General Assembly launched 17 Sustainable Development Goals (SDGs) to preserve our world and to achieve a more sustainable future. Among these goals the climate action goal (SDG 13), life on land goal (SDG 15) or decent work and economic growth goal (SDG 8) meet the mining industry requirements [15].

Preparation of environmental impact assessment is necessary to start a mining area in which the preliminary conditions of the territory must be shown together with the environmental issues and possible hazards. The effect of the mining activity on groundwater is one of the main issues.

As the mining surface area rises the humus layer from the soils’ upper layer disappears and later the abandoned mining area becomes a mine lake which effects the ground water level of the surrounding area as the evapotranspiration rate rises. The diversity of the flora and fauna around the mining territory decreases.

The mine reclamation process lasts for long and costs a lot. Soil reconstruction process is easier together with the restoration of water-related functions and the vegetation influences the nutrient accumulation of the topsoil. The rehabilitation status of the abandoned mine territory can be mostly monitored by the soil structure development [16].

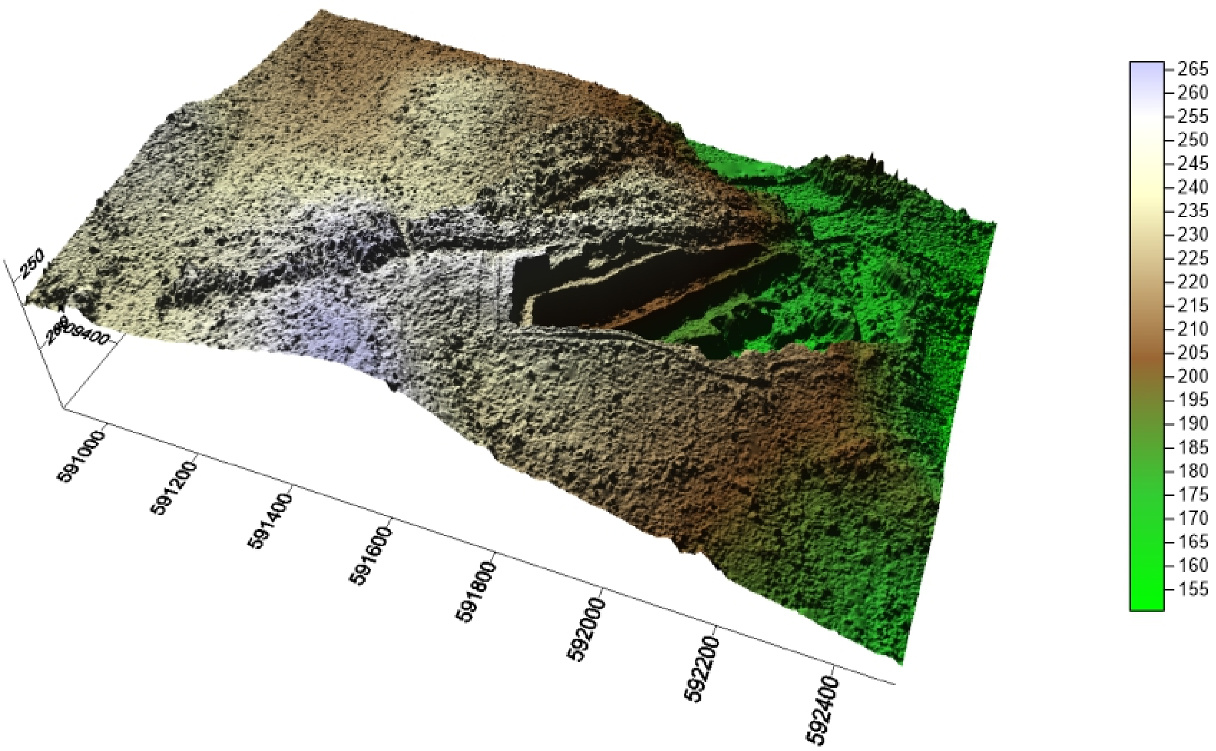

Fig. 7. Interpolated DEM of 2005 in Surfer

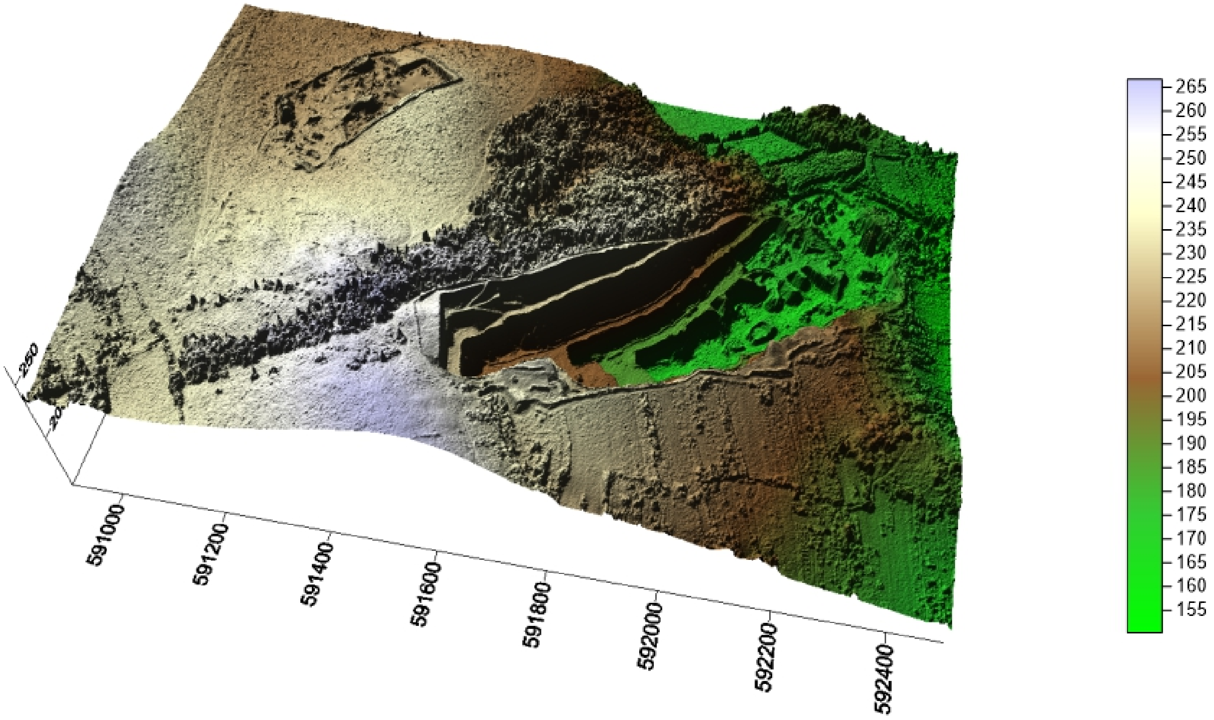

Fig. 8. Interpolated DEM of 2011 in Surfer

We used Surfer 12 for comparison of the produced DTMs. The result is seen in Fig. 9. and 10. In Fig 9 was produce as an image map by the formula of DEM2005-DEM2011. The color scale indicated the differences of heights in m. We can see clearly the enlargement of the quarry indicated in red colors. For better visual interpretation we added the othophoto of 2005 in Fig 10.

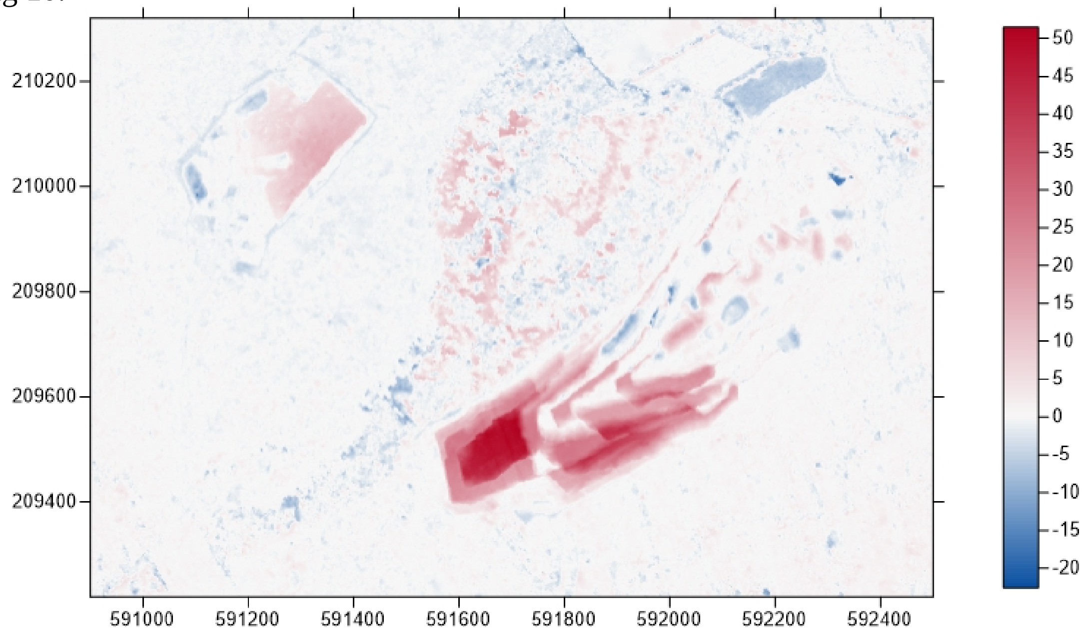

Fig. 7. Difference image of DEMs (DEM2005-2011)

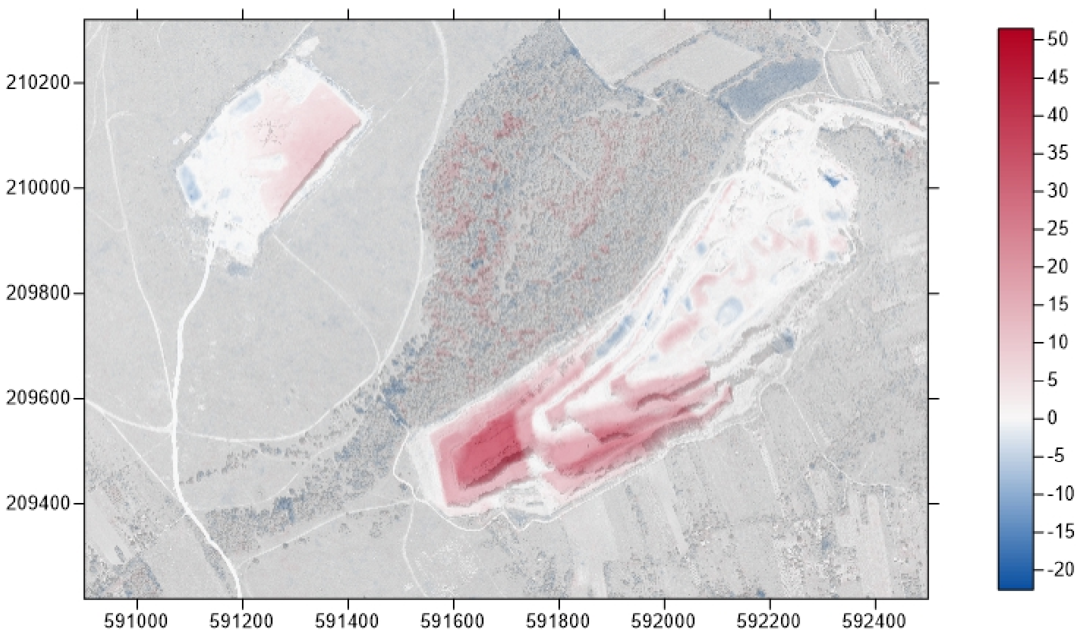

Fig. 8. Difference image of DEMs with a background orthophoto of 2011

4. Conclusions

During the data integration tasks we collected a lot of experience and we can give you the following advices:

- Try to achieve data integration with as few transformations as possible.
- Data integration that greatly degrades accuracy should be omitted from the data integration.
- Try to collect as much metadata as possible. We never know when it will come in handy.
- Define the goal first and only then start collecting and integrating the data. It is a typical mistake to integrate the collected data sources indiscriminately before the goal is defined.
- There is no single recipe for data integration. In many cases it is software-dependent and the software developers and their application programs tie our hands.

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