PROCESSING LIDAR INFORMATION TO INCREASE PRECISION IN FIELD NUMERICAL MODELS

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Abstract: *The purpose of this paper is to create a 3D land model based on LIDAR (Light Detection and Ranging) satellite images. LIDAR is an active remote-sensing method based on distance scanning and measurement that produces a DTM (Digital Terrain Model). It "sees through trees" and provides an exact model of the land surface in areas that have been inaccessible so far. LIDAR technology operates in a similar manner as RADAR, which uses radio waves, while LIDAR uses light waves generated by a pulse laser (laser-generated electromagnetic energy is spread by air gas molecules and particulate matter). In general, the wavelengths used by a LIDAR system depend on the type of measurement and vary between 355-1064 nm in the UV – VIS – IR range. Due to the laser beam, LIDAR is small enough to penetrate tree branches and reach the land surface, generating data with an accuracy of up to 1.5 m. While overflying the designated area, a laser beam scans the land and the ground objects. After soil contact, the laser beam returns to the plane and produces both point data and infrared images. Following data collection, the data are processed into a point-derived image. Each 3D point can be visualised in any direction, providing a 3D model of an area. In this way, a segment can be viewed vertically or laterally or it can spin in different directions. All data obtained in this way can be processed in several weeks, unlike manual photogrammetry methods that require months to be finalised. Data processing with the help of LIDAR satellite images facilitates creating 3D models, detecting and removing points outside the area of interest, modelling the soil surface and filtering data, generating elevation profiles, creating DSM and DTM in raster format, TIN, level curves or slope patterns, classifying soil surface and buildings, vectorisation of buildings, classifying the vegetation (high, medium and low) and detecting and classifying towers and high voltage cables. To create our 3D model, we performed field measurements with the GPS Leica 1200 equipment. For the areas where the GPS measurements could not be taken, we employed the Leica TC805 Total Station. To generate a 3D model of the terrain based on LIDAR images, we used Global Mapper v 16.1. Our source was the second, improved version of the ASTER GDEM altimetry data set, which was released by NASA and METI. GDEM2 has 260,000 more stereo pair images than GDEM1. Global Mapper is a viewing instrument that can display the most common raster, elevation or vector data sets. For viewing, we used the "ASTER GDEM v2 Worldwide Elevation Data (1 arc-second resolution) data set and SRTM (3 arc-second Resolution) data.*

Key words**:** *LIDAR, 3D Model, GPS, ASTER, SRTM, DTM, Global Mapper, TransDatRO, WGS 1984*

INTRODUCTION

Digital terrain model is the generic term for the digital representation of land area. This representation can be done based on altitude that can represent both relief and other topographic details.

The idea of LiDAR (acronym of *Light Detection and Ranging*) was advanced since the 1950s, but it took it years to prove it is an extremely viable mapping technology. In brief, LiDAR is a sensor fixed with high precision in a plane cockpit specially adapted for such operations that sends laser pulses to the Earth and the re-receives them with a receiver. The integrated processor determines the time interval in which the pulse leaves the aircraft, reaches the soil and comes back, correlating the precise position of the aircraft, altitude, and speed to finally calculate 3D positions of soil points (X, Y, Z), thus producing a "cloud of points" made up of thousands or even millions of points.

By LiDAR laser scanning, one can produce an interactive topographic map with a height accuracy of up to 20 cm. Current data have an accuracy of up to 1,5 m. In addition to topographic measurements, the technology can be used to evaluate different alternatives in constructions, education and research, and engineering.

Based on LiDAR data and using photograms, we can analyse and classify LiDAR points depending on the requirements of the project. Once the draft is ready, the topographic plan is subjected to checking and completion; eventually, the topographic plan required by the topographer is ready. Data thus collected can be used to produce the land digital model.

MATERIAL AND METHODS

To develop the land digital model, we used the points obtained by measuring with a ***Total Leica Station TC805*** the points obtained by measuring with a ***GPS Leica 1200*** equipment. Raw data thus obtained were processed with a Leica ***Geo Office Combined*** programme (to download raw data), a ***TransDatRO 4.01*** (to turn coordinates WGS1984 into Stereographic 1970 data), a ***DXFGenerate*** (to turn the file GSI into a file of the DWG/DXF type), a TopoLT (to develop the 3D models of the land and the import of 3D type points). To fill in the gaps, we sued the programme ***Global Mapper v16.1.2*** where we also activated the ***LiDAR module***, and to develop situation plans we used the ***AutoCad Civil 3D***.

In order to develop the LiDAR point clouds, we used the programme ***Global Mapper v.16.1.2***, a GIS application providing Access to a variety of spatial data sets. For advanced processing, we used the LiDAR Module, an optional accessory of the Global Mapper programme that provides numerous advanced opportunities of LiDAR processing. The LiDAR Module was launched together with Global Mapper V15 (version 15), to which a set of new LiDAR instruments was added upon the appearance of Global Mapper V16. To carry out this study, we used the version 16.1.2 of this programme that has numerous improvements compared to the previous version such as automated reclassification and extraction of points for buildings and trees, improving dramatically the automated classification of soil points as well as the ability to filter LiDAR points depending on class, altitude, colour, LIDAR LAS/LAZ filtering support, etc. Data obtained with the programme ***Global Mapper v.16.1.2*** and the ***active LIDAR module*** were possible with this LICENSED programme.

RESULTS AND DISCUSSIONS

Using altitude digital methods in different fields such as geomorphology, hydrology, environmental protection, etc. has become easier with the increasing availability of these modules in the recent years. The land digital model procedure used in topographic maps is time consuming; this is why the possibility of directing towards new altimetric sources is a step forward.

The Digital Elevation Model is the starting point in both calculating morphometric elements of relief and developing digital geomorphologic maps, and in space analysis and mathematical modelling, methods that are specific to Geographic Information Systems in the solution of theoretical and practical issues in geography and not only.

Digital Elevation Models are necessary "tools" in almost all type of analysis or modelling. This is why, ever since the 1950s, when land mathematical modelling applications started to be developed, digital elevation models have represented basic components of Geographical Information Systems and are currently subsystems of the latter (Digital Terrain Modelling Systems).

The term digital terrain model was first used in 1958 by Miller and Laflamme who defined it as “a statistical representation of a land continuous area using a large number of points whose horizontal coordinates (x, y) and altitude (z) are known, a representation developed in a random coordinate system.”

The quality of terrain digital models is determined by the quality of the pixel values (in the case of DEM) or their equivalent in other models. Their quality depends on a set of variables such as terrain hardness, quality of the data source, method of data acquisition, sample density, interpolation algorithm, and vertical resolution.

DEM is made up of an ordered set of information regarding the planimetric position and the elevation of some points that describe the configuration of the space distribution of relief structures and facilitates the reconstruction of areas in new points.

Modelling areas is the process through which we represent graphically a natural or artificial area through one or several mathematical equations.

Digital Elevation Model refers, in general, to a digital representation of land areas through altitude values. They are distributed evenly and make up a matrix represented as a network of regular cells most frequently square and rarely triangular or hexagonal. This designation is familiar in the U.S.A. and Canada.

At present, it is also used to represent values digitally (other than altitude values) or phenomena that vary continuously in space and that can thus be represented through continuous areas. In this case, the starting data no longer represent land altitude but the magnitude of the phenomenon in those points: this is how we produce digital models with high applicability (for instance, the digital model of air temperatures, of rainfalls, of piezometric levels, etc.).

The datum built up by Global Mapper contains a list of 368 Data. In this paper, we present only the datum used to carry out the research, i.e. the Piscului Hill 1970; Table 1 presents the transformation parameters for this datum. Table 2 presents the parameters of the Krassovsky ellipsoid.

Table 1

Shift parameters DEALUL PISCULUI 1970 (extracted from Global Mapper v16)

Datum Name	EPSG Code	Ellipsoid Name	dX (m)	dY (m)	dZ (m)	rX (as)	rY (as)	rZ (as)	Scale (x 10^-6
DEALUL PISCULUI 1970	6317	Krassovsky	28.00	-121.00	-77.00	N/A	N/A	N/A	N/A

Table 2

Parameters of the Krassovsky Ellipsoid (extracted from Global Mapper v16)

Ellipsoid Name	Semi-Major Axis (m)	Semi-Minor Axis (m)	Inverse Flattening
Krassovsky	6378245.000	6356863.019	298.3000004

SRTM was a joint project of NASA, the German and Italian space agencies, and the National Geospatial-Intelligence Agency. It was managed by NASA's Jet Propulsion Laboratory, Pasadena, California, for NASA's Science Mission Directorate, Washington, D.C. The newly released 30-meter topographic data products will be publicly distributed by the U.S. Geological Survey (USGS) along with the 90-meter data. These data are being made available via a user-friendly interface on USGS's Earth Explorer website.

SRTM flew aboard the Space Shuttle Endeavour in February 2000, mapping Earth's topography between 56 degrees south and 60 degrees north of the equator. During the 11-day mission, SRTM used an imaging radar to map the surface of Earth numerous times from different perspectives. The combination of these radar data were processed at JPL to produce a global topographic map created by bouncing radar signals off Earth's surface and back to the shuttle.

The Shift Radar Topographic Mission (SRTM) consisted in a radar system especially modified that flew on board the Endeavour for 11 days (from February 11 to February 22, 2000) that provided elevation data at almost global level to generate high-resolution digital topographic data on 119,560,000 km^2. SRTM is an international project carried out by *National Geospatial Intelligence Agency (NGA)* and *National Aeronautics and Space Administration (NASA).*

SRTM version 3 was designed to remove gaps in DEM, firstly for the filling in of the gaps wit elevation data from ASTER GDEM2 (*Global Digital Elevation Model v2)* and secondly to develop the elevation model *USGS GMTED2010* or *USGS National Elevation Dataset (NED).*

SRTM data for regions outside the U.S.A. were sampled at 3 arc-seconds, i.e. 90 m. The new data generated by SRTM at 1 arc-seconds or about 30 m provides a high resolution.

The map below shows the sets of currently available data through OpenTopography. The data are available in a range of formats depending on the type of acquisition and on their destination. The classes of types of data include LiDAR point clouds, Digital Elevation Models and Google Earth image files. One can also generate LiDAR POINT CLOUDS to generate personalised DEM data. There are also extensions, METADATA.

Data inlaying and re-projecting was done with the application Global Mapper. From here, the mosaic was exported into an ESRI ASCII (.asc) and GeoTiff (.tif) format at a space resolution of 80 m (Vasile Craciunescu, 2007).

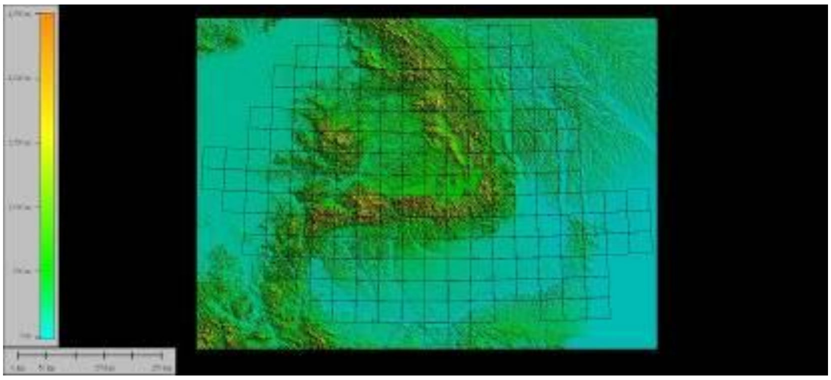

Fig. 1 – Sets of available data - OpenTopography

Fig. 2 - SRTM Worlwide Elevation Data (3-arc-second Resolution)

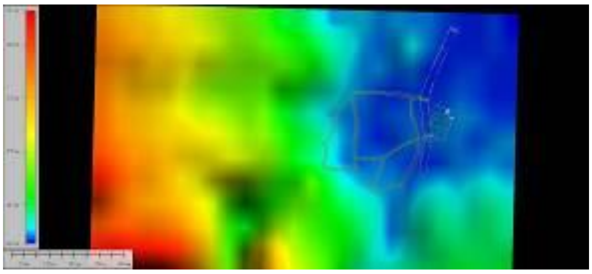

Fig. 3 - SRTM Worlwide Elevation Data (3-arc-second Resolution - LIDAR_rasters_srtm.tar.gz), data personalised with OpenTopography

Fig. 4 – Level curves developed based on SRTM data (3-arc-second Resolution)

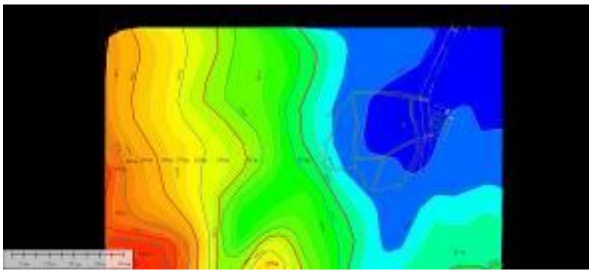

Fig. 5 - Realizarea curbelor de nivel pe baza datelor SRTM, (LIDAR_rasters_srtm.tar.gz), date personalizate cu OpenTopography

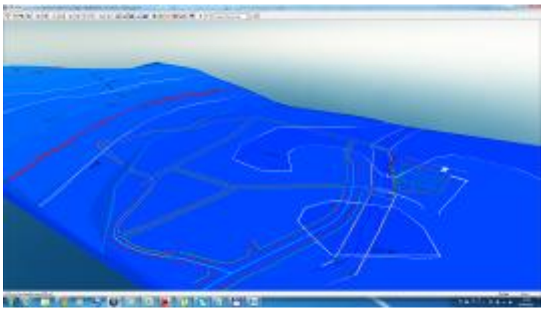

Fig. 6 - 3D model of the terrain SRTM (3-arc-second Resolution)

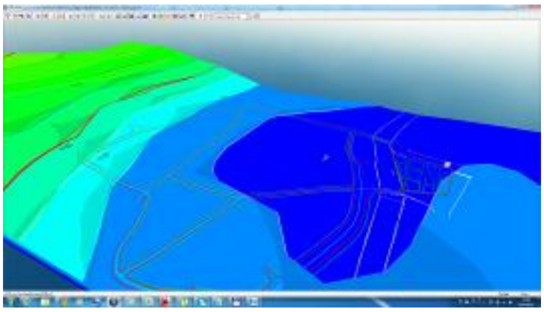

Fig. 7 - 3D modelof the terrain (LIDAR_rasters_srtm.tar.gz), data personalised with OpenTopography

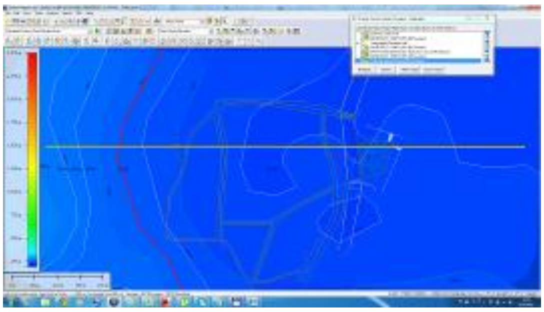

Fig. 8 – Transversal profile (to note the lines) SRTM (3-arc-second Resolution)

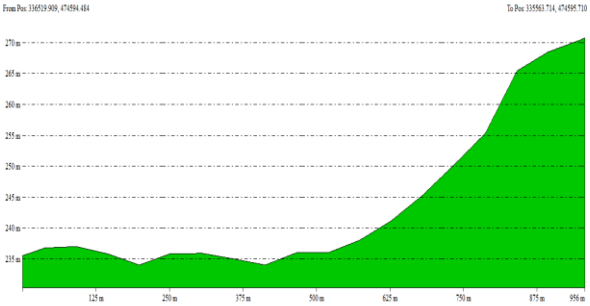

Fig. 9 – Transversal profile

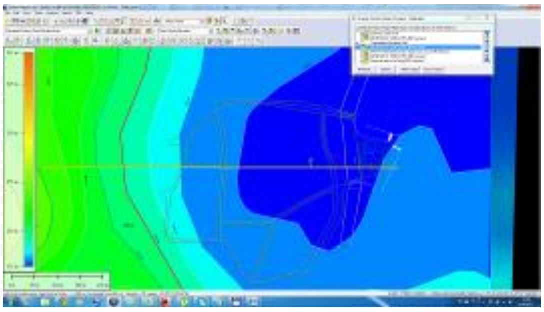

Fig. 10 - Transversal profile (to note the lines) (LIDAR_rasters_srtm.tar.gz), data personalised with OpenTopography

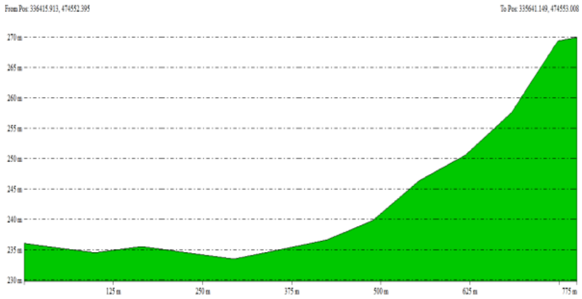

Fig. 11 – Transversal profile

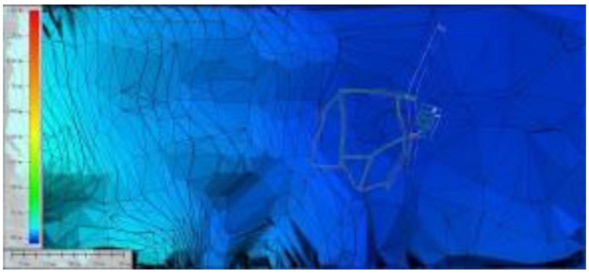

Fig. 12 - GRID model based on SRTM model

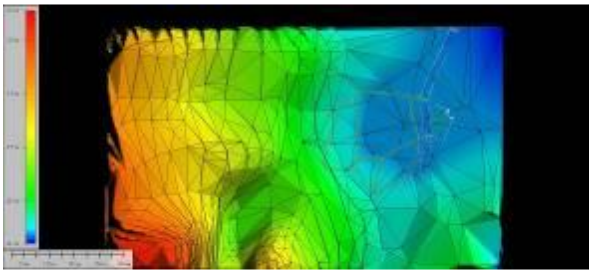

Fig. 13 - GRID model based on SRTM model (LIDAR_rasters_srtm.tar.gz), data personalised with OpenTopography

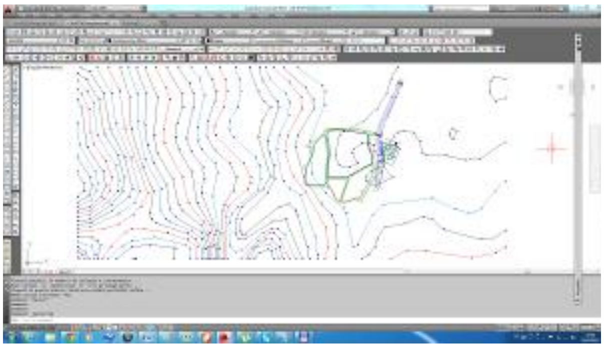

Fig. 14 – Importing points in AutoCad 2014, SRTM (3-arc-second Resolution)

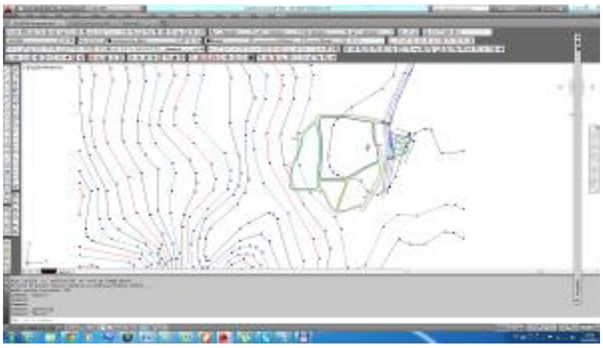

Fig. 15 - Importing points in AutoCad 2014, (LIDAR_rasters_srtm.tar.gz), data personalised with OpenTopography

Analysis and preparation of data personalisation was done with the portal OpenTopography to improve the precision of the SRTM data strictly for the measured area.

1. Chosing and establishing the area to be studied

2. Index map of new maximum resolution available data

Fig. 16 – Analysis and preparation for data personalisation with OpenTopography

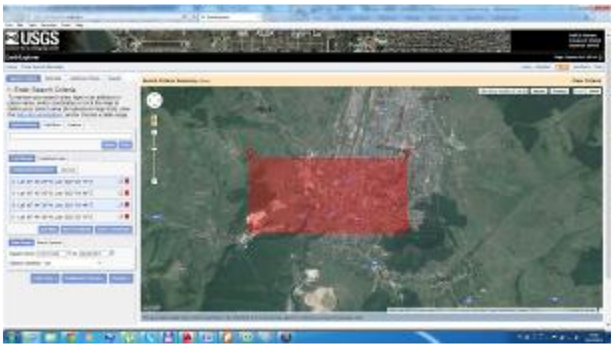

Fig. 17 – Connecting to USGS NAtional Lidar Dataset (http://earthexplorer.usgs.gov/)

3. Crearea norilor de puncte LIDAR

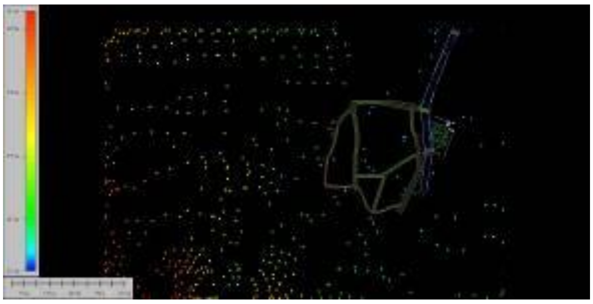

Fig. 18 – LIDAR point clouds

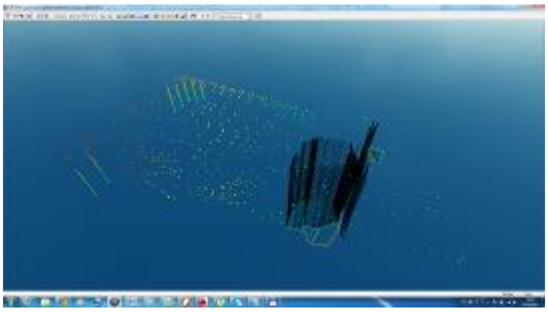

Fig. 19 - 3D visualisation of LIDAR point clouds

4. Rectification of LIDAR point clouds

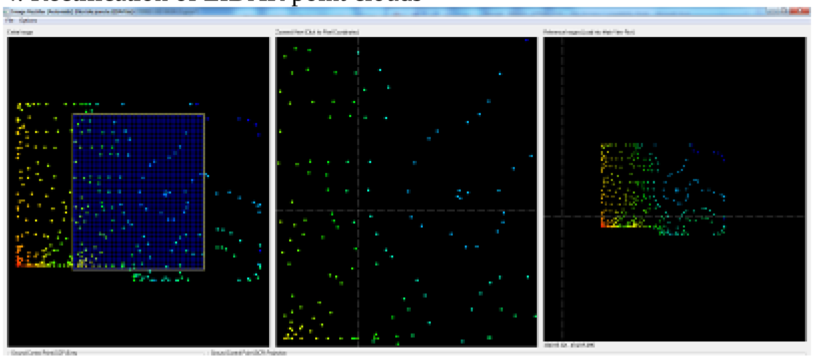

Fig. 20 – Automated image rectification (RECTIFY - Modify Layer Position/Projection)

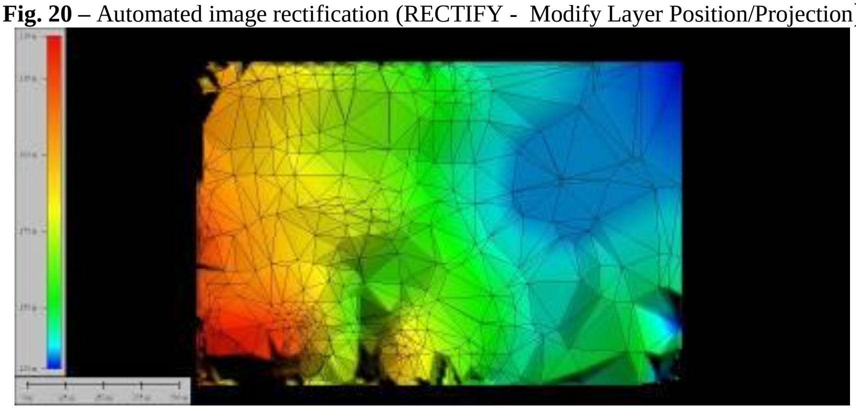

Fig. 21 - Developing TIN model based on LIDAR point clouds (Trialngulation - Grod TIN of Points)

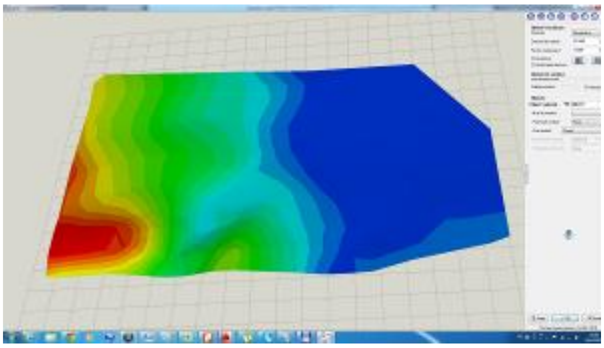

Fig. 22 - 3D model with TopoLT

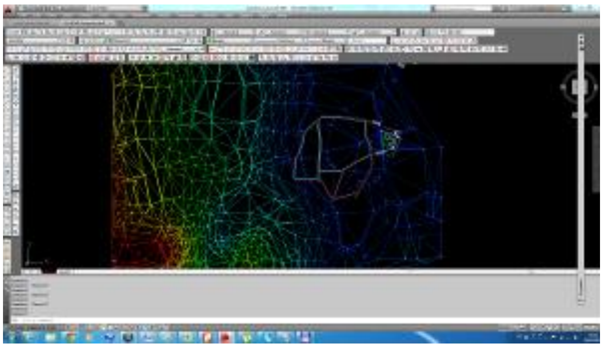

Fig. 23 – Presentation of data in AutoCad 2014

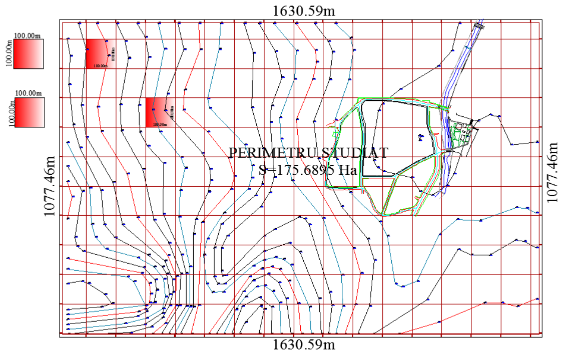

Fig. 24 – Presentation of studied area (175,6895 ha)

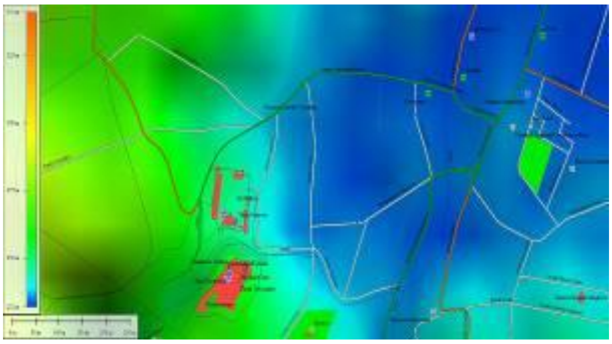

Fig. 25 – Superposition of maesurements over procesed LiDAR image

Fig. 26 – Processing data and producing a street map

Fig. 27 - Processing data and producing a detailed map with objectives of interest

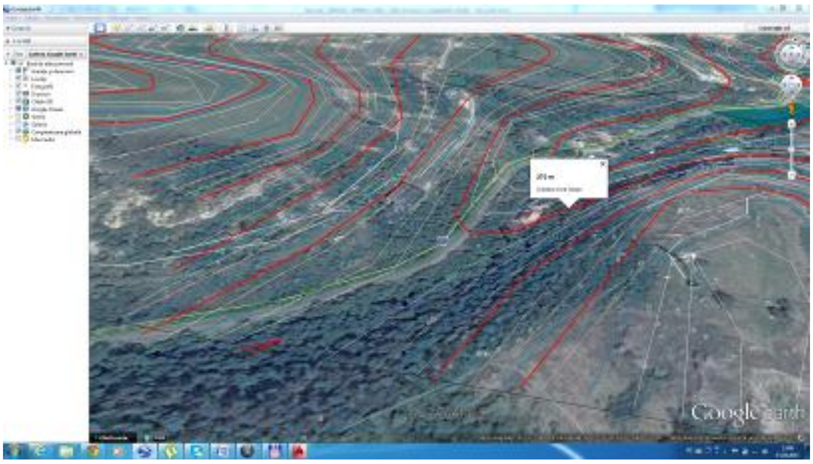

Fig. 28 – Importing level curves and their presentation in Google Earth

CONCLUSIONS

This paper aimed at:

1. Firstly, developing a terrain digital model based on measurements with the total station Leica TC805 and with the equipment GPS Leica series 1200 with the programmes Leica Geo Office Combined, DXF Generate, AutoCad Civil 3D, and TopoLT;
2. Secondly, developing a 3D representation of the terrain based on satellite images of the LiDAR (Light Detection and Ranging) type, by developing a Terrain Digital Model, and providing an accurate model of the land area with the programme Global Mapper v16.1.2 where the LiDAR module, AutoCad Civil 3D, TopoLT was also activated.

The LiDAR module operates like a RADAR: however, a RADAR used electromagnetic waves in the radio range, while the LiDAR systems use light waves generated by a laser in pulse regime. The laser beam of the LiDAR module is small enough to penetrate tree branches and reach the land surface, generating accurate data up to 1.5 m.

Following data collection, the data are processed into a point-derived image. Each 3D point can be visualised in any direction, providing a 3D model of an area. In this way, a segment can be viewed vertically or laterally or it can spin in different directions. All data obtained in this way can be processed in several weeks, unlike manual photogrammetry methods that require months to be finalised. Data processing with the help of LIDAR satellite images facilitates creating 3D models, detecting and removing points outside the area of interest, modelling the soil surface and filtering data, generating elevation profiles, creating DSM and DTM in raster format, TIN, level curves or slope patterns, classifying soil surface and buildings, vectorisation of buildings, classifying the vegetation (high, medium and low) and detecting and classifying towers and high voltage cables.

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14. *** http://www2.jpl.nasa.gov/srtm/
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16. *** http://www.geo-spatial.org/download/datele-srtm90-reproiectate-in-stereo70