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APPLICATIONS OF LIDAR DATA EXPLOITATION FOR DISPLACEMENT MEASUREMENTS AND CHANGE DETECTION

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Abstract: *The denser the Lidar data, the more faithfully it models the terrain. This property of dense Lidar data allows a detection of changes but also their quantification at a level of precision that can highlight even displacements of objects in all three spatial directions. The point cloud has different densities and accuracies depending on the platform on which the scanning system is installed (manned aircraft, drones or ground stations). Density and precision parameters drive different approaches in change detection algorithms. For completing these tasks, two independent applications were developed to highlight both major landscape changes and smaller changes such as displacement of objects, construction settlements, landslides.*
Keywords: *Lidar, change detection, application, cloud points*

1. Cloud points

The point cloud used for mapping objectives has different densities and accuracies depending on the sensor and the platform on which the scanning system is installed (manned aircraft, drones or ground stations). In the technological processes implemented, 3 density classes were used in the analysis of landscape or object changes, for each class using slightly different algorithms.

– Classic cloud points (20p/m2 > ρ > 1p/m2) with sensors on manned aerial platforms;
– Dense cloud points (500p/m2 > ρ > 20p/m2) with sensors on UAVs;
– Super-dense cloud points (250000p/m2 > ρ > 500p/m2) with sensors on ground scanning stations.

In practice there are also point clouds with even higher density, but that field does not belong to the cartographic or topo-geodetic field, it being a field of mechanics, it refers to the investigation of construction defects of some mechanical parts or deformations following the use of those parts, pipes, etc. Point clouds with a density of less than 1p/m2 can no longer be considered point clouds, they are treated as a network of points from which point grids can be generated.

The higher the density of the point cloud, the better the accuracy of the points, which allows the different approach in change detection. In reality, we consider it to be landscape change when the changes are greater than a T value of an order of magnitude. For landscape modifications, the use of classical density point clouds is sufficient. The detection of landscape changes has applications in the identification of landslides, the appearance/disappearance of constructions, the calculation of volumes of excavations/fills in quarries or transport infrastructure works, the calculation of plant mass volumes in the processes of monitoring the growth of agricultural crops.

When the changes are of centimeter order, they must be highlighted by the analysis of higher precision data and using dense and super dense clouds. This kind of changes is characteristic of displacements following catastrophic events or intense natural phenomena (strong winds). They are not analyzed on large landscapes; they are identified on portions of relatively small landscapes and on those portions where clouds of classic density do not detect significant changes.

If the changes are smaller, on the order of millimeters, they fall into the field of tracking constructions, movements of various objects, and can only be identified using super dense clouds produced by terrestrial scanning systems.

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2. Move detection program - MoveDetect

While CloudCompare, a classic change detection application, was designed to perform direct comparisons between super dense 3D point clouds using algorithms based on easy-to-generate triangle mesh analysis for relatively flat surfaces [1], our MoveDetect application (figure 1) identifies displacements in all 3 spatial directions using independent surface model extracts where areas or points considered fixed are precisely identified. In practice, displacements are determined in relation to those stable elements in the field.

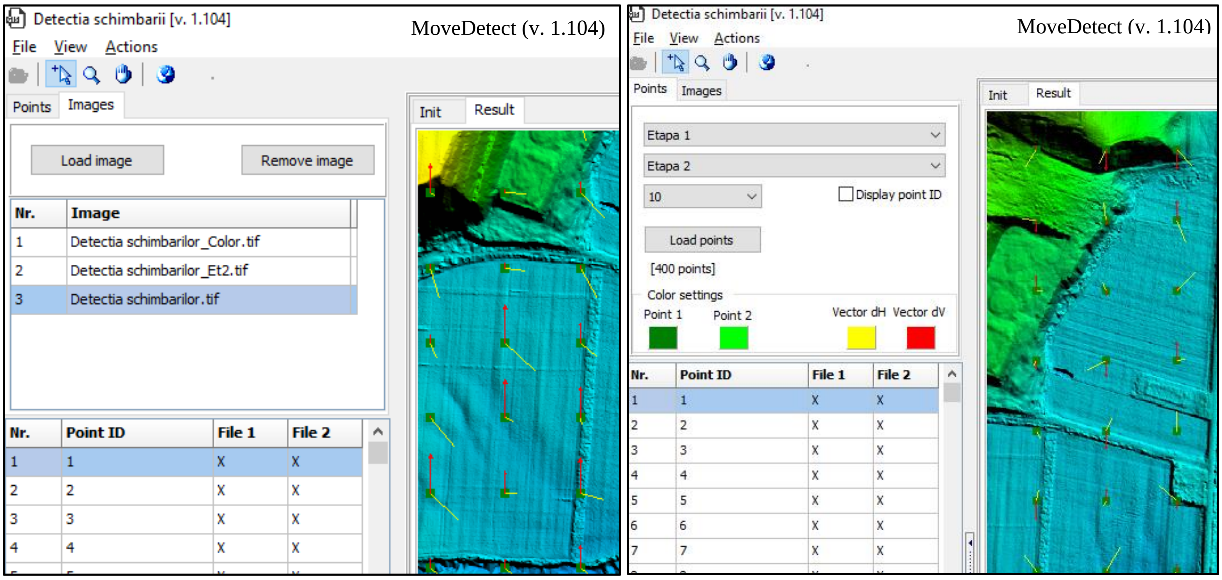

Fig. 1. MoveDetect Application – background interface

LIDAR data determined over an area at different periods or stages are not located at exactly the same points and therefore comparing them to detect change or displacements could be more difficult because there would have to be some correspondence between the points. The best correspondence is spatial position. To ensure this position, the cloud of points is transformed into a grid of points with the same density but using the correlation principle for the second cloud. Practically, for each point in the cloud of points N1 there will correspond another point in the cloud N2 determined on the principle of autocorrelation from photogrammetry, but this one has different coordinates according to the displacements between the points.

To compare these values, the MoveDetect program determines the changes in each point based on the correlation between them. The program allows the loading of the following information into a database:
• LIDAR cloud points stage I of measurements;
• LIDAR cloud points in other stages of measurements with information auto correlated with stage I;
• Raster images with the Digital Terrain Model
• Orthophoto images for positioning

In order to be able to easily visualize but also to be able to use this information in change detection processes, an interface was designed that graphically highlights planimetric and vertical displacements distinctly.

The application screen is divided into 5 control and data view windows (figure 2):
– the command window in which given load commands can be given, a reference date and a displacement calculation date can be selected, the displacement representation scale;
– background information selection window for viewing;
– graphic display window where point files and images can be presented in real terrain coordinates;
– window displaying the displacements between the two data for each point;
– helper window for highlighting the points and the files in which they are found.

Main features of the MoveDetect app:
- Upload point cloud files at different dates;
- Loading georeferenced raster images;
- Display points on a specified date;
- Selective display of images;
- Fixing point or group of points between two dates;
- Graphical display of displacement vectors at a certain date compared to a reference date;

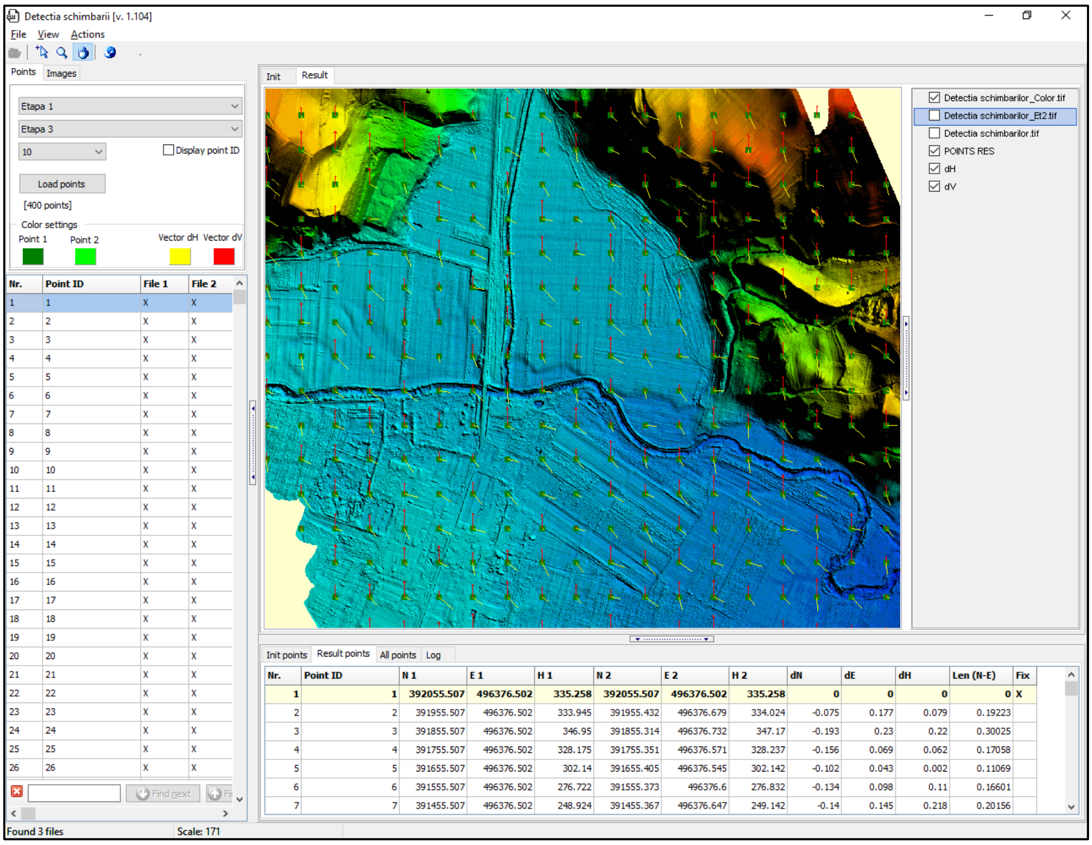

Fig. 2. MoveDetect interface

To determine the displacements between two stages of measurements, it is necessary to know at least one point considered fixed. Considering that the measurements at different stages are affected by systematic errors that do not represent significant changes, a point or points that can be considered fixed should be chosen and against them the planimetric and altimetric variations should be determined.

In the MoveDetect application, fixed point selection can be done in the graphics window by using the mouse and selecting the point or in the list of points in the helper window. However, we make the selection in the view window of points and differences, the selected point will have the differences on coordinates equal to 0 and will be marked by an asterisk as a fixed point (Figure 3).

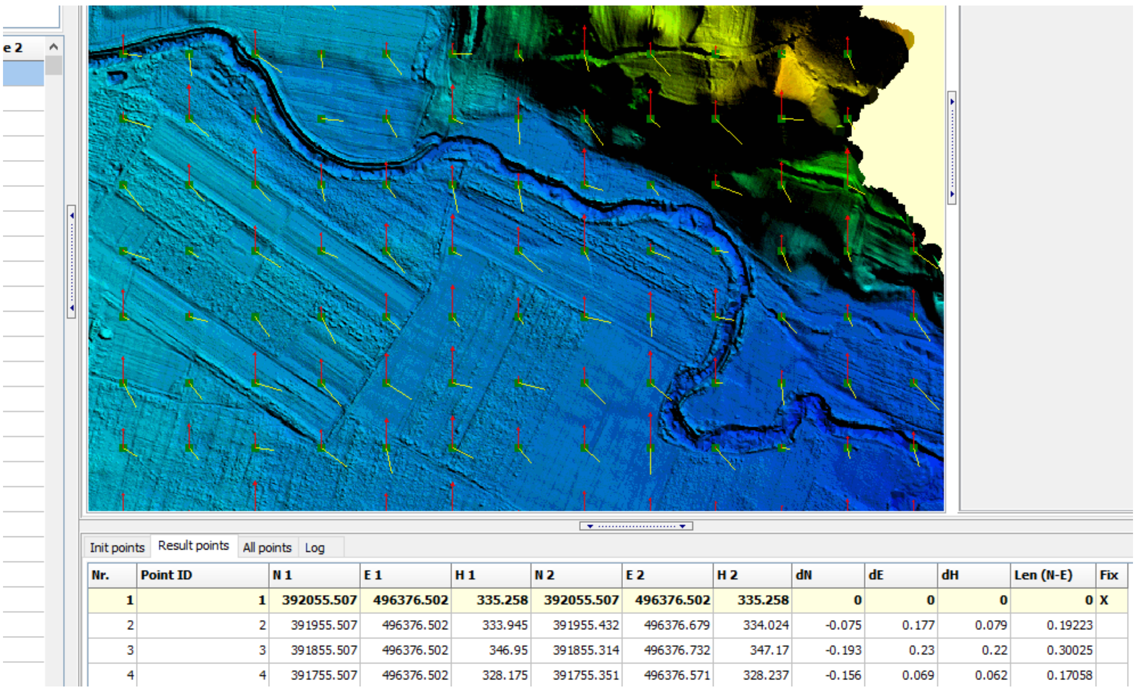

Fig. 3 MoveDetect selection interface for a fix point

Graphical display of displacement vectors against a datum

A representation scale of 10x, 100x, 1000x, 10000x and 100000x will be used to display the displacement vector depending on its size relative to the distance between the points. Once the representation scale is selected in the command window it will be adjustable with the + and **-** keys, up for +, down for **-**.

Planimetric changes will be displayed with a default displacement vector in dark blue and vertical deformations with a vertical vector on the screen, up or down according to the value of the difference on Z, default in red.

For images there is a special control window through which any number of images can be uploaded provided they are in TIFF format with additional TFW file type. In the view control window the name of the image file is automatically checked when it is loaded into the database. In order for the images to be visible the images must first be georeferenced to the same common coordinate system as the LIDAR point cloud.

The identified displacements are automatically saved in a file corresponding to the point grid from the initial stage.

3. Change detection module in LidarTools application

The individual application MoveDetect is adapted to the detection of small changes through monitoring points. That's why, MoveDetect can also work with small group of points loaded from standard text coordinate files. For major detections that occur frequently in landslides or in landscape evolution, a special LasCompare detection function has been introduced in the LidarTools application by which two sets of data taken at different dates over the same region can be loaded and the difference between them can be calculated. The program works with point clouds stored in LAS format files [2].

If the initial stage LAS file is E0 and the last stage LAS file is E1, then the LAS file being saved contains only points from the E0 or E1 file as follows:

One cell will always contain the point in E1, on the class in E1 because it is the final version. This point will be colored according to the calculated difference as specified in the color bar. The difference value can be passed for further use in an additional special field. If the difference E1-E0 is greater than the tolerance and point E1 is not ground, then the point in E1 is moved to a new class, "new objects", where objects can be buildings, vegetation, etc.

In the same cell, a point from E0 is passed only if it does not represent terrain and if the difference E1-E0 in absolute value is greater than the working tolerance, respectively if the object from E0 has disappeared in E1. This point in E0 is passed to a new class, erased objects, where objects can be buildings, vegetation, etc.

This way the LAS file will contain more points but it will be immediately possible to see what's new, what's gone and what hasn't changed, and if it's changed by how much it's changed

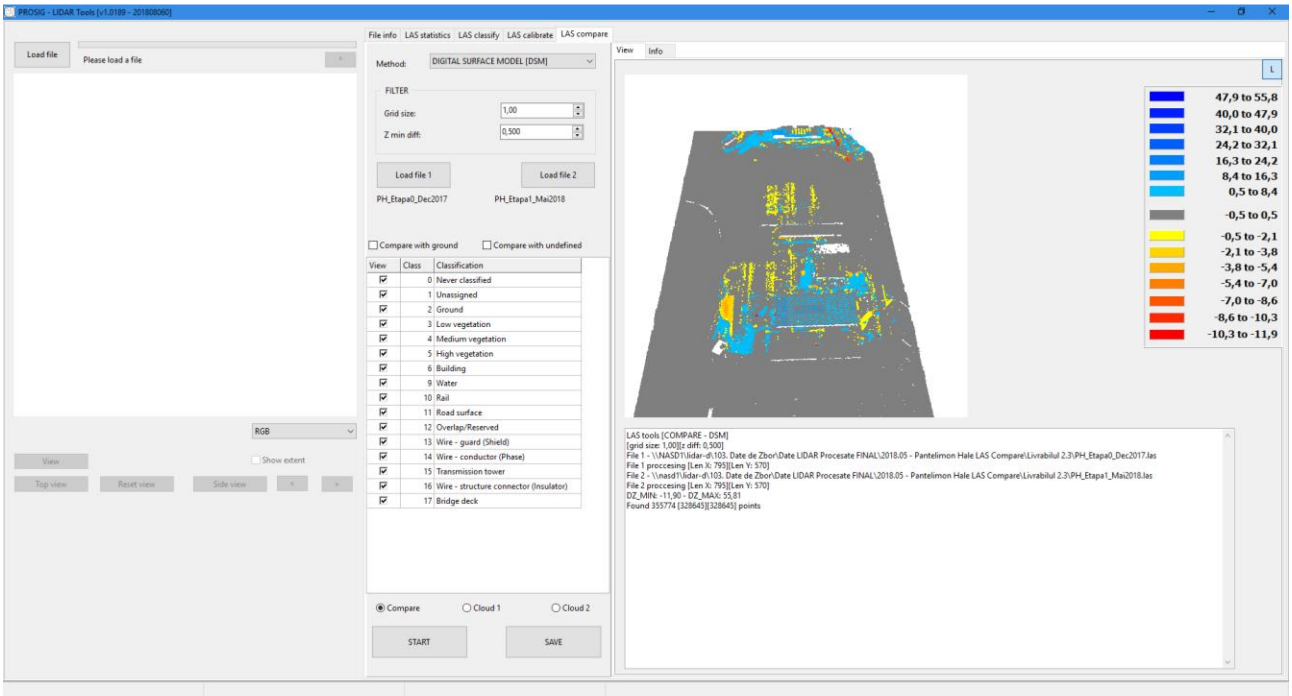

Fig. 4 Change detection module in LidarTools (DSM method)

4. Conclusions and recommendations

For detailed detections of landscape changes, the MoveDetect application can be used, but on a limited area. For this, a grid of points is extracted from the area of interest, corresponding to minimum two stages of measurements to be monitored.

For the detection of landscape changes, the LasCompare function from the LidarTools application will be used. In order to identify landscape changes on various thematic classes, the same LasCompare procedure and one of the two implemented methods will be used (comparison based on minimum quotas - DTM method or comparison based on maximum quotas – DSM method). In the case of the LIDAR data comparison procedure based on minimum elevations (DTM), the maximum slope or variation tolerance will not be used, as in the case of ground point classification. The graphical interface and parameterization mode is similar to that of the DSM point comparison method.

The principle is based on a linear traversal of each point cloud, using a parameterizable unit cell. In the case of the method of comparing the two data sets based on the DTM, for each unit cell the minimum point (from an altimetric point of view) is identified. The two points are differentiated by recording the obtained value in a new matrix. The elevations of the two LIDAR points in the traversed unit cell are differentiated according to the principle: Elevation_Final_Stage – Elevation_Initial Stage.

As with the other method, if the difference is negative and greater than the tolerance (Z min diff), it is considered that there are landscape changes in that unit cell by removal/digging/disappearance. For this reason, the point will be given the red color in the RGB value field. The obtained difference, together with the planimetric coordinates of the point from the initial stage, are saved as a new point in the matrix of landscape changes. If the differences between the analyzed points fall within the parameterized tolerance (both in the negative and in the positive range), the points are quantified, but receive the gray color as RGB value. This means that there have been no significant changes in that area.

Depending on the landscape changes that will be highlighted, various parameterizations of the application are used. Thus, several parameterizations were made to identify the usefulness of each value. For example, when using a larger tolerance (1.00 meter), new constructions and other large objects are particularly highlighted. This is also done if the tolerance is 2.00 meters, but the analysis data is more filtered.

If detailed identification of landscape changes is desired, a smaller unit cell is used. But even in this case, the point comparison tolerance of each cell must exceed the sum of LIDAR point determination errors (relative/internal positioning error, post-processing error.

If the aim is to identify changes in the construction class, a unit cell between 0.50 meters and 1.00 meters will be used, respectively a tolerance of height differences of at least 2 meters.

For ground change detection, only LIDAR point clouds with ground points will be used. For a better result, the user can choose the thematic classes that will be included in the analysis of landscape changes. In this case, the LIDAR point files will need to be classified before.

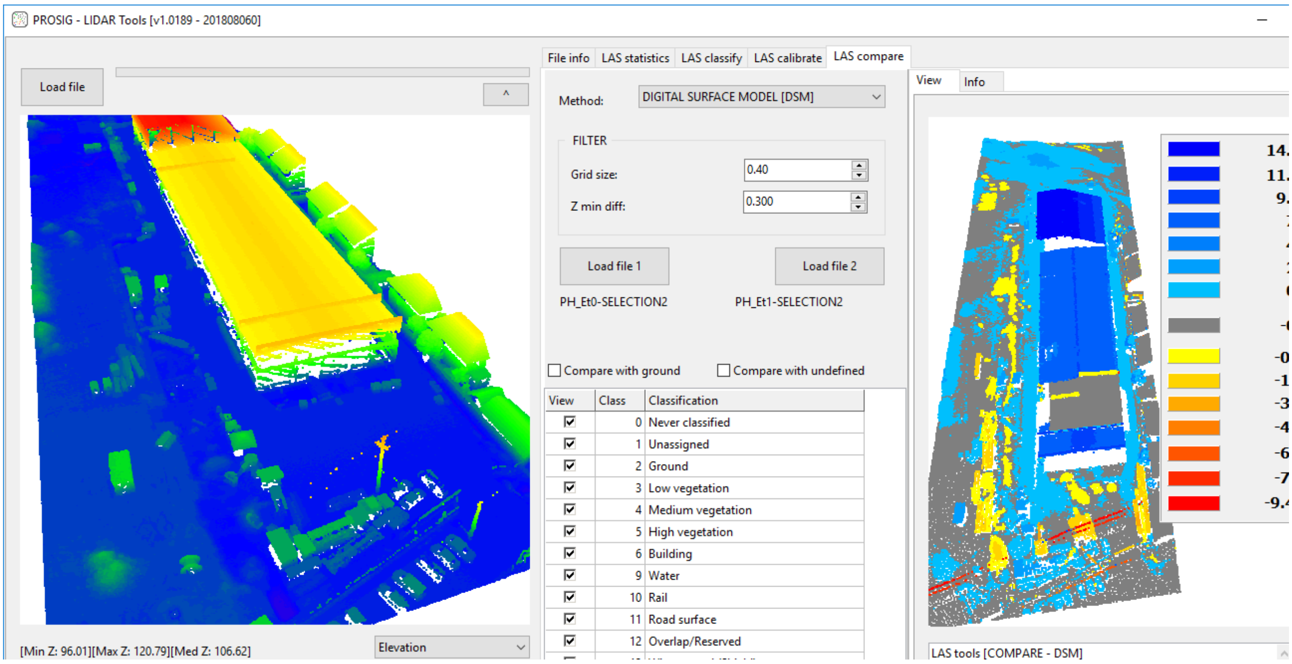

Fig. 5 Graphical representation of the differences between two point clouds

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At the end of the experimental results, it was found that the previously made assumption is true. In conclusion, by parameterizing the tolerance factor, landscape changes in certain classes of objects will be highlighted.

The LidarTools application, through the LasCompare function, performs the comparison between two point clouds both on each individual class and on all classes simultaneously or without taking them into account. The results are conclusive and easy to understand, as seen in figure 5.

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