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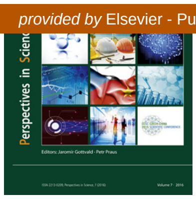

3D documentation of outcrop by laser scanner — Filtration of vegetation[☆]

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Summary This work deals with separation of vegetation from 3D data acquired by Terrestrial Laser Scanning for detecting more complex geological structures. Separation of vegetation is not an easy task. In many cases, the outcrop is not clear and the vegetation outgrows the outcrop. Therefore the separation of vegetation from 3D data is a task which requires adjustment of algorithms from image processing and remote sensing. By using cluster analysis and analysis of spectral behaviour we can detect vegetation from the rest of the scene and erase these points from the scene for detection of geological structures.

Introduction

LASER scanning systems (terrestrial or aerial) together with digital photogrammetry or SAR interferometry belong nowadays to commonly used techniques of land surface description. The number of their applications increases alongside with the price affordability of these devices. In the field of geosciences, in connection with Terrestrial Laser Scanning (TLS) or Lidar (Light Detection And Ranging), 3D computer visualisation outcrops have started to be created, commonly referred to as a DOM — Digital Outcrop Model (Bellian et al., 2005; Gigli and Casagli, 2011) or as a VO — Virtual Outcrop (McCaffrey et al., 2005). Lidar is an established method for rapidly obtaining three-dimensional geometry of outcrop, with unparalleled point density and precision (Buckley et al., 2013).

In the year 2000, Bryant et al. (2000) published their work focused on the production of DOM for the purposes of petroleum industry where the advantages of 3D computer visualisation outcrops were demonstrated. With the increasing popularity of GPS, total station, digital photographs and Lidar, other works dedicated to this topic emerged (McCaffrey et al., 2005; Hodgetts, 2013). For example, Slob et al. (2005) used Lidar in civil and mining engineering works dealing with rock masses which require a good understanding of discontinuities (joints, faults, bedding) in the rock

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mass. Consequently, many authors tried to extract structural elements from a thoroughly created 3D outcrop through semi-automatic or automatic detection.

Gigli and Casagli (2011) attempted to create semi-automatic extraction of ten parameters for the quantitative description of discontinuities in rock masses (orientation, spacing, persistence, roughness, wall strength, aperture, filling, seepage, number of sets, and block size) for the purposes of engineering geology. For an automatic identification of discontinuities at a granite quarry, Deliormanli et al. (2014) used Lidar as well as optical methods. Buckley et al. (2013) tried to use hyperspectral imaging not only for identification of structural elements, but also for mineral composition. Hartzell et al. (2014) made a similar effort by using radiometrically calibrated TLS for a complex description of outcrops. These efforts led to the development of specific tools or software: i.e. Vulcan; Surpac; 3DM analyst; 3DGeomec (Gigli and Casagli, 2011).

Lidar — advantages and disadvantages

Nowadays, the application of Lidar is becoming still more and more popular in geological sciences. It is a powerful device offering a lot of advantages for the collection of terrain data. Nonetheless, we agree with Hodgetts (2013) that Lidar will not replace traditional fieldwork and fieldtrips.

According to a number of authors (Gigli and Casagli, 2011; Slob et al., 2005; Hotgetts et al., 2004), the advantages of Lidar are: the possibility to collect data from otherwise inaccessible areas; minimum safety risk; virtual viewpoints — being able to view the data from many different angles; the possibility to analyse outcrops in the office; increased sample size — as it obtains data from every part of the outcrop; generation of new attributes — it records attributes which can be otherwise overlooked in the terrain; rapid data collection — 10’s to 100’s thousands of points per second; improved use of fieldwork time; it enables more objective description of the outcrop.

Among the disadvantages, we find the following: unhandiness of the device due to its heavy weight; poor battery life and its long charging time. When scanning, vegetation is a sort of a handicap, as it covers the view of the outcrop. Another disadvantage can be seen in a large number of data which may be difficult to process and interrogate (Hotgetts et al., 2004).

Aim of the work

The above-stated procedures are demonstrated by the authors merely on the outcrops with simple structural terraces. In most of the works, DOM of sedimentary rocks with sub horizontal folds or monoclines were created. None of the authors (Bellian et al., 2005; Gigli and Casagli, 2011; McCaffrey et al., 2005; Buckley et al., 2013; Bryant et al., 2000; Hodgetts, 2013; Slob et al., 2005; Deliormanli et al., 2014; Hartzell et al., 2014; Hotgetts et al., 2004) has carried out an extraction and detection of the structural elements on the outcrops of folded sedimentary rocks. None of them has either published a work demonstrated on the outcrops of tectonically affected metamorphic rocks. Therefore our second goal is to develop a semi-automatic detection system of the structural terraces working also in the difficult geological conditions. Before we can proceed to the detection itself, we need to solve the problem of separation of vegetation from the data cloud. Our article deals with this problem.

Methodology

3D scans were obtained using a Stonex X300. It is a compact 3D scanner with a pair of cameras for capturing RGB scene and a 2.5—300 m range laser beam. Stonex X300 enables to scan in the horizontal range of 360° and vertical range of 90°. Its big advantage is high precision of 6—40 mm and high scanning speed of 40,000 points a second.

The basic principle of scanning outcrops is choosing the number of viewpoints and their position. We try to place the viewpoints in such a way so there will not emerge blind spots in the final data cloud caused by the shades from vegetation or from the profile outcrop. Then the targets are placed, serving for mutual connection of point clouds from the viewpoints.

The processing of points into a single data cloud was carried out in the program Stonex Reconstructor which enables the connection of the individual viewpoints into one viewpoint based on the targets, and exporting them to various formats. In this work, we used export to format x3d which is from the xml language family and which enables easy processing in Python language. To compile software for vegetation processing, we used OpenCV and scikit in Python language.

Separation of vegetation

The separation of vegetation is one of the first problematic tasks when working with a Terrestrial Laser Scanner. The vegetation often overlaps the scanned area and causes problems with the automatic processing of the point cloud. The correct removal of vegetation creates the basis for subsequent data processing. Many authors (Bellian et al., 2005; Gigli and Casagli, 2011; McCaffrey et al., 2005; Buckley et al., 2013; Bryant et al., 2000; Hodgetts, 2013; Slob et al., 2005; Deliormanli et al., 2014; Hartzell et al., 2014; Hotgetts et al., 2004) describing vegetation removal from 3D data indicate examples in which the vegetation, mainly trees, do not overlap the scanned area. Those are often individual trees located in front of the quarry wall or outcrop. In such cases, the separation of vegetation is based on the distance from the quarry wall and the manual removal is quite easy because the points representing the vegetation are simply cut out or erased from the point cloud. With automated vegetation removal in such easy cases, assessing the distance of points from the furthest points in the direction of measurement is used.

In our work, where we are trying to create a procedure and software for general use, it is necessary to think about the separation of vegetation in the most difficult locations against the geological outcrop. The vegetation often overgrows the outcrop (Fig. 1) or the trees and bushes grow directly on the rock. Thus, separation of vegetation by using distance based filters which were applied in the simple

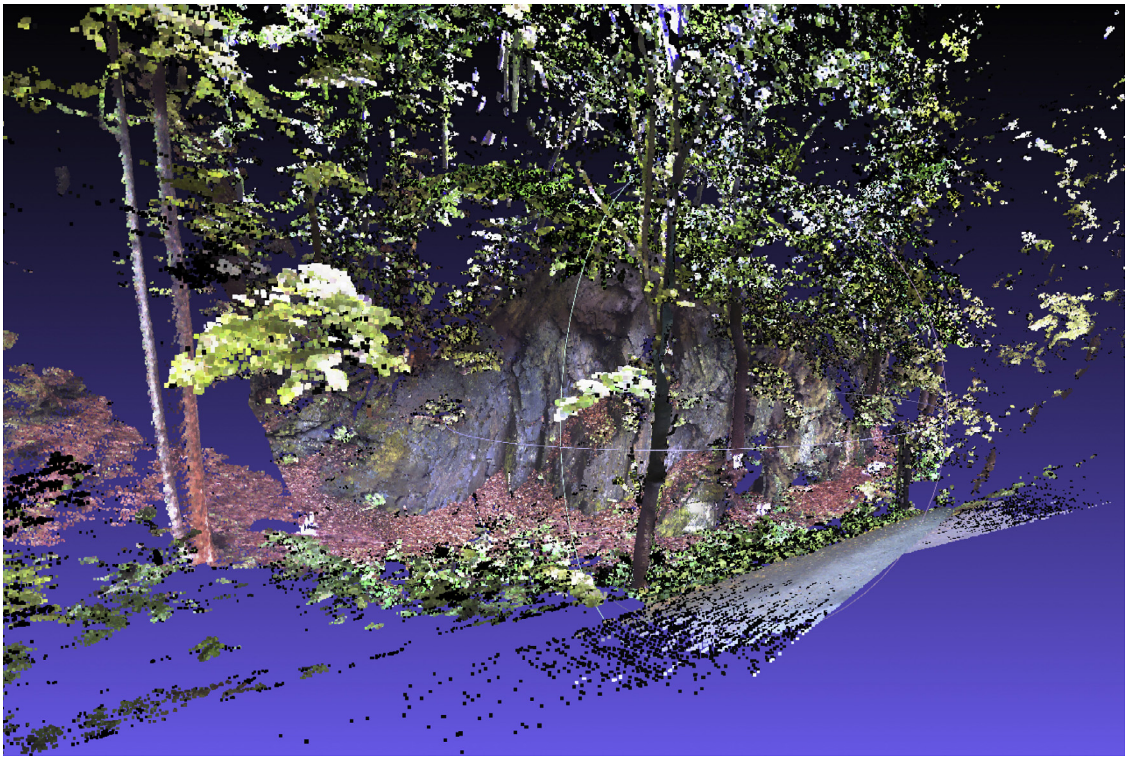

Figure 1 Point cloud with RGB colour.

cases, is not possible. Distance based filters would cause a large number of erased points which belong to the outcrop.

In our work, we are trying to use procedures enabling to use automatic vegetation removal in the most general terms (Fig. 1). Our solution uses object classification of the image from remote sensing.

Above the surface, trees and bushes basically consist of stems, branches and leaves. It is necessary to find these particular parts automatically in the point cloud and erase them. One of the most logical ways for detecting stems and branches in the point cloud is using edge filters, in our case Canny filter. When processing 3D data, the absence of common algorithms of image processing is a big problem.

When using common algorithms, it is necessary to convert 3D data to 2.5D data. Converting data from 3D to 2.5D by using Terrestrial Laser Scanning with more viewpoints can cause a partial loss of information due to an overlap or point of view when creating a 2.5D scene. We have designed a procedure for removing these effects. By using a simple pattern we go through the point cloud and create N-scenes to which we can apply Canny filter.

At first, points representing leaves and vegetation are removed from the point cloud. The points are classified on the basis of their spectral behaviour in the visible spectrum. We can use per-pixel classifier (Fig. 2). In our example, we have one class in which we have defined statistic traits, and we compare these figures with values in each pixel. The excluded class of removed points contains parts of vegetation like leaves and grass. By removing this class we get clearer data for further processing. However, this method does not include spatial and density characteristics.

By the use of DBSCAN algorithm (Fig. 3) we can detect clusters with high density and spatial proximity. By means of DBSCAN, clusters separated into categories and outliers are created (Fig. 3). These clusters are very likely to represent vegetation and we can remove them from the point cloud. The combination of spectral behaviour and spatial characteristics of objects gives us better and more accurate results of vegetation classification than the results we get from using only spectral characteristics.

Each point is only a part of a bigger whole; therefore it is necessary to choose the same method when doing detection. The goal is not a thorough removal of all points representing vegetation, but achieving the best possible results with the highest precision of detection.

Stems and branches are also a part of vegetation. Branch detection is quite difficult because a 3D scanner is not able to detect the whole branch. We remove small branches in the step where we detect clusters representing leaves. These branches are located inside of the clusters and due to this spatial characteristic it is easy to detect and remove them. In 3D point cloud, thick branches behave like stems.

For stem detection in 3D point cloud we use systematic scene detection and 2.5D image generation. Generated images can be then processed by common edge detection algorithms of image processing. Canny filter has given us the best results and enabled an accurate edge detection of stems.

In the first step, the algorithm creates a box with minimum and maximum coordinates for all axes. In the second step, we cut 3D point cloud into horizontal cuts with 0.5 m step. Horizontal cuts are then transformed into images. Generated images comprise XY data in the required cutting

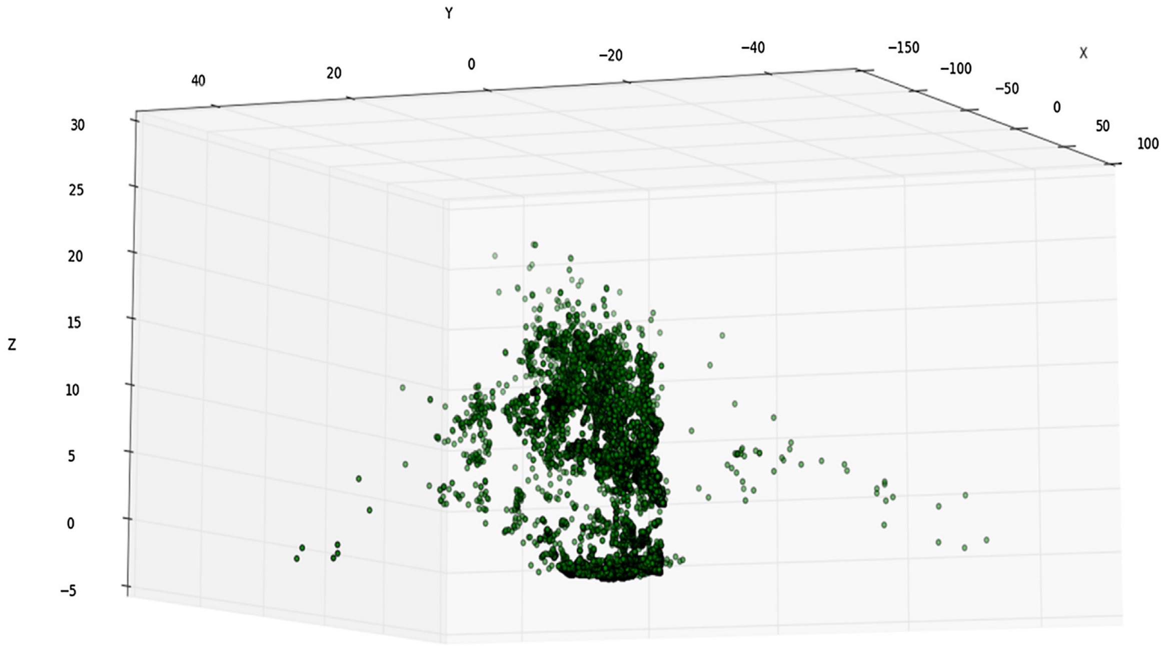

Figure 2 Pixels separation based on the spectral value.

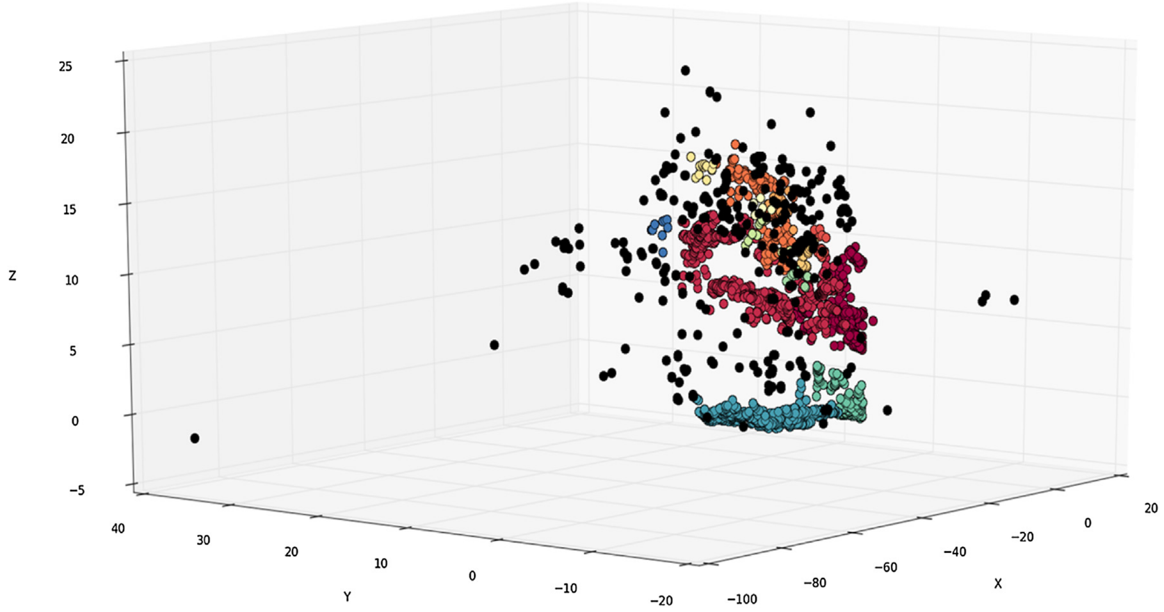

Figure 3 DBSCAN cluster analysis.

height. In this case, tree stems behave like ellipses — if the stem is scanned from several viewpoints, or like a part of an ellipse — if the stem is scanned from a single viewpoint. Then we find the edge with the use of Canny filter. We can calculate the approximate axes of the ellipse. From the centre of gravity we generate points for the whole ellipse. The same procedure is applied for all cuts. We use the resulting centres of ellipses like cluster centres for k-means function which detects all points in the cluster in the proximity of this centre. In this way it is possible to detect tree stems in 3D point cloud and remove them.

Conclusion

Separation of vegetation is not a trivial task. It is important to modify the already existing procedures and adapt them to a local situation. Our solution tries to be adaptive and also enables the removal of vegetation in general terms. We do not use only the positions of points from the outcrop but we implement classifiers from Remote Sensing and methods of image processing. We are able to remove vegetation that interferes with outcrop by combining these disciplines. Our goal is not only to process adjusted quarry walls with a simple form of vegetation position, but also to recognise complex geological structures of current outcrops which are often a part of forest and other vegetation and it is not possible to completely remove this vegetation from the direction of scanning. Generally, the 3D data processing is computationally demanding and algorithms that are used for image processing do not allow the processing of 3D data. Modification of these algorithms and their right combination with procedures of remote sensing allows the processing of 3D point cloud.

Conflict of interest

The authors declare that there is no conflict of interest.

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