Visualization of Woody Vegetation Changes in 3D Point Clouds

Zuzana Fialová[1], Radim Klepárník[2], Jozef Sedláček[2]

[1]The Department of Landscape Planning, Mendel University, Brno/Czech Republic · kontakt@zuzanafialova.cz
[2]The Department of Landscape Planning, Mendel University, Brno/Czech Republic

Abstract: This paper tests a series of point clouds created between 2019 – 2021 to capture changes in the vegetation structure of a particular area and subsequently to visualize possible future scenarios using Unreal engine. The case-study area has encountered a significant decline of pine species, therefore a future scenario without any pines is proposed. The point cloud is used as an alternative to the landscape model, which is created from scratch. Any proposed changes in the landscape were made directly in the point cloud. The advantage of this procedure is that the landscape is captured in the current state with a relatively good amount of detail and allows the observer to choose any viewpoint. The game engine software is used to test various light and atmospheric conditions.

Keywords: Point cloud, landscape model, UAV, Unreal Engine

1 Introduction

Monitoring vegetation changes using aerial surveys has a long history. Aerial images, orthophoto maps and satellite images are most common. In environmental planning, visualizations are an established technique for displaying a previous or a proposed state (BISHOP & LANGE 2005, SCHROTH 2007), but there is also need for objectivity and accuracy. Spielhofer et al. (2017) suggest using point clouds for representing changes in landscapes. The technically realistic visualization of landscape changes and its representation using a laser scanning 3D point cloud model have been used as the stimulus for landscape preference studies (WISSEN HAYEK et al. 2019), and in the design process (URECH et al. 2020). “The visual expression of point cloud models reveals the physical form of the environment. It exposes aesthetic considerations that enable the management of the wild, cultural, or urban character of the landscape.” (Ibid.) Comparing photogrammetric point clouds and mesh representations in landscape change assessments are also a viable method (SEDLÁČEK & KLEPÁRNÍK 2019).

The aim of this study was to verify the possible use of point clouds for making an accurate visual comparison of vegetation changes in a particular area. Over a long-term observation with NDVI images, changes in vegetation were observed in the area around the Pond Chateau. The need to present possible future scenarios of vegetation decline to experts and stakeholders opened the need of determining possible tools for making accurate visualizations. The photogrammetric process, like the laser scanning process, generates 3D point clouds which can be compared in a series of visualizations and provide users information about changes in volume, changes of visibility of the area or changes of insolation in areas. While it is possible to use both methods, UAV photogrammetry was chosen for this study not only because of its availability and cost effectiveness, but also because it includes visual information of objects (not only their position).

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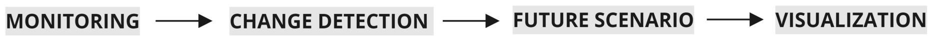

Fig. 1: The general thought process of the case study

1.1 Point Cloud

Point clouds are digital 3D representations of a physical object represented by points – geometric primitives with xyz coordinates and information about RGB or intensity (GROSS & PFISTER 2007). In 3D digital graphics, a model displayed as a set of points is called a surfel model, where a surfel is a geometric primitive; a sphere or rectangle on which RGB or a colour ramp representing height (the Z coordinate respectively) can be rendered. Point clouds can be obtained by various techniques, e. g. LiDAR (LiDAR point clouds) or photogrammetry (photogrammetric point clouds) from the ground or from an aerial survey. Lidar data are more accurate than photogrammetric and contain information about intensity (strength of a returned laser beam), but acquisition is relatively expensive. To transfer colour information to data, it must be colorized from a photograph (or aerial photograph).

A photogrammetric point cloud is obtained from a photogrammetric process, where georeferenced photographs are precursors, acquisition is cheaper and there is an RGB value as an intrinsic value. The level of accuracy is lower and depends on the quality of the light condition. Fewer points might be generated in shady locations.

There are several programs that enable generating point clouds, such as Pix4D (source: www.pix4d.com), DroneDeploy (source: www.dronedeploy.com), Capturing reality (source: www.capturingreality.com), and Agisoft Photoscan (source: www.agisoft.com). Interesting, free alternatives include WebODM (source: www.opendronemap.org/webodm/) and VisualSFM (source: www.ccwu.me/vsfm). Point clouds in a web browser can be viewed using WebGL and allow users to view data in 3D, resize points, or measure distances and volumes (DISCHER et al. 2018). Known services are, for example, Pointbox (source: www.pointbox.xyz), Voxxlr (source: www.voxxlr.com) and Sketchfab (source: www.sketchfab.com).

Even though point clouds represent the surface we are scanning, they are only discrete points of the surface and do not provide any information about neighbouring points or connectivity. This discrete character of point clouds presents a processing problem for most GIS Software, which is the reason why they are mostly processed into 3D meshes or interpolated to raster datasets. Point clouds therefore do not have the character of a functional surface, such as raster datasets or meshes, which is why it is impossible to perform geoprocessing analyses, such as a slope analysis or a visibility analysis. On the other hand, this aspect, which presents a disadvantage from the geoprocessing point of view, presents an advantage with respect to visualization.

2 Materials and Methods

2.1 Location

The study took place by the Pond Chateau, a site within the designed landscape of the Lednice-Valtice complex (Czechia). The complex has been a UNESCO World heritage since 1996 and consists of several historical follies spread throughout the countryside. This area consists of a landscaped terrain surrounding the Chateau and occupies approximately 14 ha on the northern bank of The Middle Pond. The terrain is quite steep with elevation of 30 m. The landscaping follows the principles of an English gardening style, as defined by Lancelot Brown, e. g. by planting domestic and exotic trees in belts and clumps and creating visual connections between objects. Among the most used species are oaks, pines, and honey locusts.

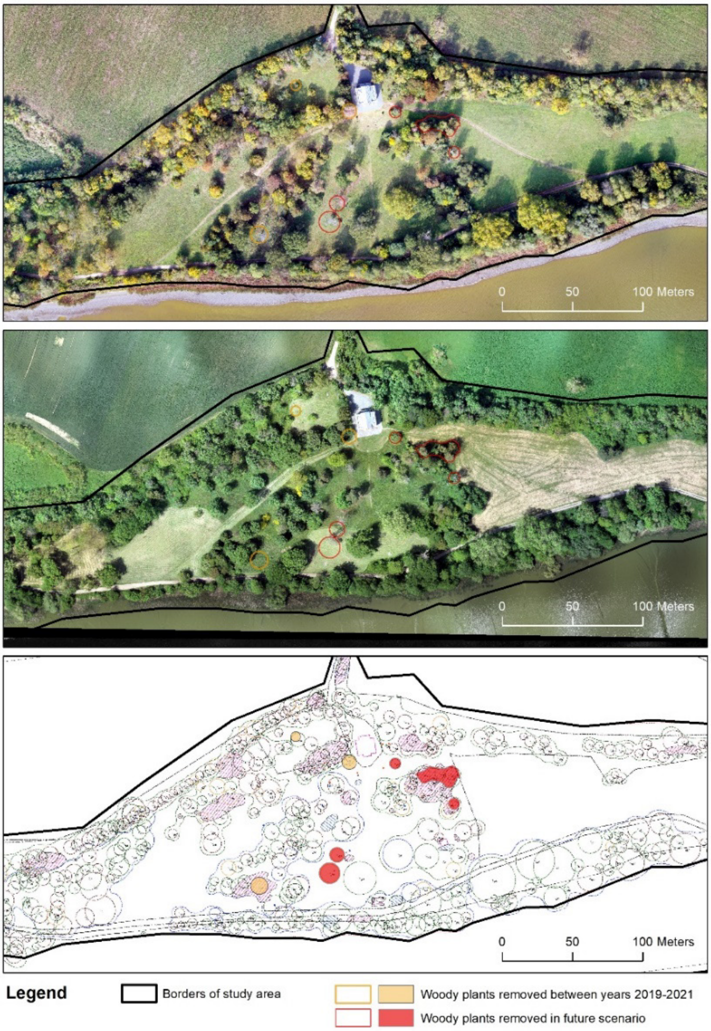

Fig. 2: A comparison of the orthomosaic of the model area from 2019 and 2021 and a vegetation scheme. Woody plants removed between 2019-2021 are marked orange; woody plants removed in the future scenario (based on the NDVI images) are red.

Over the past few years, the vegetation near the Pond Chateau has been changing. The decline of pine species has been observed since October 2019, not only in multispectral NDVI images, but it is also noticeable in-situ with needle abscission in several trees. Since the value of the vegetation in cultivated landscapes is both ecological and cultural, it is vital to show the impact of these changes to the stakeholders.

2.2 Method

After the surveys were conducted and the main goal of the visualizations was defined, it was decided to use Reality Capture SW to process the collected data and generate the point clouds. Because this SW offers good tools for editing point clouds it was determined as a good tool to create the future scenario. While most of the SW allows for displaying and rendering point cloud scenes, Unreal Engine was used because of its ability to adjust atmospheric conditions.

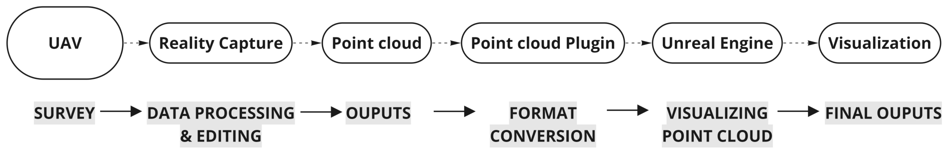

Fig. 3: A schematic visualization of the workflow

Data acquisition

As mentioned above, the location has been observed since 2019 using NDVI images. For the survey, we used a UAV DJI Matrice 210 with an x4S camera. The survey was conducted four times between October 2019 and June 2021 in automatic flight mode using the Pix4d mobile App. The flight mission was grid and linear and occurred over two consecutive nadir flights. The height (above ground level – AGL) was set at 80 m and 60 m respectively. The overall area covered was ~ 26 ha. For better accuracy, we used 10 ground control points, measured with an RTK single station receiver. In the end, only data from 2019 and 2021 were selected for visualization, since they showed the best quality point clouds, and they are far apart to show visible changes.

Table 1: Specifics of individual flight missions

Date	Mission type	Number of Calibrated Images	Number of 3D Densified Points	Avg. Ground Sampling Distance [cm/pixel]	Avg. Point Density [points/ m3]	Time for Densification
04/2019	Grid	769	258460760	2.85	471.9	04h:33m:51s
03/2020	Grid/ Linear	477	38096669	2.63	177.84	00h:43m:59s
10/2020	Linear	271	472006824	2.68	1243.15	04h:45m:31s
01/2021	Grid	578	50503334	2.82	71	01h:01m:26s

Data processing

The aerial photographs were processed in Pix4d Mapper (source: www.pix4d.com). The point cloud was processed in Capturing Reality software (source: www.capturingreality.com). The outputs were a dense point cloud in an XYZ format containing 80 million points. Adjusting point clouds is possible in any program that can display a point cloud and contains at least the basic form of a coordinate system, assuming the data has been adjusted for the software or there is a plugin installed (e. g. Point Cloud Visualizer (source: https://jakubuhlik.com) for Blender). ArcScene (source: Esri www.arcgis.com), AutoCad (source: Autodesk www.autodesk.com), Blender (source: www.blender.org) and Cloud Compare (source: www.cloudcompare.org) differ only in their functionalities for point cloud editing or the in degree of difficulty in setting the size and coordinates of objects. In our case the editing of a point cloud for the future scenario (removing woody plants in a deteriorating state) was also created in Capturing Reality to limit transfer between different software.

Visualizing point cloud

Some of the above-mentioned SW lacks the ability to apply atmosphere effects on the point cloud. Therefore, it was decided to use the Unreal 4.24.3 game engine (Epic games, www.unrealengine.com), which can draw shadows and light on the point cloud. Since version 24.5 was released, it imports the point cloud natively via its built-in Point cloud Plugin (Epic games, www.unrealengine.com) though the functionalities are same. All point clouds (2019, 2021 and the future scenario) were uploaded into Unreal and aligned. A cinematic camera was placed on location to capture the scene from different observation points. The visualization in this case study is dynamic and allows for the selection of the location using the position of the camera. In addition, light and atmosphere effect were adjusted to imitate different times of day using lighting and color adjustment. Each capture was exported via a high-resolution screenshot.

3 Results

This section discusses the possibilities of the above-mentioned process based on the case study. After completing the series of visualizations, some advantages, and limitations of the use of point clouds, their editing and visualizing in Unreal engine were discussed. Among the advantages are data availability, a high degree of realism, accuracy, the possibility to edit variables and the ability to adjust dynamic visualization. The limitations include hard-to-capture objects, seasonal dependency, lack of foreground detail and limited editability.

3.1 Advantages

Data availability. The use of aerial photogrammetry in combination with UAV allows us to get an up-to-date 3D representation of the landscape in a point cloud and we do not have to rely on any other party's data.

High degree of realism. Point clouds represent only space samples and can capture complex shapes that are not possible when converted into mesh. In the case of objects with complex geometries such as plants, the topology is not simplified, because point clouds have no topology. The high degree of realism is also based on the medium from which the point cloud is created – photography. The photographs capture the space and the objects in it under the light conditions that prevail in the location at a specific time.

Accuracy. Using point clouds eliminates needing to model the scene. A real-world scene is captured in detail, with lighting and objects corresponding to the time of shooting. Such environment cannot be achieved by conventional means of visualizing. It is possible to adjust lighting and vegetation season by changing the time and date of shooting.

Visualization variables. Adjusting the variables consists of varying degrees in setting the lighting or atmospheric conditions, which are reflected in the overall tone of the visualization.

Visualization dynamics. Point clouds are fully implemented in the digital environment, so it is possible to dynamically change the position and parameters of the camera. It is possible to create a static or animated visualization. The ability to move in space allows for viewing in either VR or WebGL.

Fig. 4: This series of images shows a scene with the object rendered at different times of day

3.2 Limitations

Hard-to-capture objects. For any object to be displayed in a point cloud, it must be recognizable by the SW in at least two photos. Some objects are hard to capture, either because they are too small (such as small branches in winter or power lines) or because they are hidden by other objects or are not differentiated much in colour (e. g., tree trunks, objects in the dark, shady areas).

Dependency on the season and weather. As written above, photos used for photogrammetry are taken at a specific time. Therefore, a point cloud created from them represents the landscape at a specific time and in a specific season. If we want to change the time of day, we might be able to do so by changing the colour temperature and by casting different shadows. But if we want to depict different seasons, we need to take separate pictures and create a new point cloud. However, this limitation is mostly compensated for by the availability of data, which generally depends on time we can spend in the field.

Fig. 5: A series of 5 scenes shows changes in vegetation; each scene is consecutively displayed in 2019, 2021 and in the future scenario (an edited point cloud without any selected vegetation)

Lack of foreground detail. Even if we use a game engine for processing a point cloud, there is still a limited level of foreground detail (this might also be due to lower computer performance). This is visible especially when rendering visualizations from the observer's point of view and not an aerial view. There are some sampling techniques which can attenuate some irregularities (e. g. BELLO et al. 2020, DIMITROV & GOLPARVAR-FARD 2015), but it is still questionable how the model imperfections might change the perception of a concept when shown to the public.

Limited editability. In comparison to mesh (polygonal modelling), the editability of a point cloud is more complicated. As can be seen in Figure 5, some gaps appear when removing parts of a point cloud. While working with mesh enables the user to easily close such gaps, a point cloud requires the additional use of mesh or algorithms for filling in gaps in point clouds (e. g. GAI et al. 2019, WANG & OLIVEIRA 2007).

4 Conclusion and Outlook

This paper presents how to use an up-to-date point cloud representation of a landscape from UAV photogrammetry for visualizing changes in vegetation. This can be used not only for the past, but also future changes. It also presents what some of the basic advantages and limitations of the process are. This process is still demanding due to the need to capture more seasons and times or manually removing vegetation for the future scenario. In the future, this might be simplified by automatising some data processing stages or by using deep learning for performing classification or segmentation (GRILLI et al. 2017) on landscape point clouds. Some further usability might include a combination with augmented or virtual reality (AR/VR), which improves the interaction between the observer and the model.

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