# Testing Dense Point Clouds from UAV Surveys for Landscape Visualizations

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**Abstract:** The article deals with the use of point clouds datasets from UAV surveys for visualization of changes in landscape scenery. The method aims for non-biased visualization of architectural proposals without any artistic effects and should be used as a basis for decision making in the area concerned. The article proposes our workflow and tests it against photo simulation and mesh-based 3D modeling. The aim is to test, whether there are significant differences between the methods and verify, whether the process is viable.

**Keywords:** Point cloud, landscape scenery, visualization, UAV

## 1 Introduction

The aim of this experiment was to use point clouds for accurate realistic visualization, enabling comparison of the current and proposed state, which will serve the stakeholders or the public for consideration of the proposal. The purpose is to visualize landscape interventions that might be essential for perceiving the landscape, such as technical infrastructure in significant landscape scenery or in viewpoints. This model will then serve the public or stakeholders as a relevant basis for discussion on the impact of the development on landscape. The purpose is not an artistic design of the proposal but its representation in actual proportions. The motivation for the experiment was the massive expansion of UAV capable of automatic flight and expansion of services that enable the processing of images from the area and the generation of a 3D model.

In the field of environmental planning, visualization is a well-established technique for displaying the proposed state (BISHOP & LANGE 2005; DOWNES & LANGE 2015; SCHROTH, 2007). For these purposes the following terms are used: 'landscape visualization' (ERVIN & HASBROUCK 2001), 'environmental visualization' (BISHOP & LANGE 2005) or 'geovisualization' (DYKES 2005). The term 'landscape visualization' is generally used for computer-generated landscape view in perspective (ERVIN & HASBROUCK 2001).

The issue of credibility of visualization used to be linked with environmental impact assessment and landscape character assessment but in recent years it has gained importance in the field of architectural competitions as well. Using marketing methods to create visualizations for the purpose of selling an architectural design, as well as visualizing a landscape intervention, introduces an ethical dimension into the issue of visualization (REKITTKE & PAAR 2018). According to Sheppard (SHEPPARD 2005), it is important to set ethical rules for creating visualizations in order to avoid misleading practices that may affect the acceptance of the plan.

### 1.1 Point Cloud as a Digital Twin

3D point clouds allow for a discrete representation of the real world. They can be obtained by various techniques, e. g. LiDAR or photogrammetry from the ground or from an aerial

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survey. Cloud points obtained by the photogrammetric method are quite affordable, unlike expensive LiDAR scanners. There are a number of programs that create point clouds such as Pix4D, DroneDeploy, Autodesk Capture, or Agisoft Photoscan. Interesting and free alternatives are WebODM or VisualSFM.

Point clouds are meant to represent the surface we are scanning. In fact, they are only samples of surface – discrete points that do not provide information about neighbouring points or connectivity. Points only bear the information about their XYZ and surface reflectance properties (e. g. RGB color), (GROSS & PFISTER 2007).

In 3D digital graphics, a point is displayed as a surfel. Surfel is a geometric primitive; a sphere or a rectangle, on which RGB color or a color ramp representing height (Z coordinate respectively) can be rendered. Geometric primitives can be adjusted upon user needs, depending on point cloud density. The denser they are, the smaller they can be rendered. 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. (SÖREN et al. 2018) Known services are, for example, LidarView, Potree or Voxxlr.

The 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 slope analysis or visibility analysis. On the other hand, this aspect presenting a disadvantage from the geoprocessing point of view, presents an advantage with respect to visualization.

The density of pixels ensures space rendering close to reality, which may often be better than mesh or raster display. Conversion of complex objects, such as vegetation, results in obvious distortion or excessive simplification. Point clouds also allow for seeing through the vegetation, which is a feature that mesh-based objects do not allow for.

Dense point clouds supply a scene that enables modifications, such as insertion or removal of objects. The advantage of this method compared to photomontages is that it allows for choosing a point of observation anywhere within the scene while obtaining unbiased visualisation and without the necessity to perform difficult re-modelling of the entire scene.

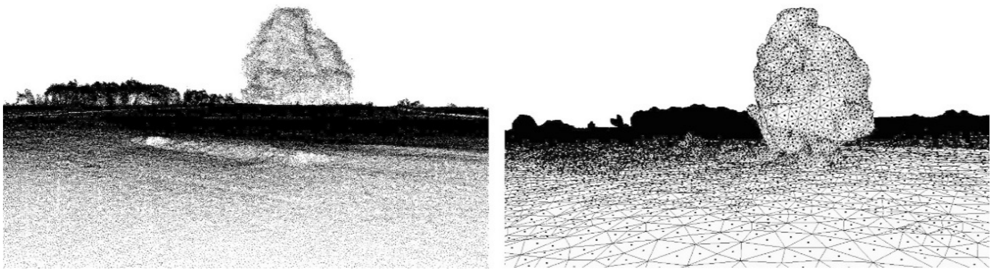

**Fig. 1:** Point cloud representation (left) and mesh-based representation (right) in black and white graphics that highlights the difference between geometries. Point clouds are simple discrete points that can be seen through, whereas mesh is a surface.

UAV Photogrammetry works with high precision data with dense point cloud with the density of 100 points per meter, therefore the whole scene is highly accurate. If the proper 3D reference points are provided with the use of RTK GNSS ground stations, it is possible to obtain a centimetre variance (GERKE 2018).

## 2 Materials and Methods

As the model area, we selected the historical composed landscape in the Lednice-Valtice Area. As an assumed intervention, the proposal of high-voltage construction was chosen. To capture the landscape scene, a photograph (and 360° spherical photograph), a mesh-based 3D model and a point cloud 3D model were used. We then tested these three methods using different display methods, like a still image from the same site of the current state, 360° photos, an interactive mesh-based representation in Sketchfab, and an interactive point cloud in PointBox. The outputs were presented in three sets: set No.1 contained static sectoral images of landscape shown as a photograph, as a point cloud and as a mesh-based object displayed as a static image from the same viewpoint. Set No.2 contained interactive panoramic image, and interactive 3D models with point clouds and mesh-based object. Set No 3. Used the same display method, but the new object was added into the scene.

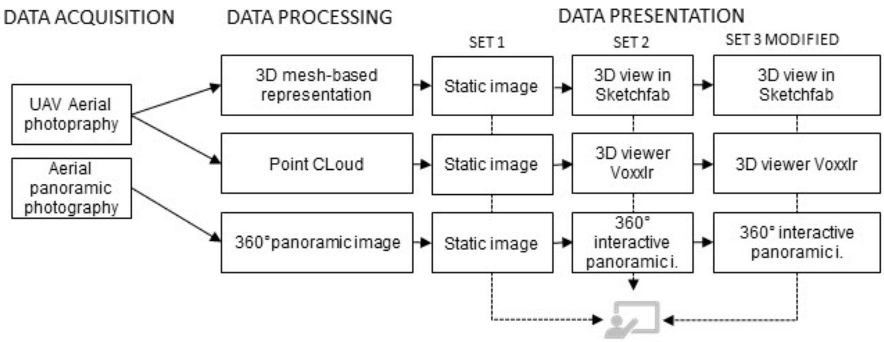


**Fig. 2:** The diagram shows basic steps of data acquisition and processing and the form of presentation

Individual sets were verified by means of an online questionnaire. Geometric accuracy of visualization was set as our main criterion. Proposed object is placed in a real-world point cloud twin; therefore its proportions are not distorted in rendered views. This approach is closely connected to the validity criterion of visualisation referred to by SHEPHERD (2005) as the match rate of the test result compared against the actual result. Should the observers find the object of visualization unsatisfactory, it is highly probable that they would not find the real object acceptable either. Some authors (BATES-BRKLJAC 2009) questioned the geographical and visual accuracy of visualization. According to their quantitative research, it had been found that the interviewee did not notice changes in the visualized object in an extent up to 15% of the geometry transformation of the object.

## 2.1 Data Acquisition and Processing

For the survey we used a UAV DJI Matrice 210 with x4S camera. The survey was performed in the automatic flight mode using Pix4d mobile App. The flight mission was double grid, which is better for 3D model outputs and is examined in two consecutive nadir flights. The flight level was set to 60 m, according to the app developer recommendation, which shrinks the size of the surveyed area. 936 aerial pictures were taken in three missions; the overall area covered was 10 ha. For better accuracy, we used 10 ground control points, measured with RTK single station receiver. The aerial photographs were processed in Pix4d Mapper. The outputs were dense point cloud in PLY format containing 80 million points. The surface reconstruction of point cloud to 3D based-mesh was processed in Pix4D Mapper and exported to OBJ file format.

With regard to their large size, the datasets had been reduced. The point cloud was reduced in Cloud Compare SW with Sub Sample tool and space method. This tool removes all points which are closer to each other than 10 cm. These measures decrease the file size by about 30 %. The reduction was processed to the extent where visual properties of the mesh and point cloud remained more or less the same. For Sketchfab presentation the mesh was reduced in Blender 3D SW by using Decimate Modifier, reducing its mesh vertices by 0.3 ratio resulting in the file size reduction from 75 MB to 27 MB. This vertices reduction does not cause noticeable changes in the appearance of the scene.

Photographs of the landscape were taken by Lumix 9 camera with 25 mm Lumix lenses using panoramic head and tripod. Another photograph was taken from aerial perspective using the same UAV, which was used for the survey. The photographs were stitched using Microsoft ICE image composition engine and the final interactive 360° photo was displayed using the Round.me web service.

## 2.2 Data Modification

All three forms of graphic representation were also modified so as to represent the proposed state. The proposed state visualizes the impact of high voltage electricity pylons built within the model area. This proposal was selected because this kind of impact is quite frequent and very invasive with regards to landscape scenery.

Mesh-based objects were processed in Blender SW. The 3D model of landscape and electric poles were imported as OBJ files with textures. The 3D model of landscape was set to absolute coordinates in order to keep the whole scene georeferenced. The pylons were aligned to the landscape model. Since the whole project was fictional, the positions of the pylons were chosen randomly. The entire scene was then exported as an OBJ file and uploaded to Sketchfab.

The point clouds were modified in Cloud Compare SW that allows point cloud modification and its grouping with mesh-based objects. In order to unite the representation of point cloud and mesh, the mesh was transformed to point representation with the same density.

It was important to keep the same position of the pylons in all the representations. This can be achieved differently in each representation. Cloud Compare enables setting the correct position in import with the tool Coordinate Shift. In photo simulation, we used rendered 3D mesh as a template. The model of landscape was rendered without pylons as a static image in JPEG file. The camera position was positioned to match the camera position of the photography in order to keep the view of render and photography the same. It was important for the first set, since it shows only a segment of the field of view. The rendered scene with the pylons was used for photomontage in the photography in the third set. For this purpose, it was rendered as a panoramic 360° image to better match the panoramic image of the real landscape. After matching, the rendered mesh was erased.

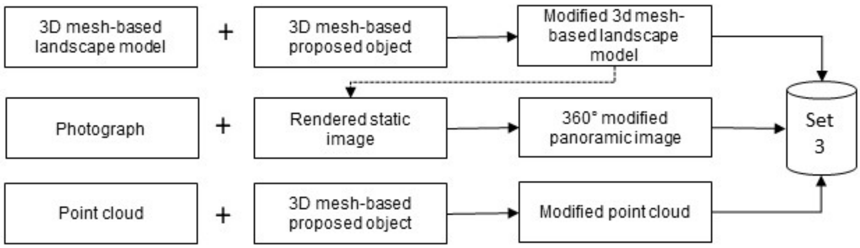


**Fig. 3:** This diagram shows the process of modification of 3d models and photograph

## 2.3 Survey

All three sets were presented via online services. The 360° photography was presented in Round.me web service. Sketchfab was selected for mesh and a platform called PointBox for Point cloud presentation. All services enable zooming and rotating. The Round.me does not allow for changing the position of the viewer. The 360° landscape panorama was selected to allow for a higher degree of interactivity than a still image and levelled the difference between mesh-based and point-cloud interactive viewing.

Variants were tested on three sets of images. The reference image was a photograph. Each set included 3 shots: photo, point cloud, and mesh-based model. The first set included a still image only. The second set enabled interactive viewing in 3D space in web services. The third set was identical to the second one with modified images with pylons replacing the original ones.

The questions were formulated as follows, only slightly changed according to the subject of each set:

1) Which of the three images do you think best reflects real space?
2) If the image you selected was rated 1, how would you rate the second-best slide using a 1-5 scale (1 being the positive and 5 being the negative end).
3) How would you rate the worst picture?
4) Which of the presented images do you find most interesting?

The survey does not have the ambition to provide a proper sociological study; its main aim was to obtain feedback from students of architecture, landscape architecture and disciplines involved in landscape management, and from colleagues working in the mentioned fields.

# 3 Results and Discussion

This chapter will be divided into three parts. The first part evaluates the efficiency of the whole process. The second part deals with the results of the online questionnaire and the third evaluates the possible improvement of the research.


**Fig. 4:** Set No. 1 (left) and set No. 3 (right). Set No. 1 contains static images that can be viewed in full screen mode. Images in set No. 3 can be zoomed and rotated. In the mesh based and point cloud model the viewpoint can be moved around (2.2 and 3.2). The images on the right show just a segment of the view that can be viewed within the survey.

## 3.1 Efficiency of the Workflow

At present there are many ways of obtaining very detailed 3D datasets of any area. Compared to LiDAR datasets or 3D meshes captured nationwide in certain time intervals and very often in the summer season, using the UAV has the advantage of the possibility to perform the survey in the season and under the conditions preferred by the user. In terms of vegetation, it is possible to create a model in different seasons, and in shorter intervals than those provided by the national agencies. A drawback of this technology is connected with state regulations, with most states regulating aerial work over built-up areas. This predetermines this method for use in open landscapes.

Data processing software is the most expensive item in the whole workflow, but the free tools mentioned in the introduction can be used for educational and non-commercial purposes. Viewing, presenting and manipulating data is easy and off-shelf products can be used. Restrictions are limited to browsers' capacity.

The advantage of landscape impact assessment in 3D is that it enables viewing from multiple angles without having to render the image again and insert it into a photo, which is a challenging process with uncertain results.

## 3.2 Survey Feedback

Set No. 1, static images, showed that a photograph is still considered the best medium to reflect real space (85 % of respondents) compared to models (15 % of respondents). In set No. 2, the interactive set, this difference was not so significant, with 66 % of respondents opting for panoramic photography compared to 33 % of respondents mentioning the model. Point cloud was considered the best by 20 % of respondents and mesh by 13 % of respondents. The rating of the second-best image was most often 2 (50 %), followed by 4 (30 %).

**Table 1:** Responses in online survey. The question No. 4 was in set No. 1 not relevant

| Question | Presentation method | SET No. 1 [% of responses] | SET No. 2 [% of responses] | SET No. 3 [% of responses] |
|---|---|---|---|---|
| **Q1: Which of the three images do you think best reflects real space?** | photograph | 84,6 | 68,4 | 63,2 |
| | mesh based model | 0 | 10,5 | 21,1 |
| | point cloud model | 15,4 | 21 | 15,8 |
| **Q4: Which of the presented images do you find most interestingß** | photograph | | 47,4 | 63,2 |
| | mesh based model | | 5,3 | 15,8 |
| | point cloud model | | 47,4 | 21,1 |

With the third set containing modified models and modified panorama, it was confirmed that the modified photography obtained the best rating (63 %), whereas models obtained 37 %. Point cloud and mesh had the same percentage (20 %). The second-best picture was rated 3 (48 %) and the worst image had rating 4 (37.5 %).

The results are based on 55 responses. 70 % of respondents were architects or landscape architects, 15 % from landscape related profession and 15 % other. 55 % respondents were university students, 30 % employed and 15 % high school students.

Although the conclusion of the survey cannot be interpolated to the entire society due to the fact that the survey does not cover a representative sample, the results show that photography and photorealistic visualisation respectively (Set 3) are still perceived as the best medium.

The other important result is that point clouds represent a viable alternative to mesh-based models. Among others, the Unreal Software, considered as possible point cloud renderer, can render all features in real time, and the option had been processed but the authors cannot share rendered results via online service. It is still promising as an VR alternative to online survey and worth of further testing.

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