Cave LIDAR data analysis

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Abstract

This report presents the analysis of point cloud data for the cave Vers Chez Le Brandt. The study involves working with meshes and point clouds to understand geometric properties of a given cave section.

1 Introduction

Point cloud and mesh analysis is a critical aspect of 3D data processing used in various applications such as computer graphics, geographic information systems, and scientific visualization. This report details the methodologies employed to analyze a few properties of LIDAR cave point cloud data.

2 Project

2.1 Data Visualization

The first step of our LIDAR cave data analysis is going to be data visualization. For this and most of our analysis we used python's library open3d which is used for working with point clouds. LIDAR data contains a lot of information, for us, the most important are going to be coordinates and colors, so we can easily visualize our cave system.

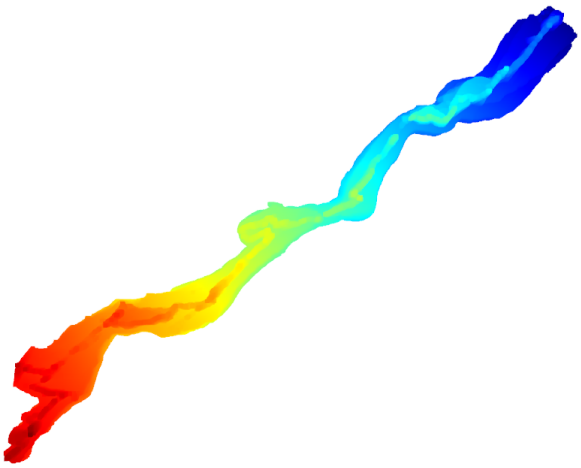

Figure 1: Whole cave visualization

The starting visualization on Figure 1 is without original colors and is in top down view.

2.2 Point Cloud Processing

Since the point cloud file is very large in size, we would require a lot of processing power to work on the whole cave. For that reason we will limit ourselves on a part of the cave in our analysis. For that we will need to crop the original point cloud.

2.2.1 Limiting the input size

To limit the input we first constructed minimal oriented bounding box, then we constructed a smaller box with the same center, which we translated to the section we will be analysing. We took all the points from point cloud which were in the translated bounding box.

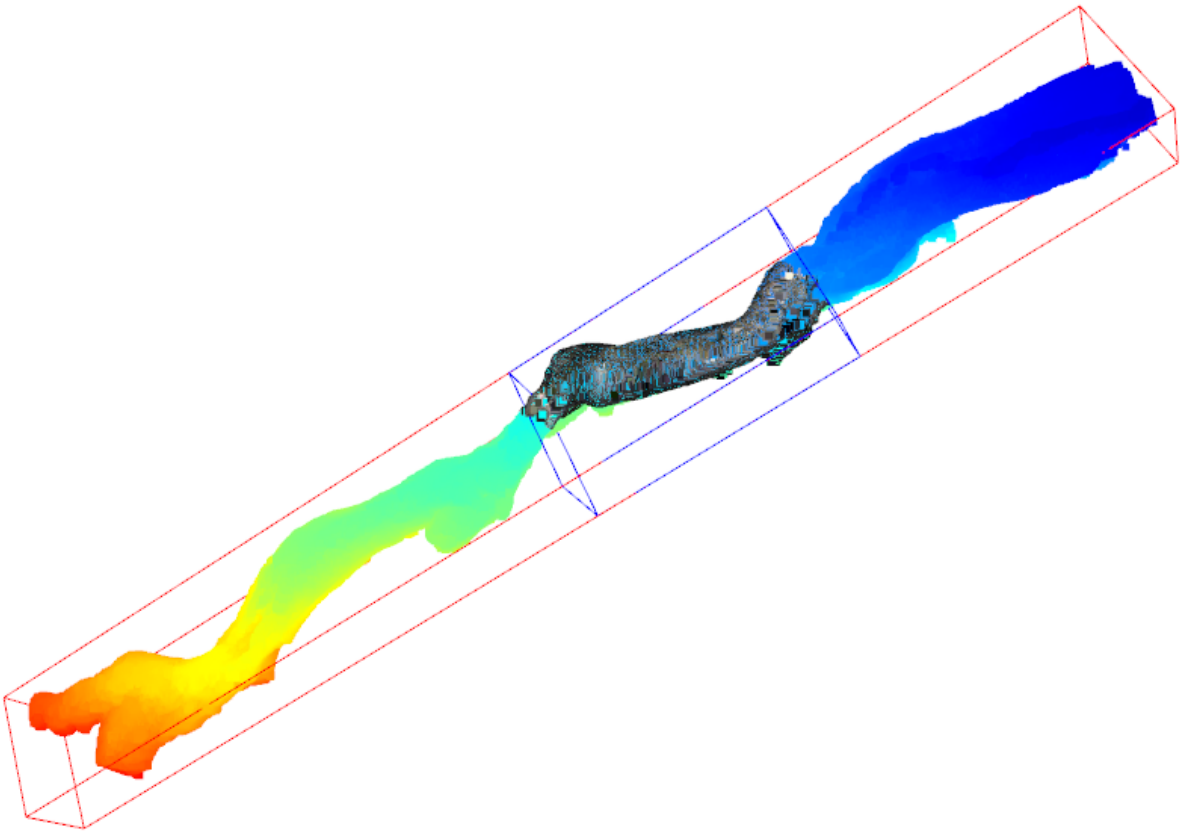

Figure 2: Visualization of cave part that we will analyse

On Figure 2 we can observe the minimal oriented bounding box in red, our smaller bounding box in blue and the selected point cloud in its original colors bounded by the bounding box. We will use similar approach for cutting our point cloud into smaller pieces later.

2.2.2 Mesh creation

Next step needed for analysing our point cloud is the creation of a mesh. Firstly we created a mesh for our smaller cave section using Poisson surface reconstruction algorithm, the results of which we see on Figure 3

Figure 3: Whole cave mesh

As we can observe, the mesh contains a lot of points which are not really a part of the cave, to remove them we will clean the mesh, we will do this in two parts. The first part will just smooth the mesh out, while the second part will remove outliers from the mesh.

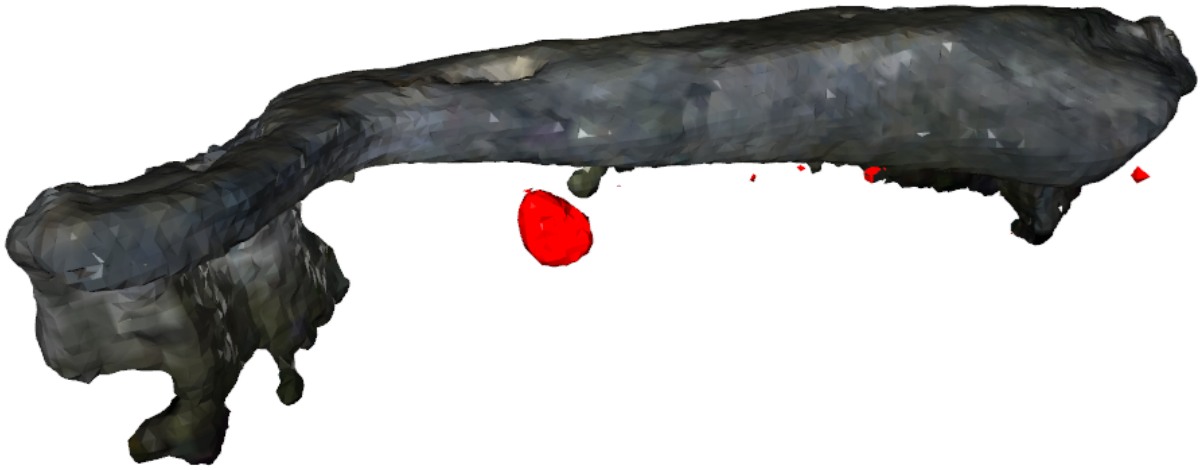

Figure 4: Mesh and removed outliers after cleaning

On Figure 4 we can see cleaned mesh and outliers which are colored in red, those we will remove so they do not impact our analysis.

2.3 Geometric analysis

2.3.1 Area

Since we already obtained the mesh, we can easily calculate the area by calculating area of each triangle in the mesh and summing them together. For this particular cave part we have obtained the surface area of 1317.53 square meters.

2.3.2 Volume

To obtain the volume of the mesh we have used an approach which can be seen on Figure 5.

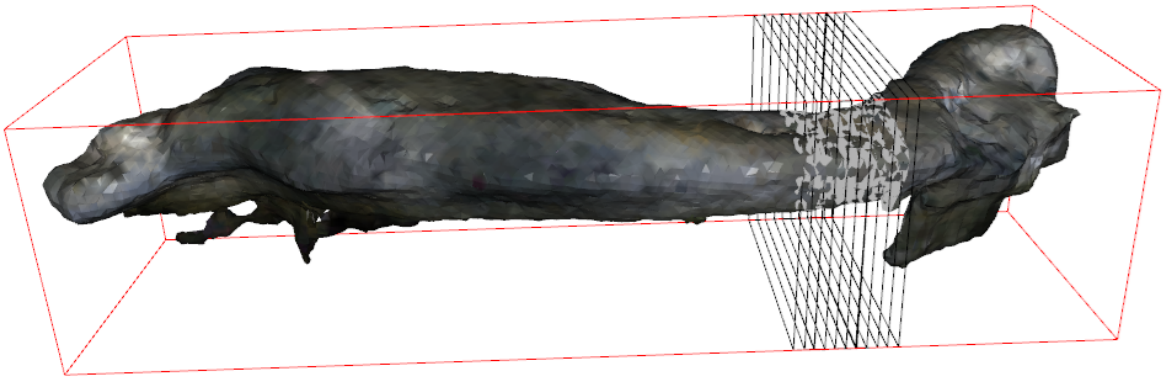

Figure 5: Mesh segmenting and convex hull calculation

Firstly we cut the mesh into tiny segments based on its oriented bounding box, on Figure 5 we have only visualized a couple of those segments for easier viewing. For each small segment we crop the point cloud and calculate convex hull of the points in the cropped cloud, for our drawn segments we can see the convex hulls as the greyed out parts inside the bounding boxes. Once we obtain convex hulls we calculate volumes for each of them and sum the volumes up to obtain the volume for our cave, which was 1666.015 cubic meters. We have tested this approach on couple of rigid structures and it seemed to provide satisfying results.

2.4 Cave skeletonization

To obtain skeleton of the cave we will use the same cutting approach, as seen in Figure 5, but this time we will compute geometric centers for the cloud and connect them. To see how the path we obtain aligns with the cave we will also construct a skeleton of the mesh which can be seen on Figure 6 together with the path.

Figure 6: Mesh segmenting and convex hull calculation

2.4.1 Length

Since we already have a line path through the cave, we can just sum the length of line segments to obtain cave length, which was 46.729 meters for our cave segment.

2.4.2 Roundness analysis

Analysing roundness is going to give us a good quantification of the shape of the tunnels. To analyse roundness we first obtain cross sections of the cave segment. For all of those sections we compute two different hulls. The first hull we computed for all of our cross sections is concave hull. One of such computed hulls can be observed on Figure 7.

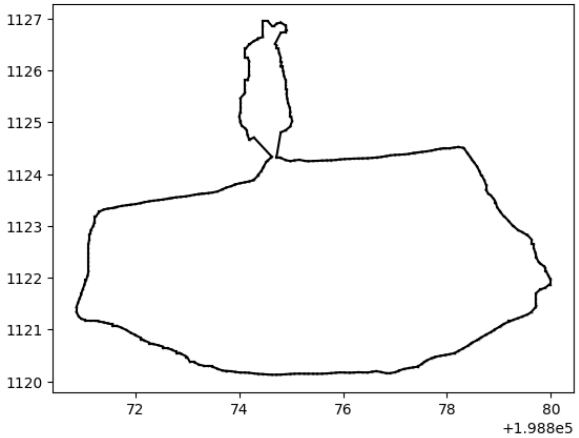

Figure 7: Mesh segmenting and convex hull calculation

Concave hull is going to approximate the shape of the cave, but the problem is that occasionally we get some bumps which should not be factored in when observing roundness of our cave, one such bump can be seen on Figure 7. Because of that we are also going to compute the convex hull for our cross sections and we will use both hulls in our roundness analysis, the convex hull will not completely approximate our cross sections,

but it will remove a bit of the impact from bumps. We can see one of computed convex hulls on Figure 8.

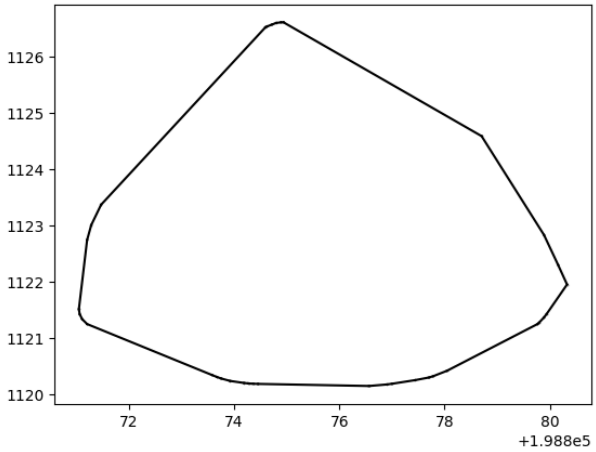

Figure 8: Mesh segmenting and convex hull calculation

To obtain roundness of a single cross section we are going to use the formula 1. The closer the value to 1 the more similar to the circle the object is.

$$R = 4\pi \times \frac{\text{Area}}{\text{Perimeter}^2} \tag{1}$$

To obtain average roundness of our cave section we are going to compute perimeters and areas of our concave and convex hulls, then we are going to compute means for both to obtain average roundness which in our case is 0.6003.

2.5 References

References are available in readme.md file on my GitHub Repository