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Chapter 5

Collision Visualization of a Laser-Scanned Point Cloud: The Revival of a Traditional Procession Route

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Recent developments in laser scanning technology have enabled the capture of the three-dimensional shapes of real objects quickly and precisely. Until now, the application of the technology to cultural heritages has been mainly to record their standing 3D shapes. This technology, however, should also be useful for analyzing the dynamic behavior of 3D culture heritages. In fact, in industry, laser scanning data is often used for collision detection and the location of facilities in production plants. Such collision detection is also useful for preserving and analyzing intangible cultural heritages such as traditional festivals, and we contend that 3D laser scanning is suitable for making a high-definition survey as it is a fast and efficient way of collecting special data on the environment.

Conventionally, collision detection of laser-scanning objects is generally performed by transforming the laser-scanned point clouds into polygon meshes, and then collision detection is calculated using depth maps generated from the point clouds. However, it is difficult to eliminate the noise and error caused by the loss of shape. There are also many other problems in generating high-precision polygons with good aspect ratios, which affects the accuracy of the collision detection. To solve this problem, instead of transforming point cloud data into polygon meshes, we proposed a point cloud method for collision visualization.

The Gion Festival is one of the most famous festivals in Japan. The festival occurs annually in Kyoto city and spans the entire month of July. The highlight of the festival is the Yamahoko float procession, which consists of parades of festival floats in the middle of July. The Yamahoko float procession that accompanies the opening of the festival is called the *Saki Matsuri*, and the return procession is called the *Ato Matsuri*. The boat-shaped float called Ofunehoko, shown in Figure 1, is an important Yamahoko float in the final position in *Ato Matsuri* procession every year.

Figure 1. Ofunehoko Float in the procession
Source: Author

Figure 2 shows a partial map of the procession, and Sanjo Street and Teramachi Street, which are marked red, were once used as a part of the original procession routes, but are not included in the procession routes of the restricted *Ato Matsuri*. However, the Kyoto city government hopes to revive the original procession route. The reason why the original route has not been revived is that it is not known whether the Ofunehoko float is still capable of traveling through these streets safely.

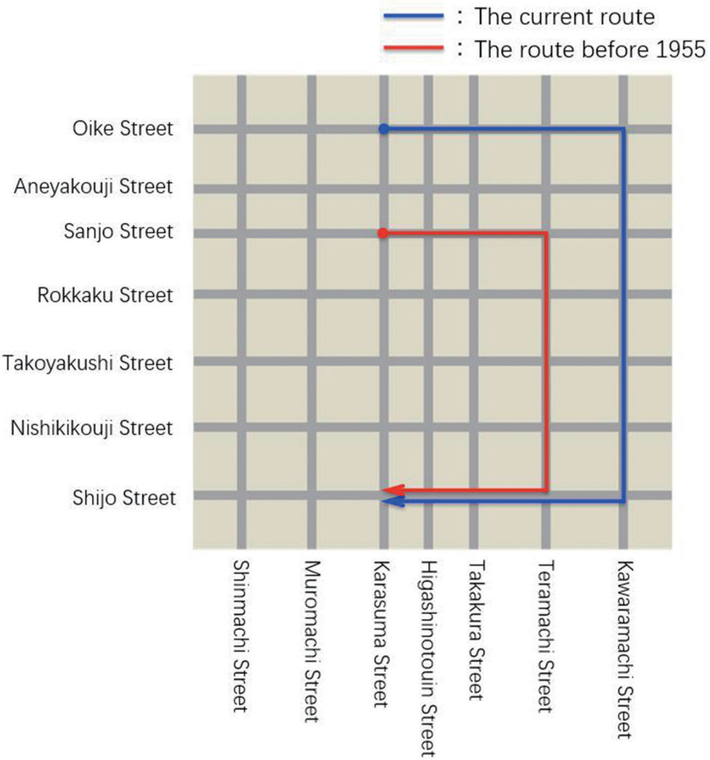

Figure 2. Partial map of the procession route
Source: Author

In fact, we do not know whether the Ofunehoko float can travel the streets without any collisions due to major changes in road conditions, such as newly built houses, power lines, and billboards.

In our work, we apply our method to analyze our simulation of the collision detection between our paradigm festival float and the street. We employed our computer simulation to detect collisions between the

Ofunehoko float and the original procession road in a virtual space for the road's revival at the Gion festival.

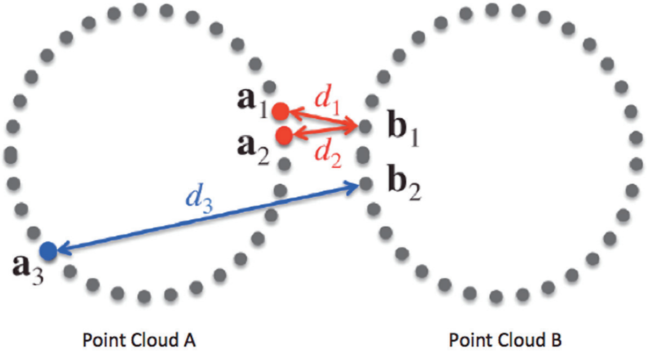

Figure 3. Collision Detection
Source Author

Methodology

First, for collision detection for the corner, an applied set (which I will explain later) of each point in the two given point clouds is determined by performing the nearest neighbor search of the points in K-d Tree binary trees. For each point in one point cloud, we search for and find its nearest neighbor point in the other point cloud. Next, we obtain the inter-point distance between these two points. As we can see here, consider two point clouds, A and B, and $a_i(x_i, y_i, z_i)$ is a point in point cloud A and $b_j(x_j, y_j, z_j)$ is the point in point cloud B, then the collision detection will be performed as follows. First, for point a_i in point cloud A, we perform a nearest label search and find its nearest label point b_j Then we can calculate the inter-points distance between these two points, a_i and b_j, based on this formula.

$$D = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$

Finally, we need to compare the inter-point distance with the threshold value, and if the distance is less than or equal to our threshold value ε (epsilon), we assign a proper collision area corner to a_i. However, if the distance is larger than ε and less than or equal to our proper known smallest distance $D_{\max}$, we will assign a proper high collision risk area corner to a_i. Here, we set the threshold value, ε.

Generally, the collision point is usually the point at which the inter-point distance is zero. However, because of the loss of laser scanning, there are very few points where the inter-point distance is completely zero, so an extremely small value ε, is set as the collision parameter. In the current work, ε is set to 1/100 or 1/500 of the bounding-box diameter of the scenes that consist of point clouds, as in Figure 4.

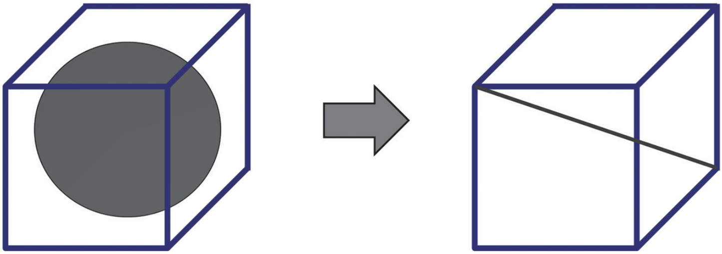

Figure 4. Determination of threshold. The accuracy is based on the length of the diagonal of the bounding box in the scene. Normally, for buildings, one-fifth of the diagonal length, about 20mm, is chosen as the threshold. For wires, one hundredth of the diagonal length, about 100mm, is usually chosen as the threshold.
Source: Author

When we consider carriages with extra wheels, the bigger value of 1/100 works better because the electric power lines are very thin, so sometimes the number of points is very small.

Next, we need to perform the transparent rendering because the conventional method cannot observe the inside and the outside simultaneously. So, in order to improve the visibility of the collision result, a precise, transparent rendering is required. The precise see-through imaging of collision point clouds can be executed with a correct depth view with interactive speed by using stochastic point-based transparent rendering (SPBR), which was proposed for dealing with large-scale laser scaling point clouds.

In our experiment, we planned to highlight collision point clouds and collision risk areas, so we used a color map and an opacity map. When executing the collision detection, we need the definitions of the collision area corner and high collision risk area corner as they must be avoided. We use the white color for the collision area and the rainbow colors for the high collision risk area. For the case that the inter-point distance is very close to ε for the minimal non-collision distance, the high collision risk corner becomes red over a proper large spreadsheet inter-point distance $D_{\max}$. The point corner is made blue, and we will designate it as a collision-free area.

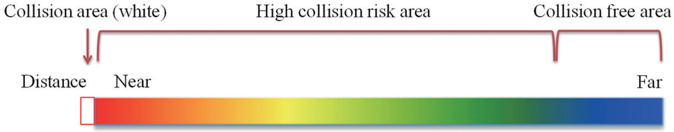

Figure 5. Opacity Map
Source: Author

Table 1. The opacity of the different areas of the rainbow.

Rainbow Color	Opacity
Blue	0.2
Blue – Light Blue	0.4
Green – Yellow	0.6
Orange – Red	0.8
White (Collision Lines)	0.9

Figure 5 shows an opacity map based on the color map. The collision area opacity is rated 0.2 to 0.9, depending on the level of collision risks. From the red to the orange area, the opacity is set to 0.8. From the yellow to the green, the opacity is set to 0.6. For the light blue, the opacity is 0.4. For the remaining blue areas which are far from the collision area, the opacity is 0.2. These opacities can be easily realized by the SPBR method.

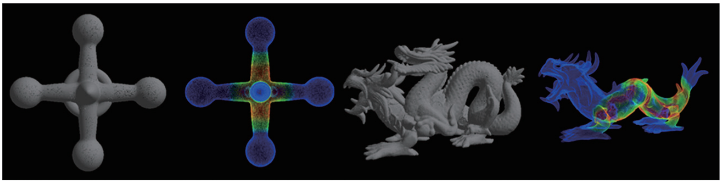

Figure 6. Result of the collision detection experimental. Left: Jack (2.5 x 10^5 points) and Torus (2.5 x 10^5 points). Right: Asian dragon (7.3 x 10^5 points) and Dragon (4.4 x 10^5 points). Source: Author

Figure 6 shows the collision detection results of our method on two sets of simple models, and the results are rendered using SPBR to visualize and analyze the collision hazard. From this result we can see that the collision area opacity and the high collision risk area opacity can also be realized within the framework of the rendering.

Next, we applied our visualization method to the collision detection simulation of the Ofunehoko float around its original procession roads of the Gion Festival. A point data model of the Ofunehoko float was moved in a virtual space constructed using the point cloud data of the street acquired by our mobile mapping system. The Ofunehoko model was constructed using CAD software. Then the collision potential of the street and the float was investigated and visualized by our method.

Figure 7 shows the cloud data of the laser scanning point of Sanjo Street, which is part of the original float procession route. It is narrow compared with the current route and contains many electrical wires, billboards, and other objects, which may collide with the festival float during the procession. This includes the road point cloud data, but in the collision-detection experiments, the road data was removed to avoid reporting the natural contact between the road and the float.

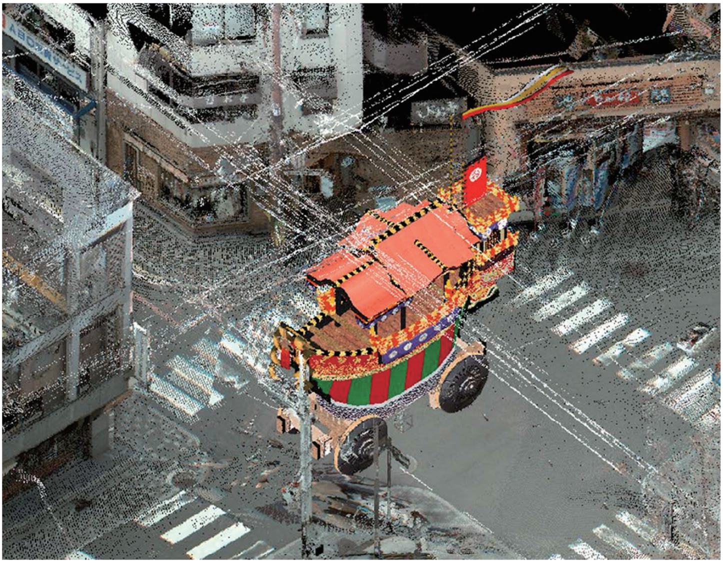

Figure 7. Point cloud of the Ofune-hoko float (9.7 × 10^6 points) placed in the scene of Sanjo Street. Source: Author

Figure 7 shows the result of placing the point cloud data of the Ofunehoko float in the crossing of the street. We can clearly foresee that the float will collide with the electric wires when moving in the street. Collisions with billboards and other objects are also expected when turning at a street intersection. Figure 8 shows an example of the proposed see-through virtual imaging of the collision points related to the collision and high collision-risk areas. The collision-free area is also visualized. Sanjo Street in the background of the Ofunehoko float is also visualized SSD using its original corners. As I explained, the opacity is the highest for the collision line and the opacity of the remaining areas is the lowest. This colored see-through view with the corrected depth view enables us to clearly observe collisions along with the whole float and the street.

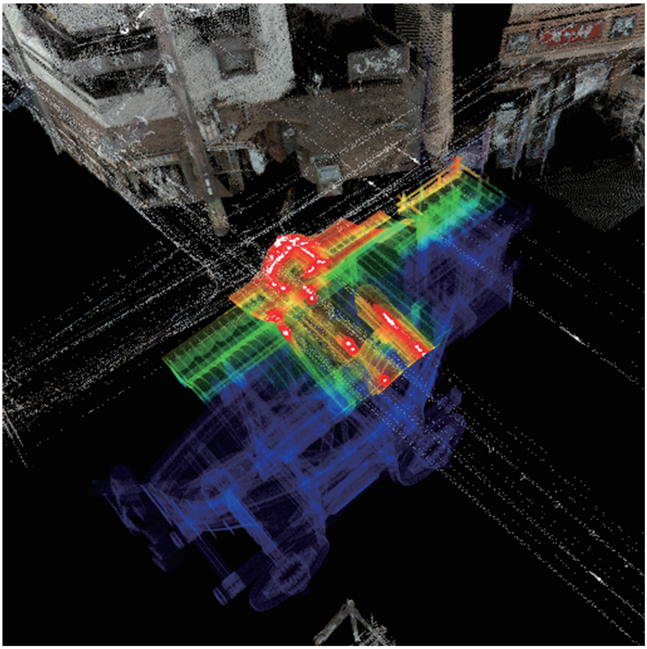

Figure 8. See-through visualization of the Ofunehoko float that collides with electric wires. The total number of points used for the visualization is 8.4 × 10^6, and the rendering speed is 16.19 fps. Source: Author

Figure 9 shows an image with see-through results in which only the collision areas of the Ofunehoko float are highlighted by the white coloring and the remaining parts of the float and the street are virtualized using the original colors. By giving high opacity to the collision areas, we can more clearly observe the areas.

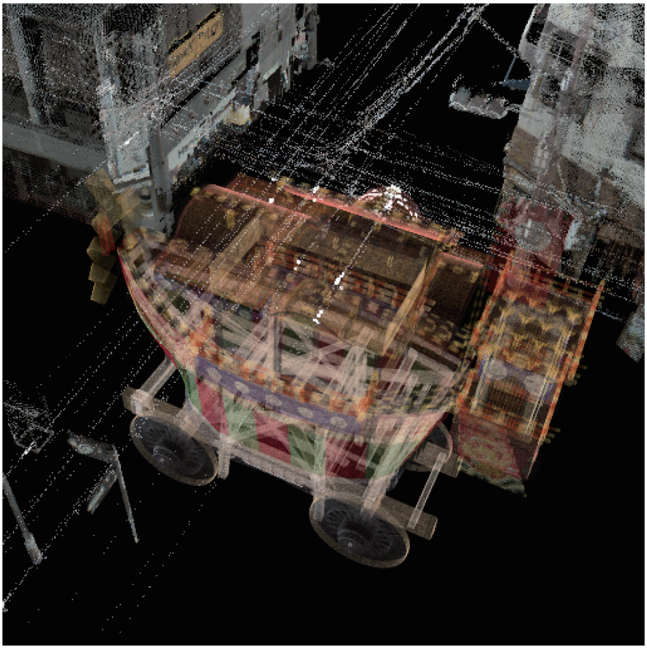

Figure 9. See-through collision visualization similar to Figure 8. Only collision areas of the Ofunehoko float are given the white highlight color.
Source: Author

Here, we consider another possible tuning of our color model to highlight collision regions. If the colliding objects are white or nearly white, it is not the best way to simply assign the color white to their collision areas. In such a case, we highlight the collision areas (white) together with narrow surrounding areas of very high collision risks (red). In this way, the white collision areas become apparent and are highlighted successfully (see Figure 10). Using areas of only very high collision risks is also helpful in keeping the original colors of the colliding objects as much as possible.

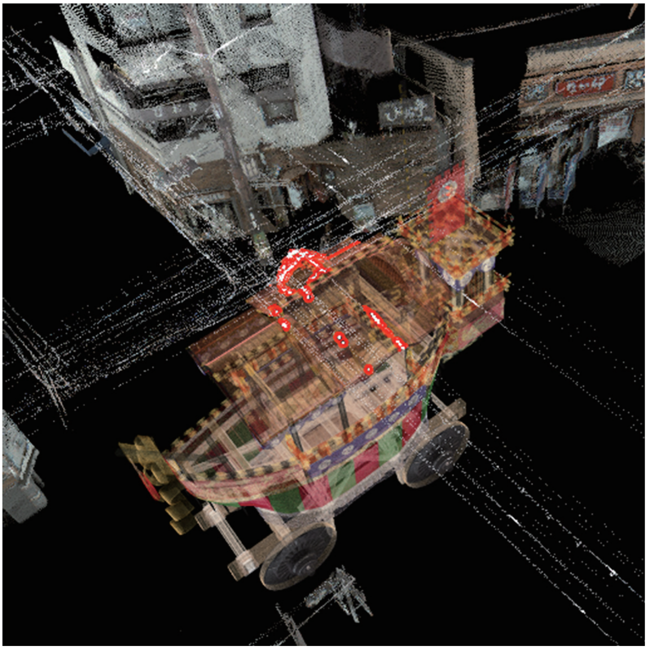

Figure 10. Highlighting collision areas (white) together with their surrounding narrow areas of very high collision risks (red).
Source: Author

It is also worth mentioning another application of our method in the industrial field. Recently, cloud data simulation has become popular for industry fields, because, in the construction process, it is difficult to determine whether a large crane can be safely placed in the construction space. In this case, we can perform the collision detection simulation with our point cloud data pairing to predict any dangerous obstacles.

Let me conclude this overview of our work by summarizing our process. Instead of transforming point cloud data into polygon meshes, we propose a point-cloud-based method for collision visualization and the collision points are highlighted with a corrected depth feel that can accurately predict collision points by SPBR.

In the future, we plan to execute our collision visualization through our real-time creation detection simulation. We hope that this technology will contribute to increased safety by helping event managers as well as construction managers to predict and avoid dangerous and potentially costly collision damage.

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Dr. Weite LI

Chapter 5. Collision Visualization of a Laser-Scanned Point Cloud: The Revival of a Traditional Procession Route

Weite Li completed his Ph.D. at the Graduate School of Information Science and Engineering, Ritsumeikan University. He is currently a Lecturer at the School of Artificial Intelligence, Chongqing Technology and Business University, China, and a Visiting Researcher at the Asia-Japan Research Institute, Ritsumeikan University. His research focuses on the reconstruction, visualization, and application of deep learning for 3D point clouds. Recently, his primary research efforts have been concentrated on utilizing deep learning techniques to process laser-scanned point clouds, aiming to achieve higher-quality visualization of 3D point cloud scenes. In his publication titled “Deep Learning-Based Point Upsampling for Edge Enhancement of 3D-Scanned Data and Its Application to Transparent Visualization,” *Remote Sensing* (June 2021, Vol. 13, Issue 13, Page 2526), he proposed an upsampling network specifically designed for edge regions in large-scale laser-scanned point cloud data. This approach, combined with translucent visualization techniques, enhances the overall quality of visualization effects. Building on this work, he is currently investigating methods to complete the shape of incomplete areas within point clouds, particularly addressing large-scale laser-scanned data from the real world.