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High-quality Visualization of Large-Scale Noisy Point Clouds Acquired by 3D Scanning

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Abstract. The recent rapid development of laser scanning technology has enabled us to record large-scale 3D point clouds that describe very complex 3D shapes such as cultural heritages, buildings, and equipment in factories. At the same time, we need to realize comprehensible visualizations that help researchers and engineers to analyze, understand, and use the laser-scanned point clouds. In this paper, we propose a new method of noise reduction that effectively utilizes the redundancy caused by large-scale to improve the image quality, called "Stochastic Noise Transparentization". Besides, we quantitatively evaluate the effectiveness of stochastic noise transparentization and visually substantiate the effectiveness of it for various laser-scanned point clouds.

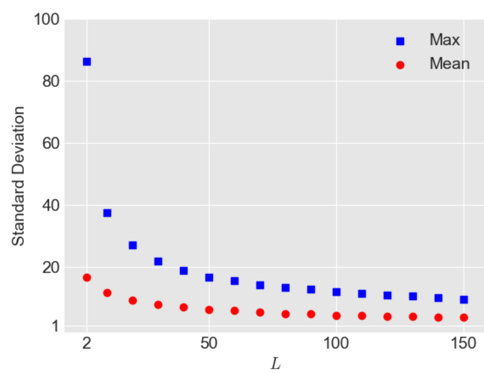
Keywords: Visualization, Laser-scanned large-scale point cloud, Stochastic noise transparentization

1. Introduction

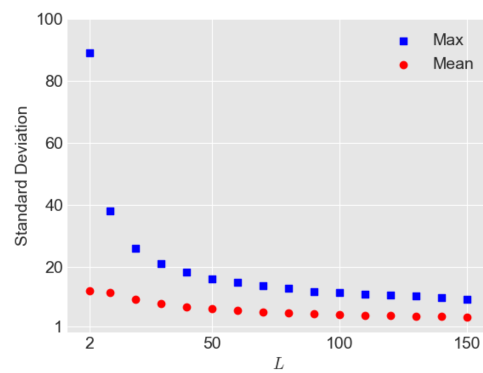
The recent rapid development of laser scanning technology has made it possible to digitally acquire real 3D objects as 3D point clouds. Accordingly, digital archives are being carried out for the purpose of preservation and utilization of real 3D objects all over the world. The recorded point cloud is large-scale data ranging from tens of millions to hundreds of millions of points. In addition, it often contains a large amount of noise when laser-scanning. On the other hand, we developed a novel method of high-quality and quick transparent visualization, called "Stochastic Point-Based Rendering(SPBR)[1]" based on a probabilistic algorithm. For the purpose of making noise transparent, in this research, consider utilizing the transparency effect that is potential in SPBR. We call this method "Stochastic Noise Transparentization", which is an effect to make the measurement noise transparent and invisible in the created transparent images. By demonstrating the effectiveness of this method quantitatively, we realize a noise-robust transparent visualization method.

2. Experimental results

We conducted a verification experiment to quantitatively evaluate the effect of stochastic noise transparentization. More concretely, we calculated the standard deviation for each corresponding pixel value of L intermediate images, where L represents the number of ensembles, that is, the number of intermediate images in SPBR. We prepared two kinds of point clouds: point cloud with Gaussian noise in coordinate space and point cloud with Gaussian noise in 256-tone color space. We added Gaussian noise to both point clouds with a probability of 10 percent for each point. Figure 1 shows the change of the mean and maximum value of the standard deviation for each corresponding pixel value of L intermediate images of abovementioned two kinds of point clouds with ensemble number $L = 2$ to 150. From the Figure 1(a) and Figure 1(b), we can see that the standard deviation decreases sharply at approximately $L \simeq 10$ and then decreases gradually at approximately $L \simeq 100$. This experimental result shows that the influence of noise decreases as L increase, whether it is noise in the coordinate space or noise in the color space.



(a) point cloud with noise added to coordinates



(b) point cloud with noise added to color

Figure 1: The change of the mean and maximum value of the standard deviation for each corresponding pixel value of L intermediate images when increasing ensemble number L.

3. Visualization results

We present three case studies that demonstrate the effectiveness of stochastic noise transparentization in various scenes of laser-scanning.

3.1. Scene with trees

Trees often cause measurement noise in laser-scanning data. When laser-scanning, trees with leaves blowing and swaying in the wind make the acquired position incorrect. Moreover, the glitter of tree leaves makes the laser light scatter, which generates many outlier 3D points at positions disconnected from the scanned object. Figure 2(a) and Figure 2(b) show visualizations of the forest of Fujinomori Shinto Shrine (Kyoto city, Japan). Figure 2(a) is created by the conventional point-based rendering (SPBR with $L = 1$), whereas Figure 2(b) is created by SPBR with $L = 100$. In Figure 2(a), we see a lot of white noise which is caused by misdetection of position. In Figure 2(b), however, the white noise is made significantly transparent, which makes each tree in the forest more visible.

3.2. Factory with powder dust

Factories are frequent targets of laser-scanning for the purpose of layout simulation. However, when laser-scanning in the factory, noise is often generated because the powder dust suspended in the air make the laser light scatter. Figure 2(c) and Figure 2(d) show the visualizations of a laser-scanned factory. The image of Figure 2(c), which is created by the conventional point-based rendering (SPBR with $L = 1$), looks blurred because of the noise emanating from the powder dust. On the other hand, in the image of Figure 2(d), which is created by SPBR with $L = 100$, the noise disappears satisfactorily and became a high-quality image.

3.3. Scene with light reflection on glass windows

Reflective objects such as the glass window also cause scattering of laser light. Figure 2(e) and Figure 2(f) show the visualizations of a laser-scanned campus building of Kyoto Women's University (Kyoto city, Japan). The scanned buildings have many glass windows, and the glass reflects the laser light. This reflection causes outlier noise. In Figure 2(e), which is created by the conventional point-based rendering (SPBR with $L = 1$), we can see many outlier 3D points apart from the buildings (see the area indicated by the yellow ovals). On the other hand, in Figure 2(f), which is created by SPBR with $L = 100$, the outlier 3D points disappear satisfactorily.

4. Conclusions

In this paper, we quantitatively evaluated the effect of the stochastic noise transparentization, which is included in the probabilistic algorithm of SPBR. As a result of the verification experiment, regardless of the type of noise, it was found that the effect of noise can be suppressed by increase the ensemble number L. We also demonstrated that stochastic noise transparentization works effectively for various measurement noise.

References

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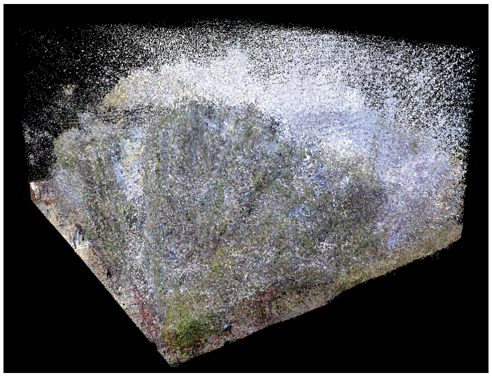
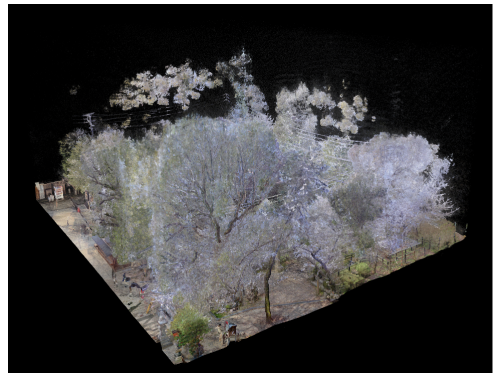
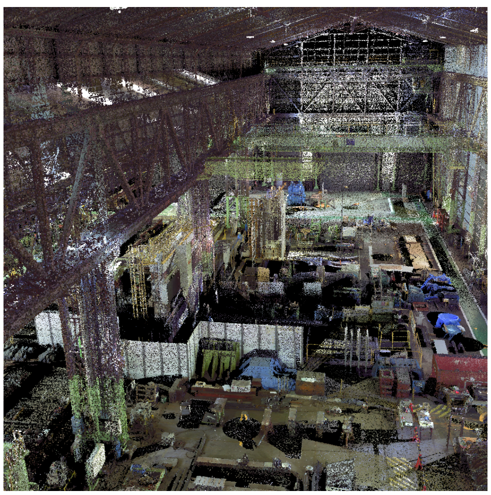


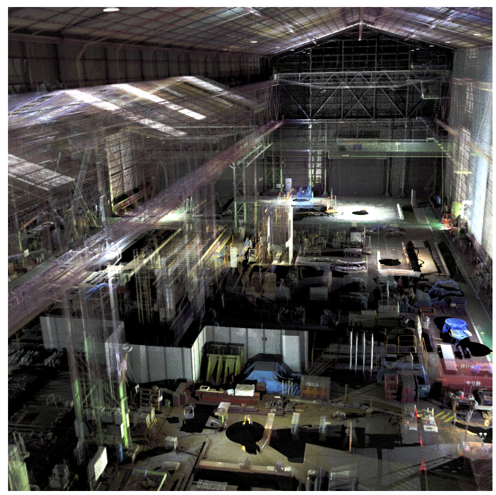
(a) conventional point-based rendering



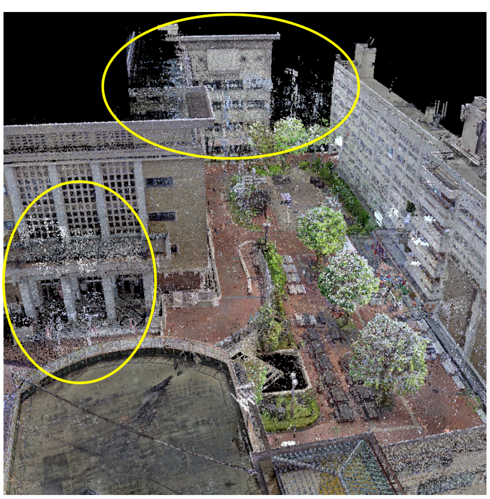
(b) SPBR with L = 100



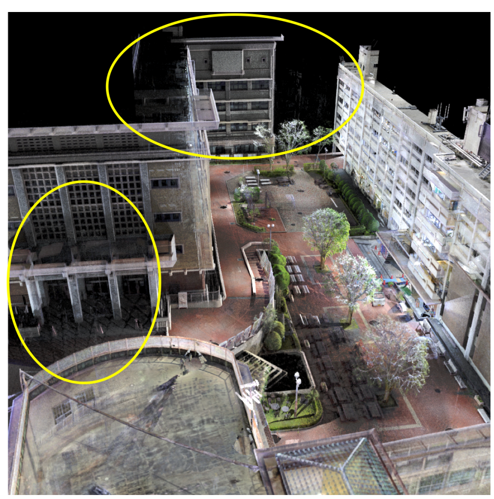
(c) conventional point-based rendering



(d) SPBR with L = 100



(e) conventional point-based rendering



(f) SPBR with L = 100

Figure 2: Visualizations of a laser-scanned (a)(b) forest, (c)(d) scene of a factory and (e)(f) campus buildings with many glass windows by using (a)(c)(e) the conventional point-based rendering (SPBR with L = 1) and (b)(d)(f) SPBR with L = 100.