Game Engine-based Point Cloud Visualization and Perception for Situation Awareness of Crisis Indoor Environments

Liu, Zhenyu; Fu, Runnan; Wang, Linjun; Jin, Yuzhen; Papakostas, Theodoros; Mainelli, Xenia Una; Voûte, Robert; Verbree, Edward

DOI
10.34726/1786

Publication date
2021

Document Version
Final published version

Published in
LBS 2021: Proceedings of the 16th International Conference on Location Based Services

Citation (APA)
Liu, Z., Fu, R., Wang, L., Jin, Y., Papakostas, T., Mainelli, X. U., Voûte, R., & Verbree, E. (2021). Game Engine-based Point Cloud Visualization and Perception for Situation Awareness of Crisis Indoor Environments. In A. Basiri, G. G. Gartner, & H. Huang (Eds.), *LBS 2021: Proceedings of the 16th International Conference on Location Based Services* (pp. 183-194). TU Wien. https://doi.org/10.34726/1786

Game Engine-based Point Cloud Visualization and Perception for Situation Awareness of Crisis Indoor Environments

Zhenyu Liu*, Runnan Fu*, Linjun Wang*, Yuzhen Jin*, Theodoros Papakostas*, Xenia Una Mainelli*, Robert Voûte*,**, Edward Verbree*

* Faculty of Architecture and the Built Environment, Delft University of Technology
z.liu-46@student.tudelft.nl, r.fu-1@student.tudelft.nl,
l.wang-21@student.tudelft.nl, y.jin-10@student.tudelft.nl,
t.papakostas@student.tudelft.nl, x.u.mainelli@student.tudelft.nl,
E.Verbree@tudelft.nl, R.L.Voute-1@tudelft.nl
** CGI Nederland B.V.
robert.voute@cgi.com

Abstract. Because unknown interior layouts can have serious consequences in time-sensitive situations, crisis response teams request many potential solutions for visualizing indoor environments in crisis scenarios. This research uses a game engine to directly visualize point cloud data input of indoor environments for generating clear interaction between the environment and viewers, to aid decision-making in high-stress moments. The prospective final product is an integration of game-oriented visualization and cartography, hosted within Unreal Engine 4 (UE4), allowing users to navigate throughout an indoor environment, and customizing certain interaction features. The UE4 project consists of 4 modules: data preprocessing, render style, functional module, and user interface. Finally, this research uses a single-floor indoor point cloud dataset collected from a building in Rotterdam, the Netherlands for the implementation.

Keywords. Game Engine, Unreal Engine 4, 3D Visualization, Situation Awareness, Point Cloud, Indoor Environment, Crisis Scenario

Published in "Proceedings of the 16th International Conference on Location Based Services (LBS 2021)", edited by Anahid Basiri, Georg Gartner and Haosheng Huang, LBS 2021, 24-25 November 2021, Glasgow, UK/online.

https://doi.org/10.34726/1786

1. Introduction

Crisis response teams often encounter situations in which unfamiliar buildings need to be reached, where floor plans can be out of date, or real-time situations are different from what is briefed. Unknown interior layouts can have serious consequences in time-sensitive situations when command centers direct first responders on the basis of out-of-date information. Compared with the other 3D data, point clouds are very suitable for visualizing crisis indoor environments as they can retain accurate details, and can be easily captured and updated. However, first responders usually lack geo-spatial experts who are proficient in terminology and the structure of spatial data (Zlatanova, 2010). Therefore, exploring the intuitive spatial-information transfer and easy-to-use environment interaction potential of point cloud-based visualization solutions for crisis indoor environments can aid first responders in the correct decision-making and situation awareness.

This research focuses on the visualization and perception of crisis indoor environments, emphasizing the direct use of point clouds with the great interaction potential offered by game engines (Virtanen et al., 2020). The research aims to answer the following question: *Can we harness the potential that point clouds have, to effectively convey the visual contents of an indoor environment to first responders?* The prospective final product is an integration of game-oriented visualization and cartography, hosted within *Unreal Engine 4* (*UE4*)[1], allowing users to navigate throughout an indoor space, and customizing certain interactive features.

2. Methodology

The product software is designed in a game-oriented scope using *UE4* aiding users in decision-making and situation awareness. 3D adventure games often have high similarities to real crisis environments, so game-oriented features can offer many design inspirations. *UE4* provides official support for point cloud data and some easy-to-use interactive interfaces, which make the development of the software more convenient.

The software consists of four modules, including the **data preprocessing**, **render styles**, **functional system**, and **user interface**. *Figure 1* describes the workflow of module design and development. Finally, the single-floor indoor point cloud data collected from a building in Rotterdam is used to test the software.

[1] www.unrealengine.com

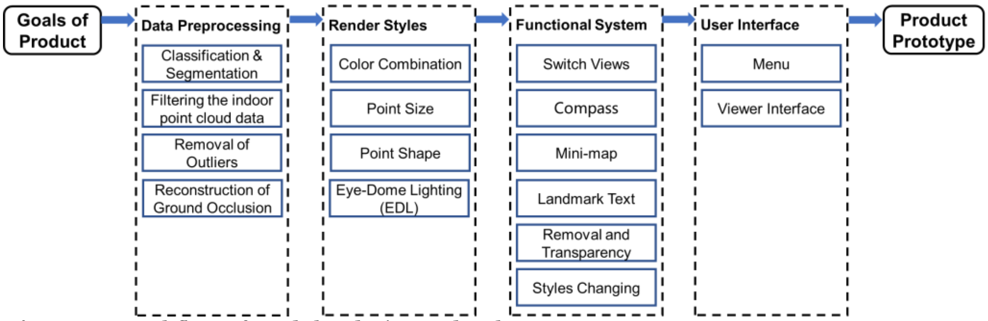


Figure 1. Workflow of modules design & development

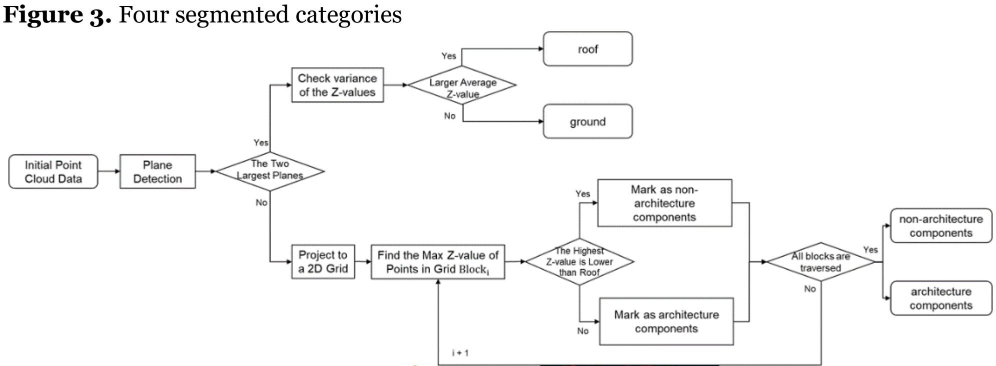
3. Module Design & Development

3.1. Data Preprocessing Module

Before importing a point cloud into *UE4*, the data should be preprocessed. The classification and segmentation operations can yield many benefits, such as significantly reducing the computation complexity, providing semantic information, offer the possibility to be demonstrated in different rendering styles, and switch between displayed and hidden states independently. A method was designed (*Figure 2*) to classify the point cloud into 4 categories: (1) **roof**, (2) **architecture components** (walls, columns, etc.), (3) **non-architecture components** (furniture, etc.), and (4) **ground** (*Figure 3*).

Figure 2. Workflow of point cloud classification & segmentation

Figure 3. Four segmented categories



To remove the external environment objects (*Figure 4*), segmented points are projected onto a 2D-grid. Each grid cell will be preserved as an indoor area only if it contains enough roof and ground points, and its density exceeds the preset threshold. The outliers (noise points) can cause non-trustworthy rendering results. Therefore a denoising method, which should keep the balance between denoising, feature-preservation, and avoiding degradation of the input (Rakotosaona et al., 2019), is also needed in this phase.

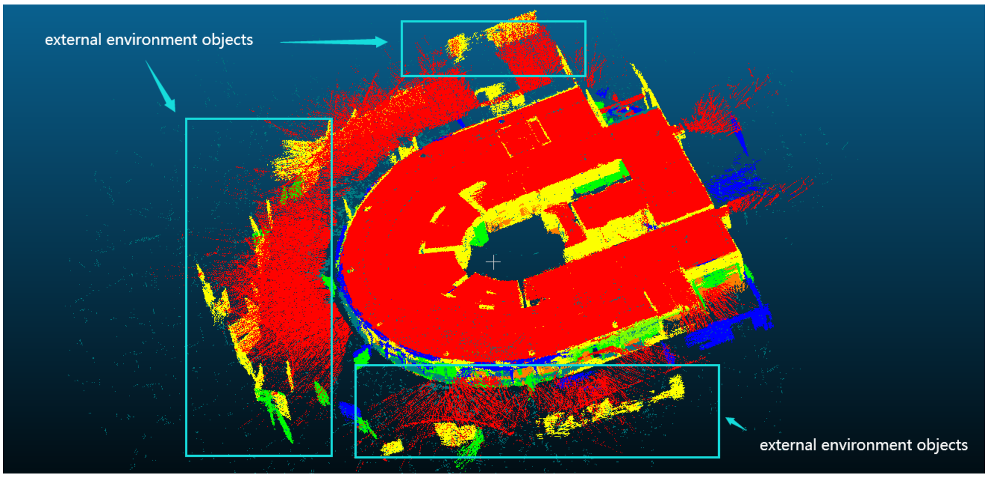


Figure 4. External environment objects

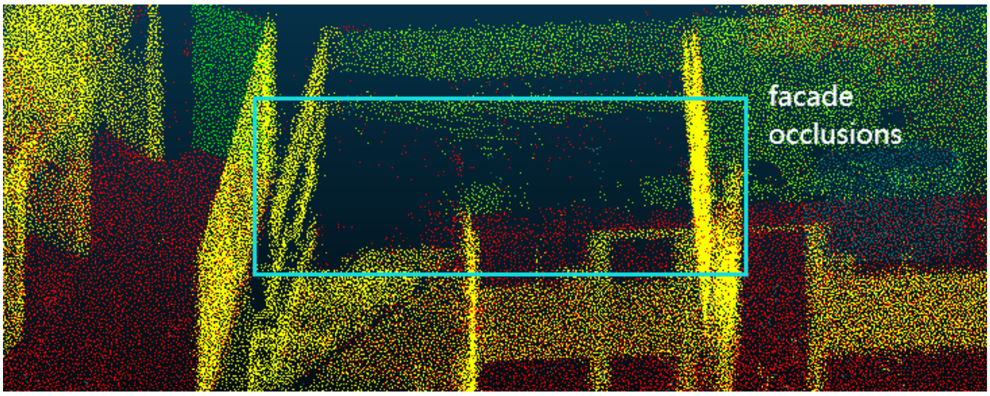


Figure 5. Facade occlusions

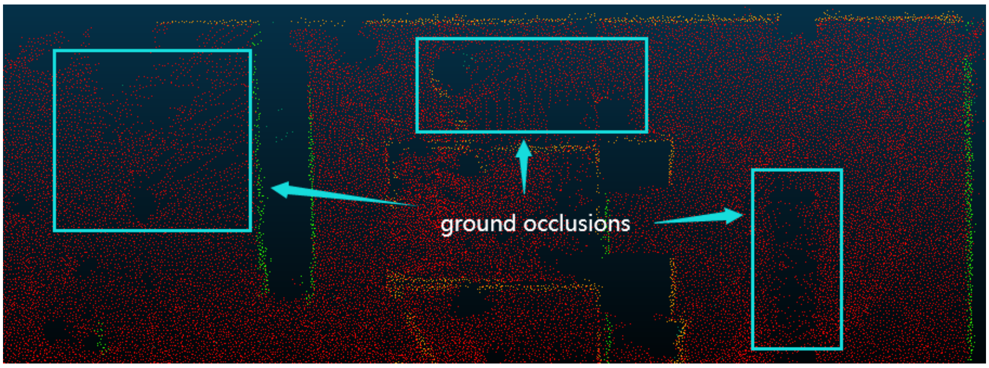


Figure 6. Ground occlusions

Many indoor point clouds contain both facade occlusion (*Figure 5*) and ground occlusion (*Figure 6*) problems (Friedman & Stamos, 2012). But only the latter may obviously hinder exploration, such as the user may fall through holes (occluded areas) in the ground. So we insert a transparent plane object with a collision property to fill the ground occlusions in *UE4*.

3.2. Render Styles Module

In order to enhance the visual effect of the built environment with topographic cartography, we follow the visualization principles summarized by (Andrienko et al., 2020) and use some 3D static visual variables (Neuville et al., 2018) to design the render module.

Color Combinations: We set three different color styles. The default (brighter) one is closer to the real materials of the objects, enabling the user to quickly understand the indoor environment. The two darker styles can highlight the architecture and non-architecture features respectively according to the users' needs.

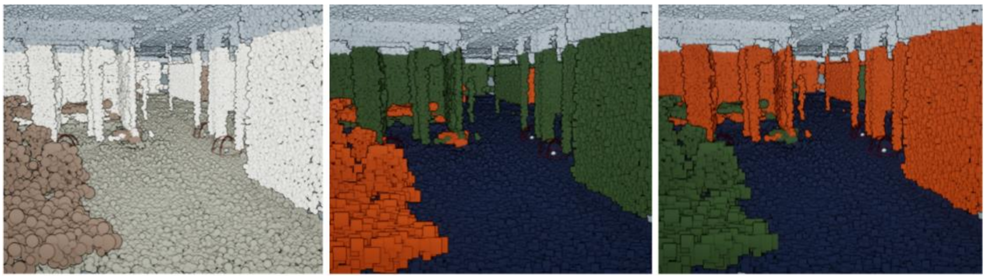


Figure 7. Default style (left), darker style 1 (middle) and darker style 2 (right)

Point Size & Point Shape: Users can adjust the shape and size of the points to change the visual and physical properties. For instance, adjusting point size to circumvent the effects of the point cloud density such as forming voids between points when the density is too low (Kharroubi et al., 2019).

Figure 8. Enlarge point size to reduce the hole area

Figure 9. Sphere points (left) and cube points (right)

Eye-Dome Lighting (EDL): Point cloud data often do not have realistic depth information, so *EDL* as a non-photorealistic lighting model can group points close to each other and shade their outlines, which accentuates the shapes of objects within a point cloud (Ribes & Boucheny, 2011). *EDL* can improve the visual quality and can quickly and self-adaptively apply to other point cloud data.

Figure 10. Visualization results without (left) and with (right) EDL

3.3. Functional Module

The functional module is based on some interaction and enhancement techniques (Andrienko et al., 2020) and 3D adventure game features, which are well designed for the exploration functions needed by users in a crisis environment.

Switch Views: Users can switch between the first-person view, the third-person view, and the bird's eye view (*Figure 11* & *Figure 12*). This function is essential to improve the immersion of the virtual environment and allows users to discover the indoor environment more comprehensively.

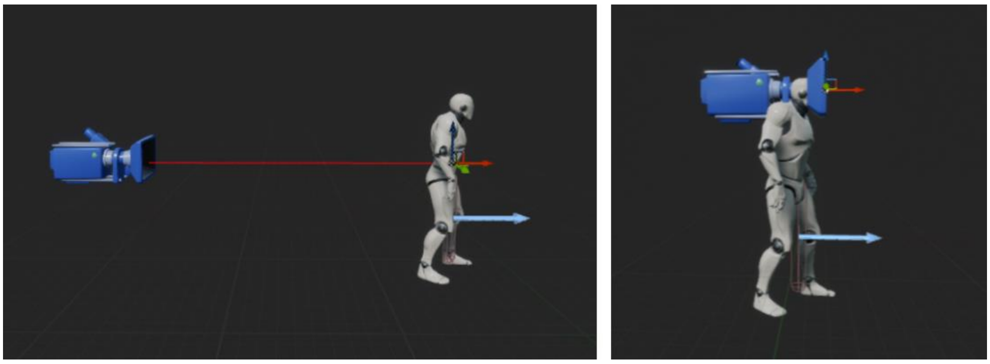


Figure 11. Camera location in third-person view (left), and first-person view (right)

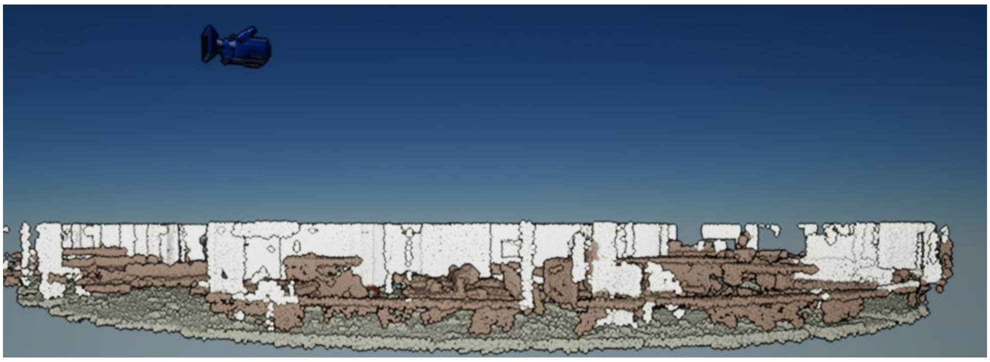


Figure 12. Camera location in bird's eye view

Compass: Compass is an important feature to improve the experience of interaction with the virtual environment. We apply a compass like a dynamic ruler and add some color marks for crucial landmarks of the building in the compass.

Figure 13. The compass with color marks

Mini-Map: A mini-map is a typical integrated feature of game visualization and 2D-cartography which aids users in orienting themselves within the virtual world. The blue triangle on the character icon in *Figure 14* shows the viewing direction.

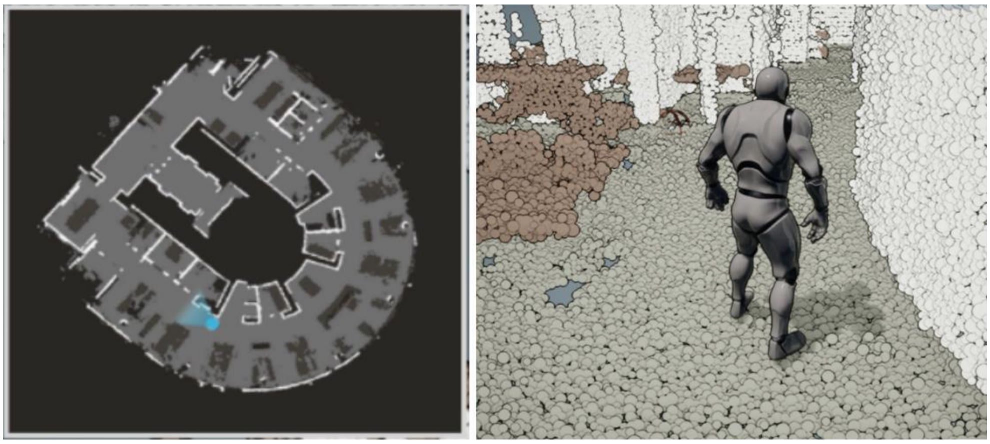


Figure 14. The mini-map

Landmark Text: Landmarks are static objects with predefined distinctive features in the model environment (Gim et al., 2021) and are often used as cues for action in situations of route navigation (Foo et al., 2005). The verbal indicator is a visual text animation, which fades in and progressively fades off to notify the users that they crossed an important landmark.

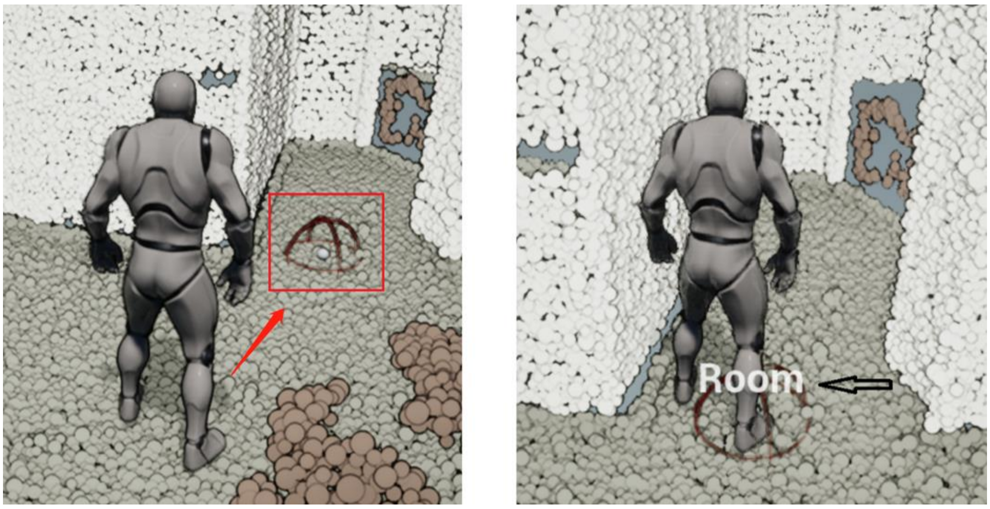


Figure 15. The collision sphere-landmark (left) and the Pop-Up text animation (right)

Roof Removal & Wall Transparency: Besides the bird's eye view, the roof can be removed, and glass materials can be applied on the wall to see the objects behind for facilitating gaining an overview of all the data. This has a better visualization effect compared with applying transparent rendering directly due to the overlapping effect (*Figure 16*).

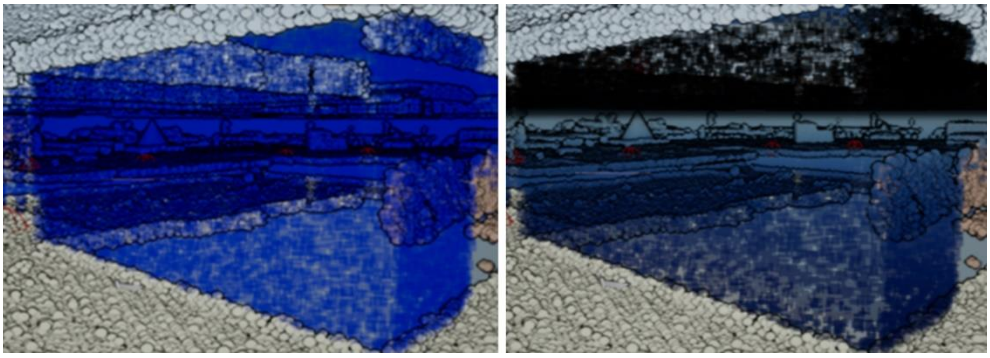


Figure 16. The wall displayed in transparency effect (left) and realistic glass materials (right)

Styles Changing: Users can switch between three different color styles to distinguish different objects and change the shape and size of points for different kinds of objects respectively.

4. Preliminary Results

We use a single-floor indoor point cloud data captured from a building in Rotterdam to test our designed modules by interacting with the point cloud data in the software (*Figure 17* & *Figure 18*).

Figure 17. The model with (left) and without (right) roof

5. Conclusion & Future Research

Visualization results show the game engine-based point cloud visualization has advantages in preprocessing and rendering efficiency, detail level, and volume perception, which are well suited for exploring crisis indoor environments. In the next stage, this research will focus on the more self-adaptive preprocessing module (such as dynamically adjusted denoising algorithms based on point density), automatic point cloud model import mechanisms (automatic alignment between the point cloud model and the transparent ground plane object), higher levels of customization (such as user-defined landmarks), and finally forming a 3D cartography and visualization framework suitable for indoor point cloud models. At last, our method will be compared with the mainstream mesh-based and voxel-based methods to evaluate its performance. In the future, the application potential of this research can be further explored by expanding to the multi-floor model, integrating with the outdoor model, and supporting VR/AR devices.

Figure 18. Visualization results: (A) circle points (first-person view), (B) square points (first-person view), (C) third-person view, (D) bird's eye view, (E) the smallest size points, (F) the biggest size points, (G) darker style 1, and (H) darker style 2

References

Andrienko, N., Andrienko, G., Fuchs, G., Slingsby, A., Turkay, C., & Wrobel, S. (2020). Principles of Interactive Visualisation. In N. Andrienko, G. Andrienko, G. Fuchs, A. Slingsby, C. Turkay, & S. Wrobel (Eds.), Visual Analytics for Data Scientists (pp. 51–88). Springer International Publishing. https://doi.org/10.1007/978-3-030-56146-8_3

Foo, P., Warren, W. H., Duchon, A., & Tarr, M. J. (2005). Do Humans Integrate Routes Into a Cognitive Map? Map- Versus Landmark-Based Navigation of Novel Shortcuts. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31(2), 195–215. https://doi.org/10.1037/0278-7393.31.2.195

Friedman, S., & Stamos, I. (2012). Online facade reconstruction from dominant frequencies in structured point clouds. 2012 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops, 1–8. https://doi.org/10.1109/CVPRW.2012.6238908

Gim, J., Ahn, C., & Peng, H. (2021). Landmark Attribute Analysis for a High-Precision Landmark-Based Local Positioning System. IEEE Access, 9, 18061–18071. https://doi.org/10.1109/ACCESS.2021.3053214

Kharroubi, A., Hajji, R., Billen, R., & Poux, F. (2019). CLASSIFICATION AND INTEGRATION OF MASSIVE 3D POINTS CLOUDS IN A VIRTUAL REALITY (VR) ENVIRONMENT. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W17, 165–171. https://doi.org/10.5194/isprs-archives-XLII-2-W17-165-2019

Neuville, R., Pouliot, J., Poux, F., De Rudder, L., & Billen, R. (2018). A Formalized 3D Geovisualization Illustrated to Selectivity Purpose of Virtual 3D City Model. ISPRS International Journal of Geo-Information, 7(5), 194. https://doi.org/10.3390/ijgi7050194

Rakotosaona M.-J., La Barbera V., Guerrero P., Mitra N. J., & Ovsjanikov M. (2019). PointCleanNet: Learning to Denoise and Remove Outliers from Dense Point Clouds. https://arxiv.org/abs/1901.01060v3

Ribes, A., & Boucheny, C. (2011). Eye-Dome Lighting: A non-photorealistic shading technique.

Virtanen, J.-P., Daniel, S., Turppa, T., Zhu, L., Julin, A., Hyyppä, H., & Hyyppä, J. (2020). Interactive dense point clouds in a game engine. ISPRS Journal of Photogrammetry and Remote Sensing, 163, 375–389. https://doi.org/10.1016/j.isprsjprs.2020.03.007

Zlatanova S. (2010). Formal modelling of processes and tasks to support use and search of geo-information in emergency response. Proceedings of the 13th annual international conference and exhibition on geospatial information technology and applications - map India 2010 - defining geospatial vision for India, 19-21 January 2010. https://repository.tudelft.nl/islandora/object/uuid%3Abd37a6e6-5f3f-4cca-a929-8ff0e40e8c84