International Cartographic Association
Association Cartographique Internationale

Deterministic Edge Extraction and Generalization for 3D Cartography

Dennis Dvořák [a], Tomáš Bayer [a,*]

[a] *Czech Technical University in Prague, Faculty of Civil Engineering, Prague, Czech Republic – dvorade3@cvut.cz, tomas.bayer@fsv.cvut.cz*

* Corresponding author

Keywords: digital cartography, edge extraction, cartographic generalization, topological skeleton, point cloud processing

Abstract:

Point clouds are a valuable source of spatial information about a territory, enabling high-resolution sampling of the Earth's surface. The resulting representation is discrete and dense, lacking an object-oriented approach, making it impossible to manipulate individual elements at once.

Laser scanning enables the detailed capture of important geometric characteristics of the sampled objects, specifically surfaces with zero/constant curvature (faces, planes) or regions with abrupt changes in curvature (various types of edges). These objects are desirable in cartography, primarily to improve terrain representation on maps, but they are also of interest in many scientific fields, such as geology, hydrology or land surveying.

Laser scanning provides dense point clouds; the scanned object is oversampled, making the spatial data redundant. These properties also affect the vector objects extracted from the point cloud. They often suffer from excessive oscillations (zig-zag sequences), incorrect topology (gaps or overlaps), and are too complex in shape for appropriate cartographic representation at the given map scale.

This paper proposes a new method automatically extracting edges from point clouds and providing their vector representation. The fundamental requirement is the topological correctness of the output data. Furthermore, an important role is played by the elimination of oscillations caused by oversampling, the reduction of excessive branching, and the removal of gaps created by post-processing. Whether in maps or 3D models, emphasis was placed on their appropriate cartographic representation; various cartographic generalization methods were tested for this purpose.

Our method is proposed as fully deterministic and does not require any training data. It is based on a modified skeleton, used to represent topological graphs of spatial objects involving point clouds. Consisting of multiple steps, intelligent branch pruning and gap filling based on a priority queue, i.e., from shortest to longest, are involved. To create the final cartographic representation, several generalization and smoothing algorithms, such as Douglas-Peucker and Bend Simplify, were tested to provide less oscillating and smoother polylines and polygons.

The new method was extensively tested on point clouds acquired by both airborne and ground-based laser scanning. These included point clouds of the Earth's surface, rock formations, buildings, and their interiors. The results achieved look promising and indicate the potential of our approach. The proposed method provides a topologically correct, continuous representation of spatial edges. Furthermore, the integration of generalization algorithms successfully adapts the extracted features for immediate cartographic use.

These promising results affirm the high potential of our method for practical applications in automated point cloud processing and offer a robust alternative to manual digitization and training-dependent machine learning models.

Acknowledgements

Acknowledgements of support for the project / paper / author are welcome.

References

Ge, X., Safa, I.I., Belkin, M. and Wang, Y., 2011. Data Skeletonization via Reeb Graphs. In: Shawe-Taylor, J., Zemel, R.S., Bartlett, P.L., Pereira, F. and Weinberger, K.Q. (eds.), *Advances in Neural Information Processing Systems 24 (NIPS 2011)*, Granada, Spain, 12–14 December 2011, pp. 837–845.

Natali, M., Biasotti, S., Patanè, G. and Falcidieno, B., 2011. Graph-based Representations of Point Clouds. *Graphical Models*, 73(5), pp. 151–164.

https://doi.org/10.5194/ica-abs-12-33-2026

Dey, T.K. and Wang, Y., 2013. Reeb Graphs: Approximation and Persistence. *Discrete & Computational Geometry*, 49(1), pp. 46–73.

Chazal, F. and Sun, J., 2014. Gromov-Hausdorff Approximation of Filament Structure Using Reeb-type Graph. In: *Proc., 30th Annual Symposium on Computational Geometry*, Japan, 8–11 June 2014, pp. 491–500.

Aanjaneya, M., Chazal, F., Chen, D., Glisse, M., Guibas, L.J. and Morozov, D., 2012. Metric Graph Reconstruction from Noisy Data. *International Journal of Computational Geometry & Applications*, 22(4), pp. 305–325.

Dey, T.K., Wang, J. and Wang, Y., 2018. Graph Reconstruction by Discrete Morse Theory. In: *Proc., 34th International Symposium on Computational Geometry (SoCG 2018)*, Leibniz International Proceedings in Informatics (LIPIcs), Vol. 99, Budapest, Hungary, pp. 31:1–31:15.

Cao, J., Tagliasacchi, A., Olson, M., Zhang, H. and Su, Z., 2010. Point Cloud Skeletons via Laplacian-Based Contraction. In: *Proc., Shape Modeling International Conference (SMI 2010)*, Aix-en-Provence, France, 21–23 June 2010, pp. 187–197.

Huang, H., Wu, S., Cohen-Or, D., Gong, M., Zhang, H., Li, G. and Chen, B., 2013. L1-Medial Skeleton of Point Cloud. *ACM Transactions on Graphics*, 32(4), Article 65, pp. 65:1–6

Abstracts of the International Cartographic Association, 12, 33, 2026
European Cartographic Conference – EuroCarto 2026, 8–11 September 2026, Brno, Czech Republic.
https://doi.org/10.5194/ica-abs-12-33-2026