International Cartographic Association
Association Cartographique Internationale

The use of graph convolutional networks in road selection for small-scale maps design

Albert Adolf [a,*], Izabela Karsznia [a]

[a] *Faculty of Geography and Regional Studies, University of Warsaw, Poland; a.adolf@uw.edu.pl, i.karsznia@uw.edu.pl*

* Corresponding author

Keywords: graph convolution network, supervised learning, feature selection, roads, small scales

Abstract:

Selection of relevant features for map representation is a crucial aspect of cartographic generalization. Historically, small-scale maps were the result of manual effort and subjective decisions of cartographers, however, automated generalization has gained influence over the recent years. While automatic methods have become popular and widely available for large-scale maps, there is still a lack of solutions dedicated to small-scale representations, which differ significantly from the large-scale ones. Road network is one of the most important thematic layers in general-purpose maps, indicating road transportation routes within and beyond urban areas. Recent advancements involving machine learning approaches, particularly those based on graph convolutions, demonstrate promising solutions in road selection (Karsznia, Adolf, Leyk, Weibel, 2024; Karsznia, Wereszczyńska, Weibel, 2022). These methods can be further enhanced by incorporating additional spatial information, such as residential areas (Lyu et al., 2022).

In this research, we implemented graph convolutional networks (GCN) to automate road selection. The scope of the research covered the use of source General Geographic Objects Database at a detail level of 1:250,000 to identify roads suitable for a target scale of 1:500,000. The database has been enriched with supplementary information, including proximity and graph centrality measures. To ensure efficient computational performance and as this research constitutes a work in progress, we limited our study to eight test areas, comprising 11,238 segments and 20,437 kilometers of roads.

In a preliminary stage, the source data (containing information about road length, category, class, surface material, number of lanes) for the road network has been enriched by incorporating attributes like centrality measures (road betweenness, closeness, load, and degree), road proximity as well as proximity to adjacent settlements. Subsequently, we implemented supervised learning using GCN. Data extracted from the atlas reference maps was used as a learning material (GGK, 1993–1997). The approach based on GCN was then compared to other machine learning models, specifically support vector machine (SVM) and neural network (NN), using the following performance metrics: accuracy, precision, recall, and F1 score (table 1).

Model	Accuracy	Precision	Recall	F1 score
GCN	52.88%	54.50%	70.86%	61.61%
NN	**72.07%**	71.82%	**84.30%**	**77.56%**
SVM	69.82%	**80.62%**	62.00%	70.09%

Table 1. Performance measures of the applied learning models. The highest performance metrics were bolded.

Accuracy determines the overall correctness of the model. Precision and recall focus on true positive predictions, with precision concerning the total number of predicted positives. Recall gives an indication of the model's ability to identify all relevant instances (true positives) or the absence of false negatives. F1 score, which is the harmonic mean of precision and recall, is particularly valuable in cases where in the dataset there is the unequal ratio of objects labeled as selected and omitted. The higher values of these metrics, the better performance of the learning model. At this stage of our research, the baseline methods outperform the proposed GCN method in terms of statistical measures. Except the recall metric, where the GCN method surpasses the SVM, the baseline methods exhibit superior performance across all other metrics (table 1). While the results achieved by the baseline methods are considered better than GCN at this stage, there is potential for improvement in the GCN implementation. The differences in models' performance may be the result of

https://doi.org/10.5194/ica-abs-7-2-2024

the variation in the requirements and characteristics of the input data. We have implemented the most basic GCN model prior to extending it, which may have contributed to its suboptimal performance.

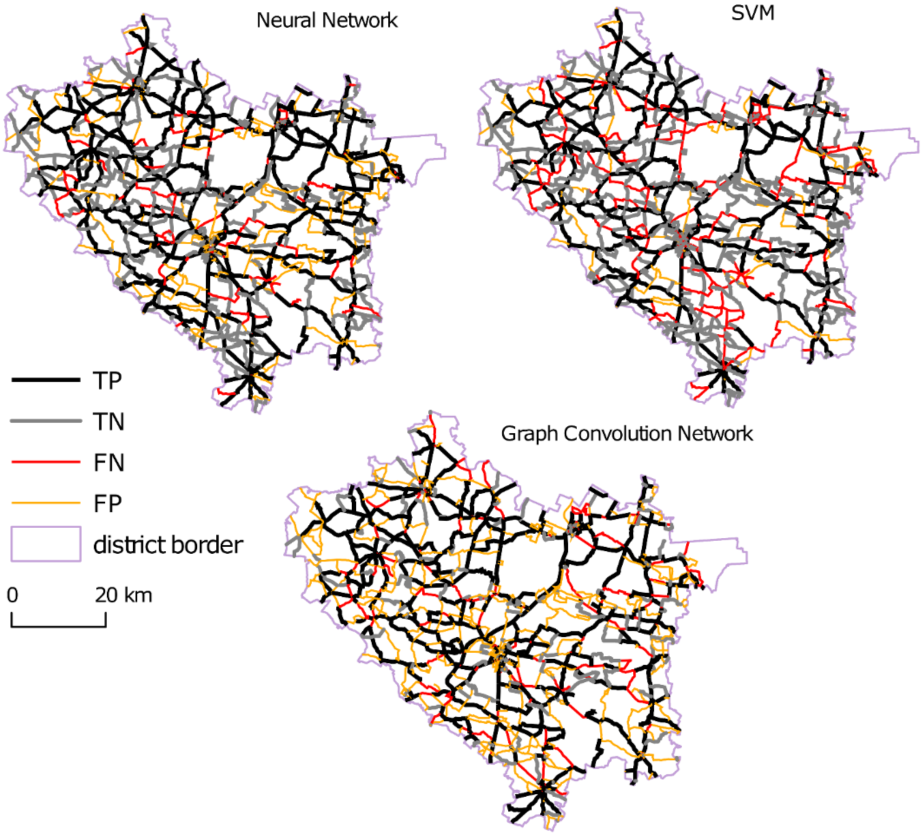

Figure 1. Visualization of road network selection with use of different models.

Moreover, the visualization of selected road networks does not align with the statistical measures. In figure 1, the selected networks appear similar and unfortunately share common shortcomings, such as disconnected road segments. While the statistical measures provide valuable insights into the quantitative evaluation, we believe that visual and qualitative assessments are of equal importance. Consequently, we are exploring suitable qualitative measures and visualization techniques to effectively evaluate our findings.

Acknowledgments

This research was funded by the National Science Centre, Poland, grant number UMO-2020/37/B/HS4/02605, "Improving Settlement and Road Network Design for Maps of Small Scales Using Artificial Intelligence and Graph Theory."

References

GGK. 1993–1997. Atlas Rzeczypospolitej Polskiej. Mapa 1:500.000, Główny Geodeta Kraju, Warszawa [Atlas of the Republic Poland, 1:500.000 map, The Surveyor General of Poland, Warsaw] (1993–1997). Head Office of Geodesy and Cartography, Warsaw, Poland.

Karsznia, I., Adolf, A., Leyk, S., and Weibel, R. 2024. Using machine learning and data enrichment in the selection of roads for small-scale maps. *Cartography and Geographic Information Science 51*, 1, 60–78.

Karsznia, I., Wereszczyńska, K., and Weibel, R. 2022. Make It Simple: Effective Road Selection for Small-Scale Map Design Using Decision-Tree-Based Models. *ISPRS International Journal of Geo-Information 11*, 457.

Lyu, Z., Sun, Q., Ma, J., Xu, Q., Li, Y., and Zhang, F. 2022. Road Network Generalization Method Constrained by Residential Areas. *ISPRS International Journal of Geo-Information 11*, 159.

Zheng, J., Gao, Z., Ma, J., Shen, J., and Zhang, K. 2021. Deep Graph Convolutional Networks for Accurate Automatic Road Network Selection. *ISPRS International Journal of Geo-Information 10*, 768.

https://doi.org/10.5194/ica-abs-7-2-2024 |