International Cartographic Association
Association Cartographique Internationale

Exploring Map Design Embedding Space: A Case Study of MapLayNet for Map Layout Recommendation

Jian Yang [a,*], Cheng Chen [b], Chenyu Zuo [c], Fenli Jia [a], Guangxia Wang [d]

[a] *School of Geospatial Information, Information Engineering University, China, jian.yang@tum.de, fljia_ieu@126.com*
[b] *Advanced Manufacturing Academy, Fuzhou University, Quanzhou, China, 228527248@fzu.edu.cn*
[c] *Department of Civil, Environmental and Geomatic Engineering, ETH Zürich, Zürich, Switzerland, zuoche@ethz.ch*
[d] *College of Geography and Environmental Science, Henan University, Zhengzhou, China, wgx@henu.edu.cn*

* Corresponding author

Keywords: map layout, map design, layout embedding, MapLayNet, ubiMap

Abstract:

The recent development of AI, especially deep learning, has raised broad research interest in achieving machine understanding of maps for various map-centered tasks, e.g., map information retrieval, map design. For instance, Smith et al. (2025) developed an object detection algorithm to extract tree symbols from digitized maps of 1890s Leeds and Edinburgh, which aimed to understand current urban forests. Christophe et al. (2022) applied Generative Adversarial Networks (GANs) to transfer map styles from simple to complex ones. Such research efforts have resonated with the trending technique of data representation learning, i.e., transforming data to vector representation to facilitate computing tasks ranging from pattern recognition to knowledge reasoning. However, most of these model outcomes, i.e., embeddings that encode map designs of training samples, are often treated as a side product of specific tasks without further exploration of their potential use in map design applications.

In this paper, we demonstrate using map layout embedding for map layout design. In particular, we developed GNN-based neural networks to learn map layout representation from crowd-sourced thematic map images online. We used the model to perform map layout design recommendations. With such data-driven effort, we argue that 1) learning embeddings with design monotonicity (i.e., the map layouts are embedded in a latent space that only little change of layout design can be identified between neigbhouring clusters of map laytous) can be helpful to building map design applications. 2) the proposed Streamlit-based demo advocates the paradigm shift from building specific map design tools to serving embedding models for AI-powered map-making solutions.

Our case study starts with building an interpretable and manipulable map layout embedding model. With an established map layout dataset, ubiMap (Yang et al., 2023), that contains thematic map images and manually prepared layout labels, we proposed a GNN-based model (Yang et al., 2025) for learning map layout representation without label supervision. The model introduces the structural features and proposes a dual-graph network architecture to enhance the model representation of complex map layouts, e.g., alignment and overlap, at global and local scales. We employed a weakly supervised learning strategy to ensure the model's generalization capability for ubiquitous maps. The model is trained with the combination of a triplet loss based on map layout similarity derived using heuristic rules and a mutual information loss to take full advantage of the dual-branch network architecture. MapLayNet's effectiveness is validated using both map layout retrieval tests and human evaluation. An ablation study has proved the effectiveness of the design in MapLayNet for structural enhancement. The analysis of embedding learned by MapLayNet has shown that the model can generate a concept hierarchy with compactness in lower-level layout patterns and partial-ordered concept relations in the higher-level layout abstraction.

With the learned map layout embedding, we build a map layout recommendation application using Streamlit[1], which is an open-source Python framework for data scientists to deliver interactive data apps. The demo application takes the manual inputs of map layout design preferences, e.g., types of map elements, desired properties of the map area, and spatial structure of map layout. Then, it recommends map images out of encoded map images in MapLayNet to meet the design preferences. The demo functionality is implemented with a three-step process, which consists of map element selection, map area preference specification, and spatial structure tuning. The first two steps are implemented on the metadata of the sample map images, which is simply a structured data query. As for the map area preference specification, we first implemented the width-height ratio of the map area, while more sophisticated shape preference can be used to tailor the sample recommendation outcomes. The final step, spatial structure tuning, leverages the

[1] https://streamlit.io

manipulable map layout embedding provided by MapLayNet, i.e., partial-ordered layout composition across the map layout embedding space, and enables the tuning of uniformity (the degree that map elements are evenly distributed on a map) and coverage (the degree that map elements has covered the space of a map) of spatial arrangement of map elements. The Streamlit-based UI to materialize the functionality above is shown in Fig. 1.

The case study, applying MapLayNet to facilitate map layout design, serves as an early investigation of embedding-focused map design services. Further questions can be pursued to approach practical use, such as incorporating more online map design resources and enriching the embedding model with more map design knowledge.

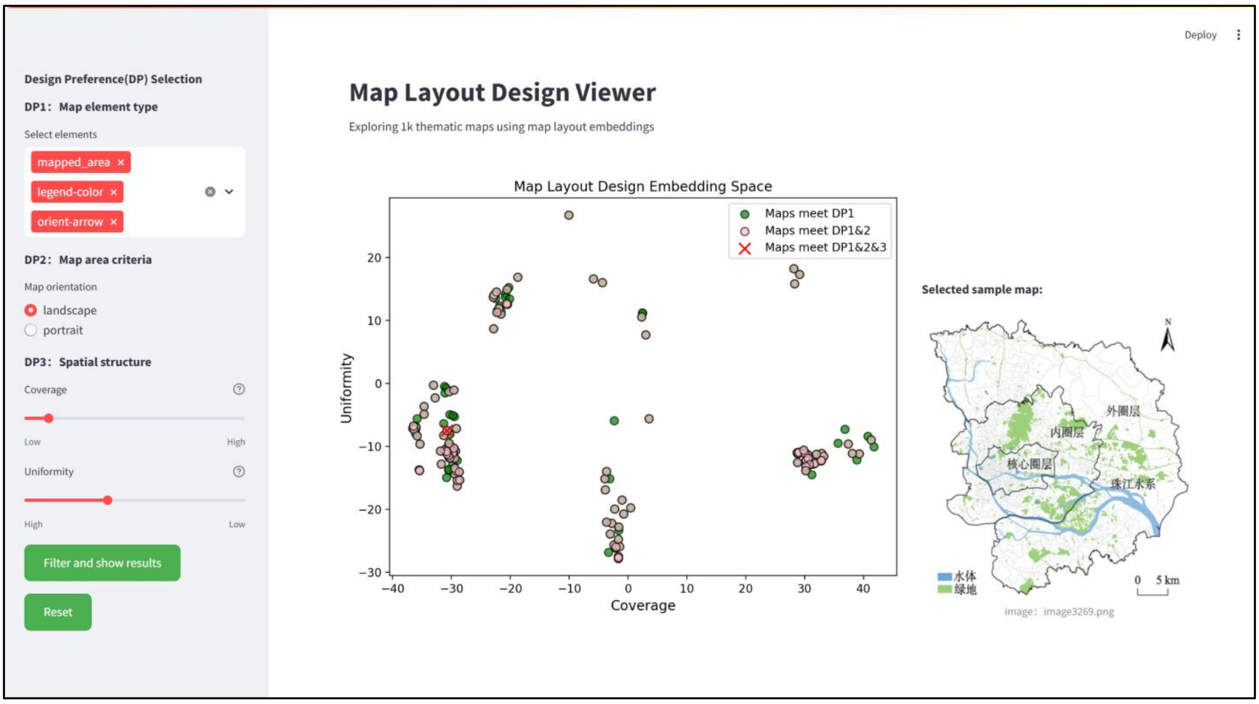

Figure 1. A Streamlit-based web application of map layout recommendation using MapLayNet.

Acknowledgements

This work was funded by China's National Key R&D Program (Grant No.2017YFB0503500), National Natural Science Foundation of China under Grant (No.41901335, No.42130112).

References

Christophe, S., Mermet, S., Laurent, M. and Touya, G., 2022. Neural map style transfer exploration with GANs. *International Journal of Cartography*, 8(1), pp.18-36.

Smith, E. S., Fleet, C., King, S., Mackaness, W., Walker, H., & Scott, C. E., 2025. Estimating the density of urban trees in 1890s Leeds and Edinburgh using object detection on historical maps. *Computers, Environment and Urban Systems*, 115, 102219.

Yang, J., Chen, C., Jia, F. L., Xie, X., Fang, L., Nie, Z. Y., Wang, G. X., Meng, L. Q., 2025. MapLayNet: Map Layout Representation Learning using Weakly Supervised Structure-aware Graph Neural Networks. *Cartography and Geographic Information Science.* (accepted)

Yang, J., Jia, F. L., Xu, Y. Q., Ding, L. F. and Liu, N. H., 2023. Building an Open Dataset of Ubiquitous Map Images for Cartographic Research: Practices and Prospects. *Abstracts of the ICA*, 6, p.281.