Topology-Aware Neural Vectorization of Printed Orienteering Maps*

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Abstract

The semantic reconstruction of legacy printed maps plays an important role in enabling structured terrain representations for downstream applications such as 3D terrain modeling and spatial analysis. While standard segmentation models handle general imagery, orienteering maps (ISOM standard) present a unique challenge due to dense, overlapping symbolism and strict topological requirements. [1] We propose a comprehensive deep learning framework for the automated digitization of these maps, structured into specialized streams: a Region-Net for area features (e.g., vegetation) and a multi-head Line-Net for high-frequency linear elements.

In this presentation, we present the architecture's core **contour extraction module** as a topological stress test [3]. Unlike traditional vectorization that treats all discontinuities as errors, our pipeline aims to distinguish between **extraction artifacts** (to be repaired) and **intentional cartographic breaks** (to be preserved in 2D but bridged for 3D modeling). To mitigate the lack of annotated data, we employ a synthetic data generation pipeline using OCAD exports, applying realistic scan degradations (noise, blur, domain shift) to train the model on "perfect" vector ground truths.

The methodology integrates a U-Net-based segmentation network[2] with a topology-driven post-processing stage. Predicted probability maps are converted to graph-consistent polylines via skeletonization and a custom cleanup workflow. This includes directional endpoint bridging and degree-2 vertex integration, designed to maintain the continuity of index (ISOM 102) and intermediate (ISOM

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101) contours without erroneously connecting distinct terrain features.

Preliminary results on a validation set of $N = 665$ tiles with the ratio 512×512 demonstrate the efficacy of the approach. While pixel-wise metrics across U-Net variants (ResNet18/34, U-Net++) are highly competitive (Dice ≈ 0.863, IoU ≈ 0.765), **topology-based evaluation** on held-out proof tiles reveals significant differences. The ResNet18-based model achieved the lowest rate of generalized topological errors (22.50 per tile) and unexplained dangles, outperforming heavier backbones. The resulting structured vector outputs (GeoJSON/SVG) serve as a
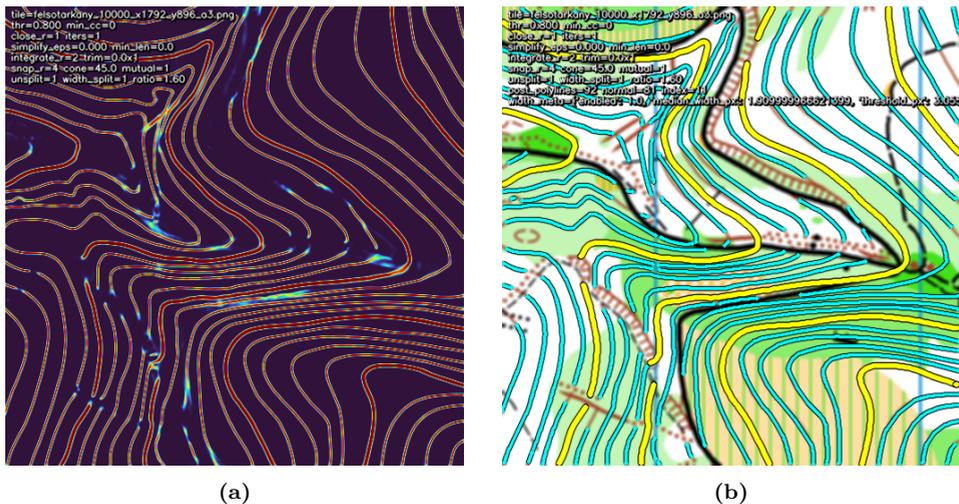
Figure 1. Automatic processing results: (a) the raw U-Net + ResNet18 prediction, and (b) the vectorization result overlaid on the original scan. Index contours (ISOM 102) are highlighted in yellow, and intermediate contours (ISOM 101) in blue.

semantic substrate for downstream GIS applications and 3D terrain reconstruction, enabling higher-level terrain interpretation beyond purely geometric elevation data. Our experiments further demonstrate that pixel-level segmentation metrics alone are insufficient to characterize map-quality linework, as topological consistency is primarily shaped by the vectorization and post-processing policy. The proposed pipeline is being extended with a Region-Net stream and context-aware rules for formally modeling allowed topological breaks. Preliminary results of these components will also be presented in the conference paper. Further work will investigate the transfer of the method to other topographic map domains. To support reproducibility, the annotated dataset is intended to be released under an open license.

References

[1] R. Petitpierre, F. Kaplan, I. di Lenardo: *Generic Semantic Segmentation of Historical Maps*, in: Proceedings of the Computational Humanities Research Conference, 2021.

[2] O. Ronneberger, P. Fischer, T. Brox: *U-Net: Convolutional Networks for Biomedical Image Segmentation*, in: Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015, vol. 9351, Springer, 2015, pp. 234–241.

[3] J. Vynikal, J. Pacina: *Automatic Elevation Contour Vectorization: A Case Study in a Deep Learning Approach*, ISPRS International Journal of Geo-Information 14.5 (2025), p. 201, DOI: 10.3390/ijgi14050201.