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Automatic Schematization of Transit Networks: An Algorithmic Approach

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Abstract:

While schematic transit maps are a cornerstone of urban mobility, their manual design remains a complex and time-consuming task. This paper presents an automated algorithmic workflow designed to transform raw geospatial data into functional, octilinear diagrams. By leveraging a multi-step methodology—incorporating variable-density grid snapping and graph-based path optimization—the proposed approach converts OpenStreetMap (OSM) data into schematized layouts that adhere to the classic design principles established by Harry Beck. The algorithm is evaluated against the Berlin S+U-Bahn network and its transferability is tested using the Paris Metro and regional highway systems.

The schematization of public transport networks has been profoundly influenced by Beck's 1931 London Underground map (Kent, 2021), which prioritized topological connectivity over topographic accuracy. Modern schematic maps typically employ octilinear layouts—restricting line segments to horizontal, vertical, and 45° angles—to enhance legibility. Despite the digital evolution of cartography, creating these maps often requires significant manual intervention. This study explores a computational framework to automate this process using OpenStreetMap geodata.

The methodology begins with the extraction of OSM "route" relations and associated station nodes. To resolve the complexity of transit hubs where multiple platforms represent a single functional station, a clustering algorithm is applied. Nodes within a threshold d (optimized between 150m and 180m in the case of Berlin) are aggregated into a single representative centroid.

A variable-density "Snap-Grid" governs station placement. Using Kernel Density Estimation (KDE), the algorithm identifies high-density urban centers and lower-density suburban areas (fig. 1, left). Grid spacing is dynamically adjusted—for instance, maintaining 250m in the core while expanding to 500m or 1000m in the periphery—to allow for the expansion of congested areas and the compression of outer stretches. Stations are then "snapped" to the nearest grid point (fig. 1, right).

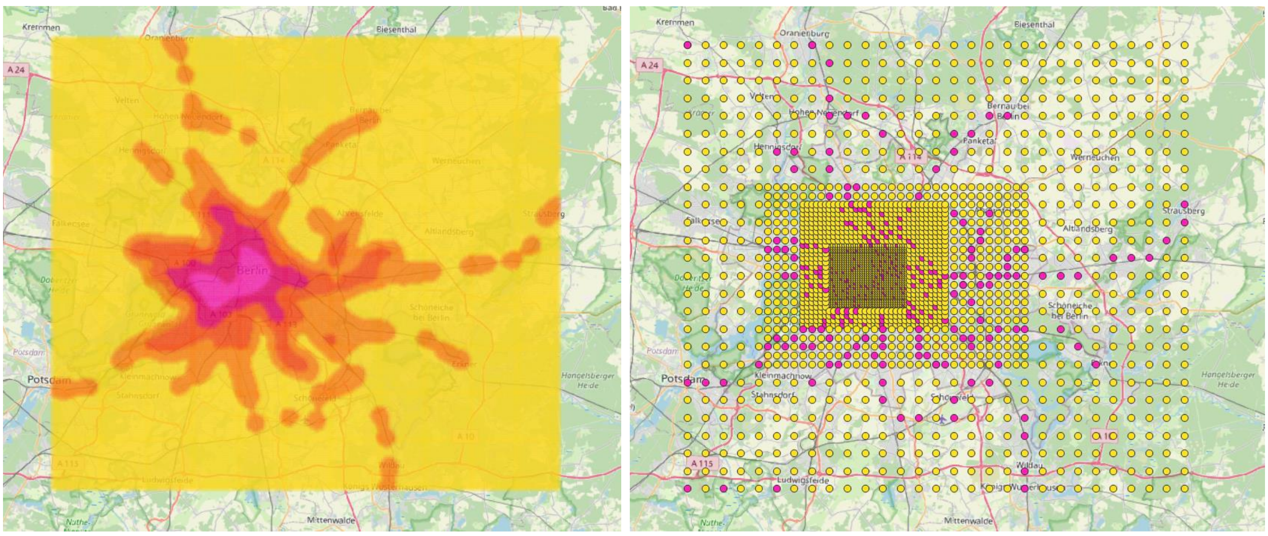

Figure 1. Left: KDE used to define variable grid spacing. Right: Snap-Grid with snapped station positions (in pink)

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The schematization is treated as a pathfinding problem on a graph using Python´s NetworkX library. Optimal paths are calculated between snapped coordinates using specific constraints:

- Octilinear Routing: Edge weights penalize non-standard angles, forcing paths into 45° increments.
- Geometric Refinement: An iterative displacement algorithm identifies "zig-zag" segments and sharp 90° turns, shifting stations to nearby grid points to maximize line straightness.
- Family Bundling: Lines belonging to the same family (e.g., Berlin's S2 and S25) are assigned a "Lineset" to ensure consistent colouring and parallel routing.
- Peripheral Simplification: For intersection-free suburban sections, the algorithm enforces strict linear alignment toward the terminus.

The algorithm was applied to the Berlin S+U-Bahn network, producing a final schematic map that adopts key features of professional diagrams, such as distinct symbols for transfer hubs and terminus labeling. Comparing the output to the official Berlin (BVG) target map reveals high adherence to octilinear principles. However, human-designed maps maintain superior "macro-structures". For example, the circular shape of the Berlin "Ringbahn" is less pronounced because the algorithm optimizes local segments rather than global geometric shapes.

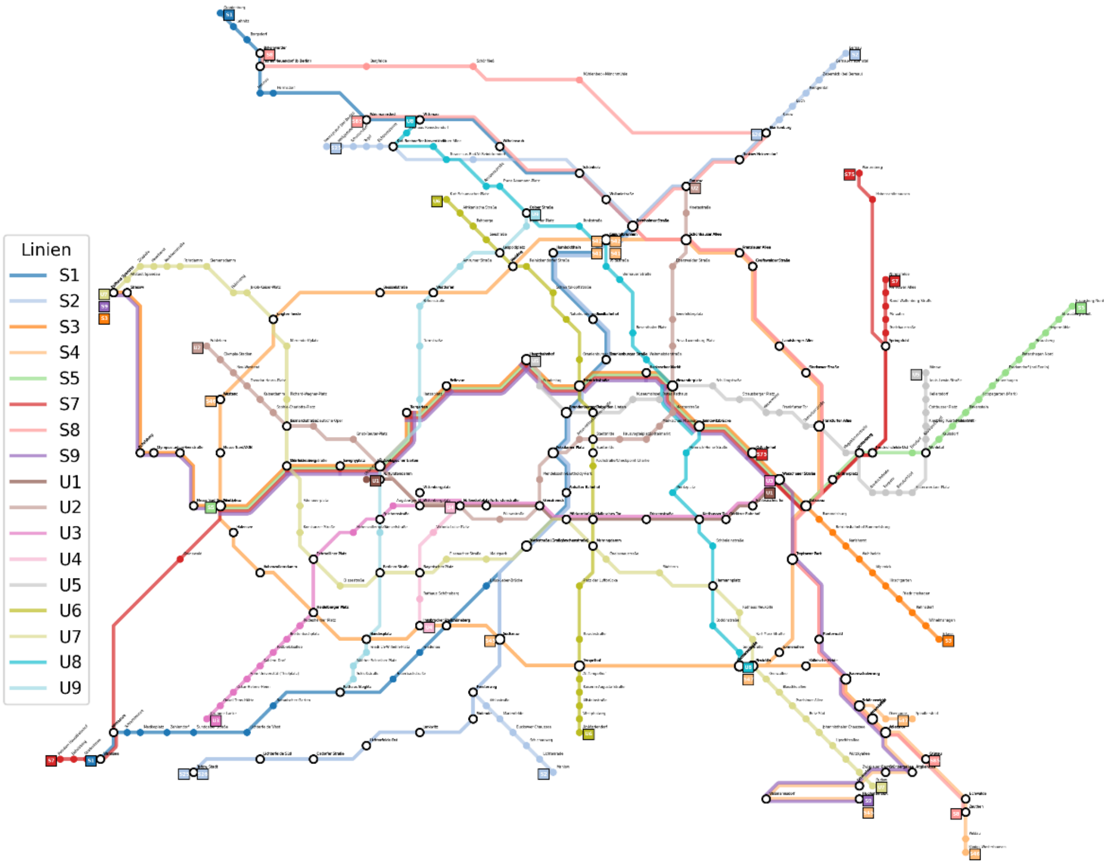

Figure 2. Automated schematic generation of the Berlin transit network.

The framework's transferability was tested on the Paris Metro/RER system, effectively managing parallel line bundles. Conversely, application to highway networks highlighted challenges: inconsistent OSM tagging and the vast distances between exits necessitated significant manual adjustments. This research demonstrates that a grid-based algorithmic approach can successfully generate legible schematic maps from raw geospatial data. While the automated results currently lack the aesthetic "leitmotif" of manual designs, they provide a high-quality foundation that reduces the labour required for professional map production.

References

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