Road Generalization Method Based on Minimum Steiner Tree

Yuki Kobayashi, Yonghwan Kim,

Daisuke Yamamoto*

Nagoya Institute of Technology

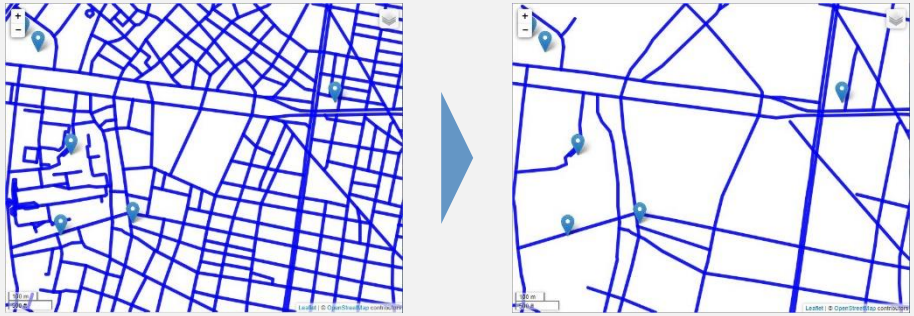
Japan

Background

- **Examples of Illustrated map**
  - Usage of illustration maps: Tourist guides, ramen shop maps, etc.
  - Maps simplified to suit specific purposes are easier for users to understand.

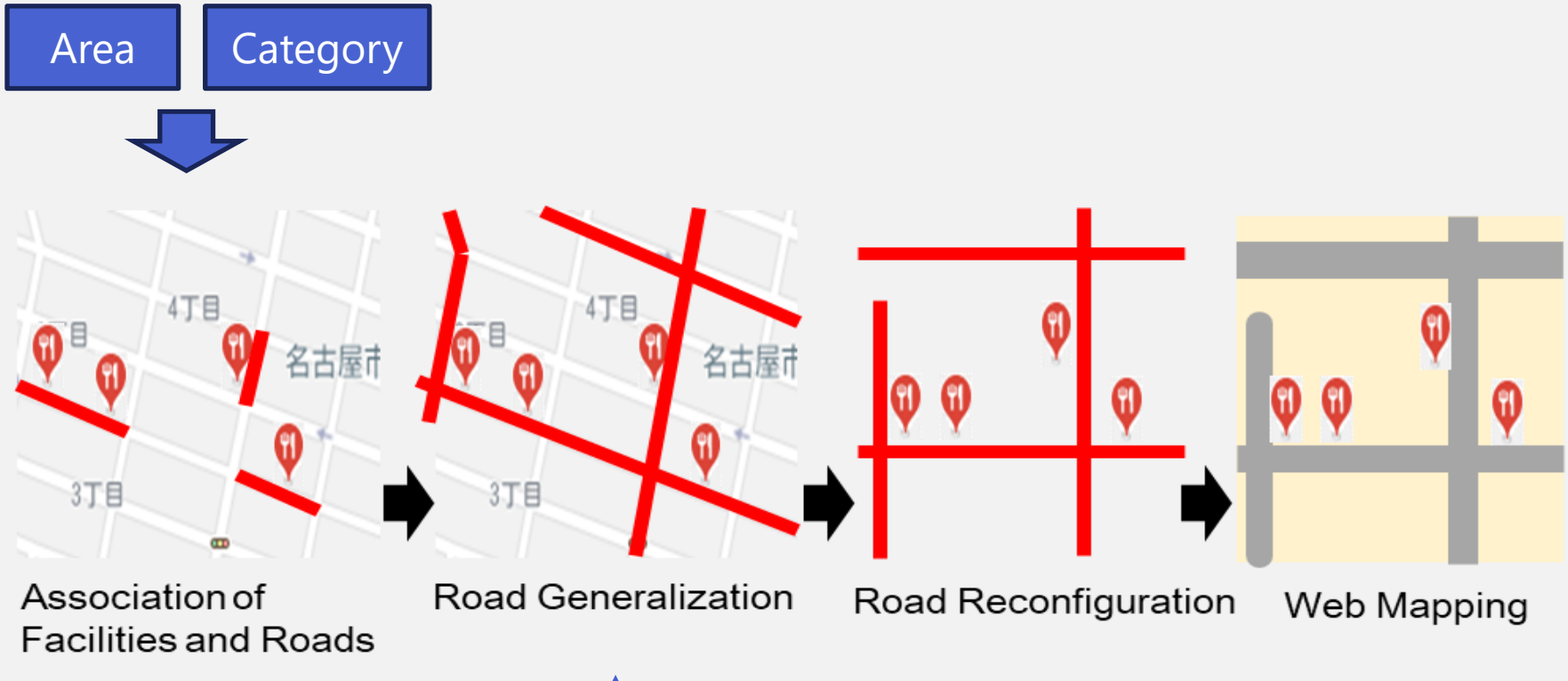
Example of Illustrated map

- **Road Generalization**
  - Less important roads are pruned based on road type and length, displaying only necessary roads



Example of Road Generalization

Dynamic Generation of Illustrated Maps



Previous Research

- **Road Generalization Method Based on Hierarchical Stroke Networks**
  - Roads are selected so that users can find routes to all designated facilities.
  - The system generates the optimized routes by exploring all possible paths in each loop road area.

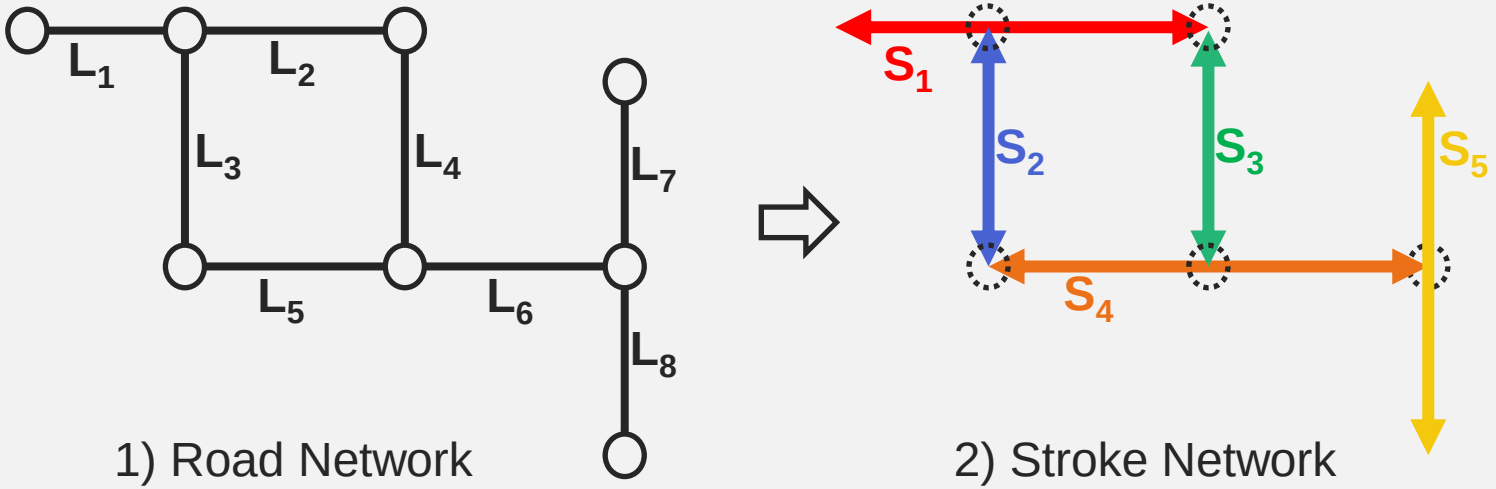
❶ Select main roads that represent the characteristics of the region

❷ Obtain the areas where facilities are located

❸ Generate a route to the facility

Stroke

- **Stroke**
  - A group of road links that follow a continuous path based on the concepts of cognitive psychology
  - Ex : $S_1 = \{L_1, L_2\}$ $S_2=\{L_3\}$ $S_3=\{L_4\}$ $S_4=\{L_5, L_6\}$ $S_5=\{L_7, L_8\}$
  - Utilized in road generalization methods.



Research Objective and Approach

Issue	The full search method used in previous techniques can result in long computation times.

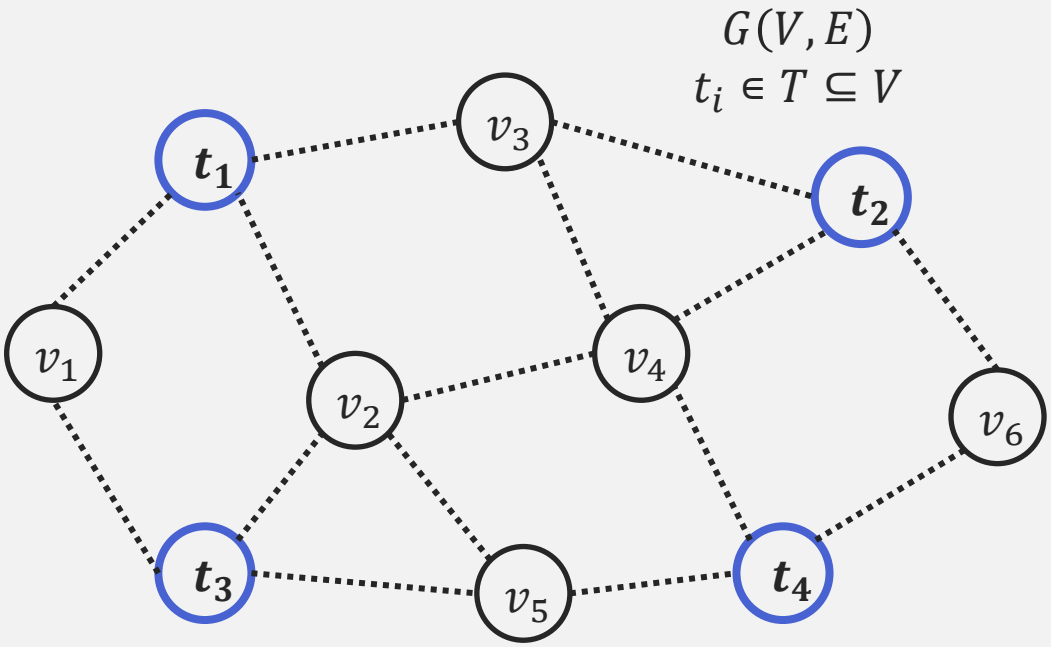
Proposed Solution :
Reducing Execution Time

⇨ **Proposal of a Road Generalization Method Based on Graph Theory**

By utilizing an approximation algorithm for the minimum Steiner tree, it is possible to efficiently determine local SN.

What is a Steiner Tree?

- In an undirected graph, a Steiner tree is a tree that includes all nodes from a given subset (terminal set).
- The Steiner tree with the smallest sum of edge weights is called the minimum Steiner tree.
- The approximation algorithm used ensures the solution is within double the optimal minimum Steiner tree.



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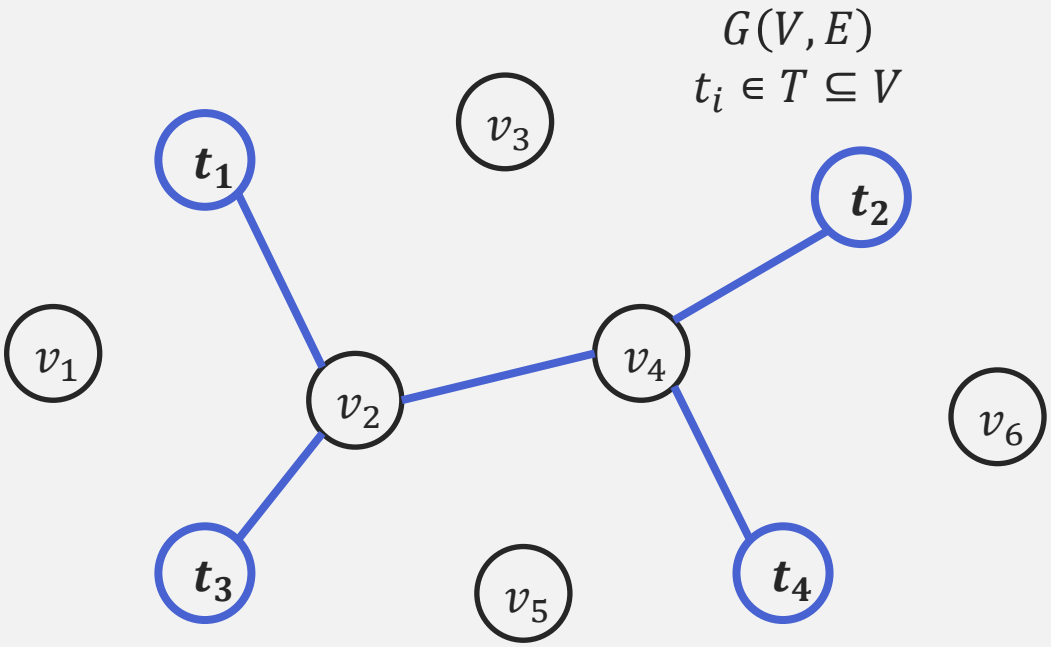
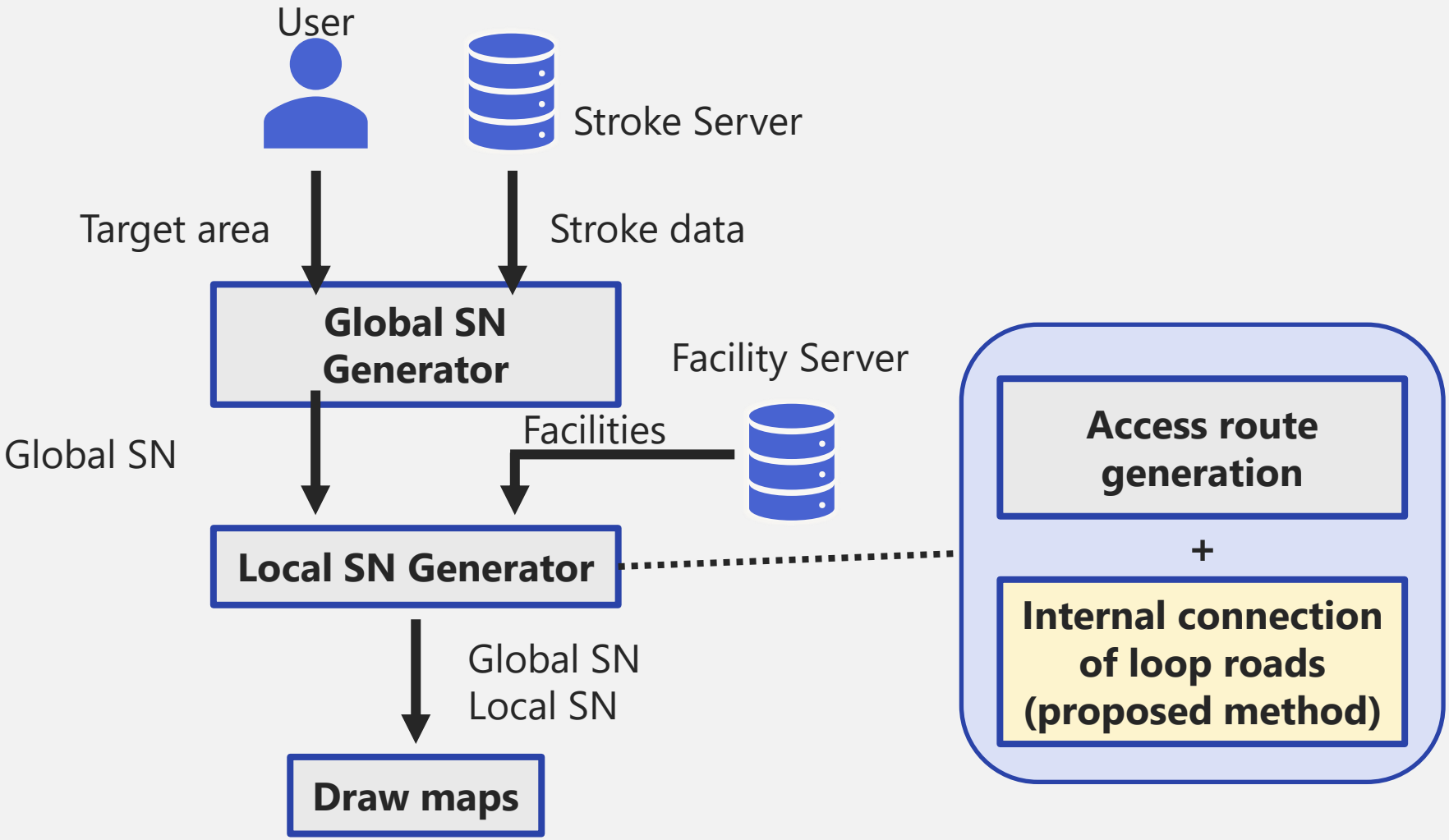
- "Within a factor of $(2 - \frac{2}{|T|})$ of the minimum Steiner tree
- Order : $O(|T||V|^2)$



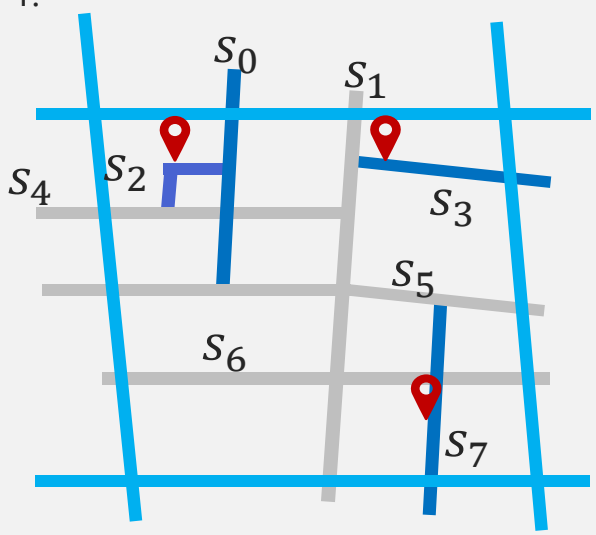
Flow of the Proposed System



Generating Local SN

1. **Access Path Generation**
2. Convert the strokes of loop roads into a stroke graph
3. Approximation of the minimum Steiner tree
4. Determination of local SN

1.



Converts strokes in loop roads into an undirected graph and approximates the minimum Steiner tree to determine the local SN

Generating Local SN

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2. **Convert the strokes of loop roads into a stroke graph**
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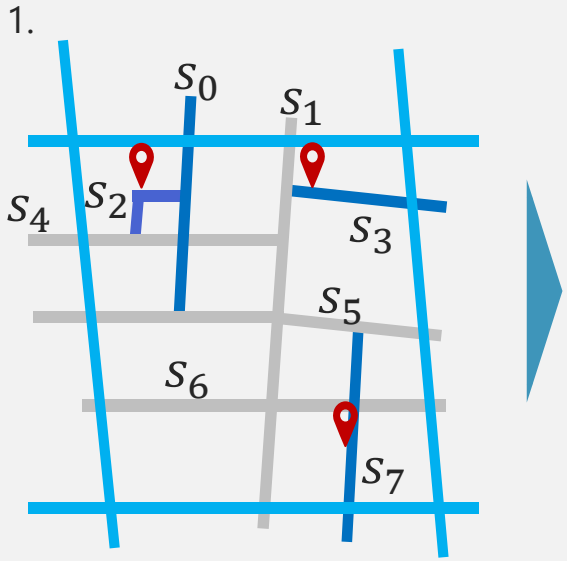
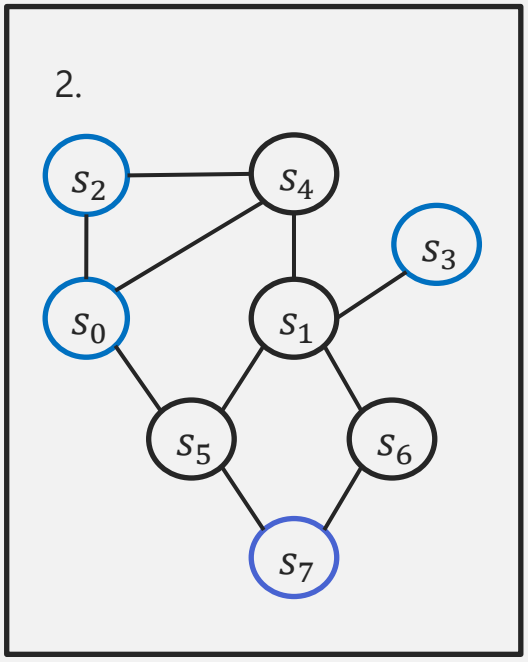
The blue nodes correspond to access routes





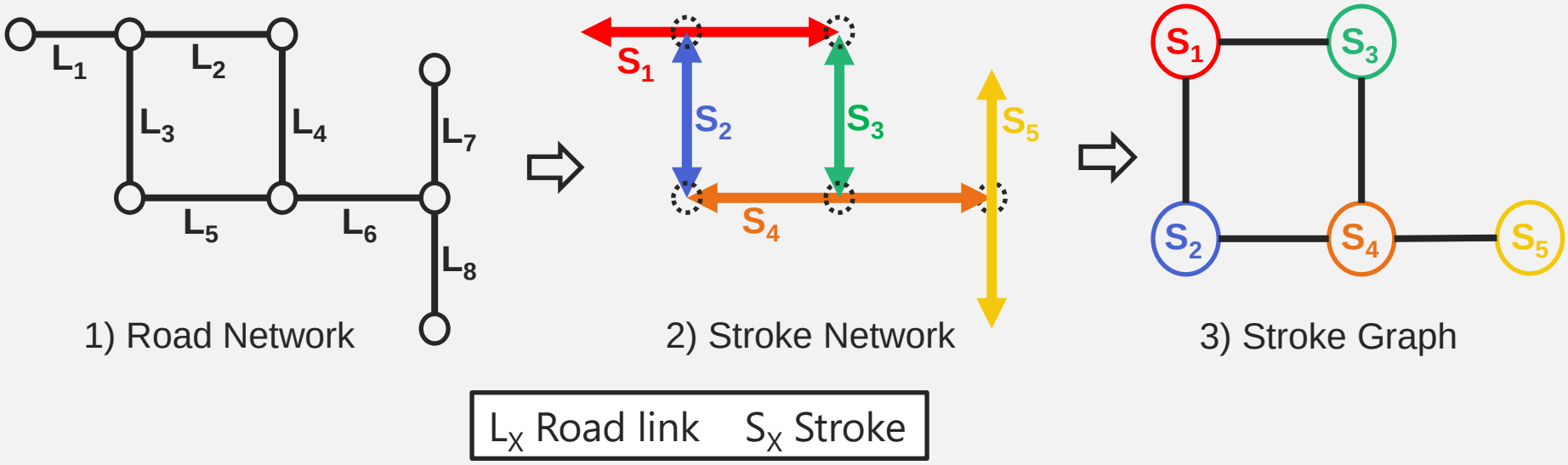
Facility

Global SN

Access path

Stroke graph

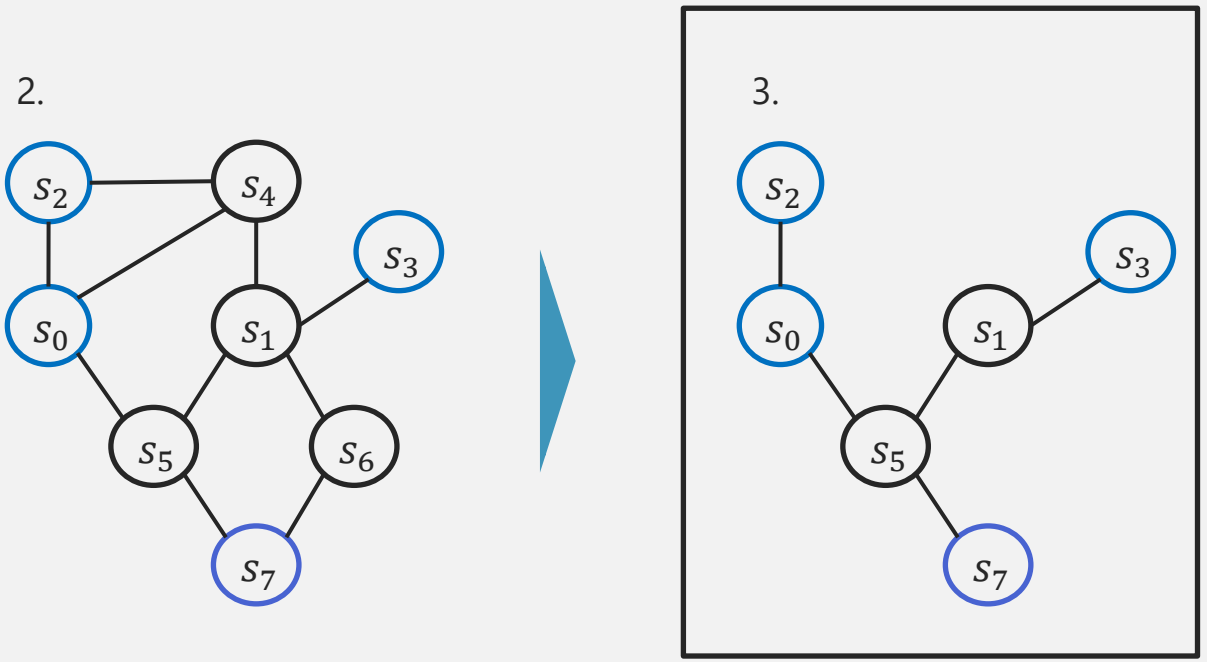
- **Stroke graph**
  - Representation of stroke intersections as a graph.
  - Ex: S1 intersects (connects) with S2 and S3.
    → In the Stroke Graph, S1 is connected to S2 and S3
  - **The new concept** proposed in our previous study[1].



[1] D. Yamamoto, Y. Hiura, and Y. Kim. K-Fewest Turn and Shortest Path Algorithm based on Stroke Graph. Proc. of ACM SIGSPATIAL 2023 Workshop (IWCTS '23), pp. 32-41.

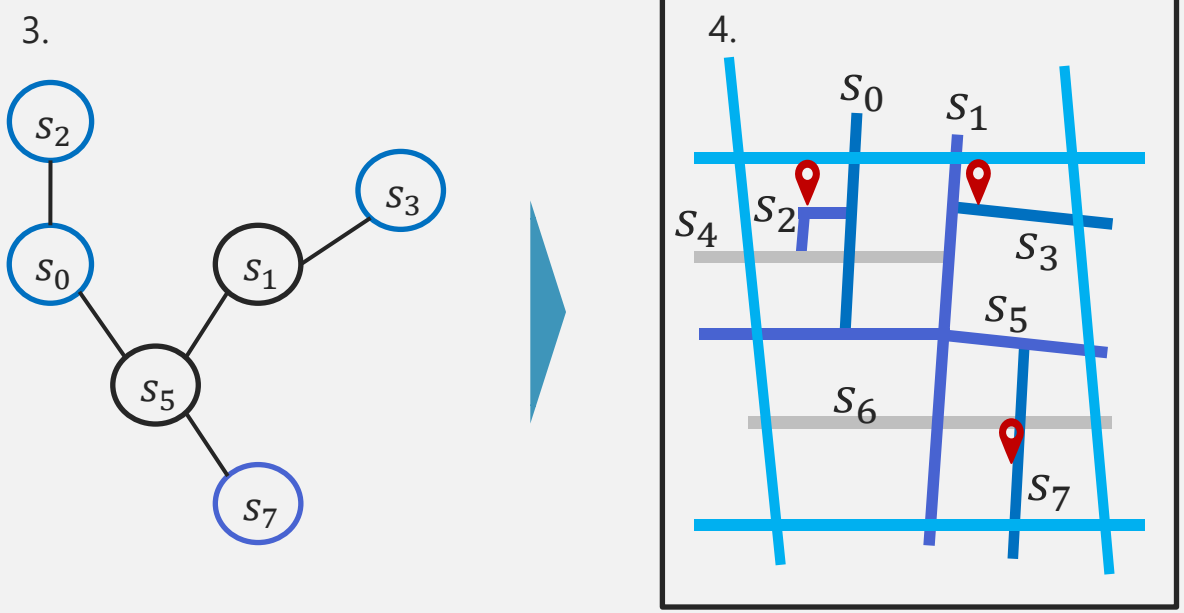
Generating Local SN

1. Access Path Generation
2. Convert the strokes of loop roads into a stroke graph
3. **Approximation of the minimum Steiner tree**
4. Determination of local SN

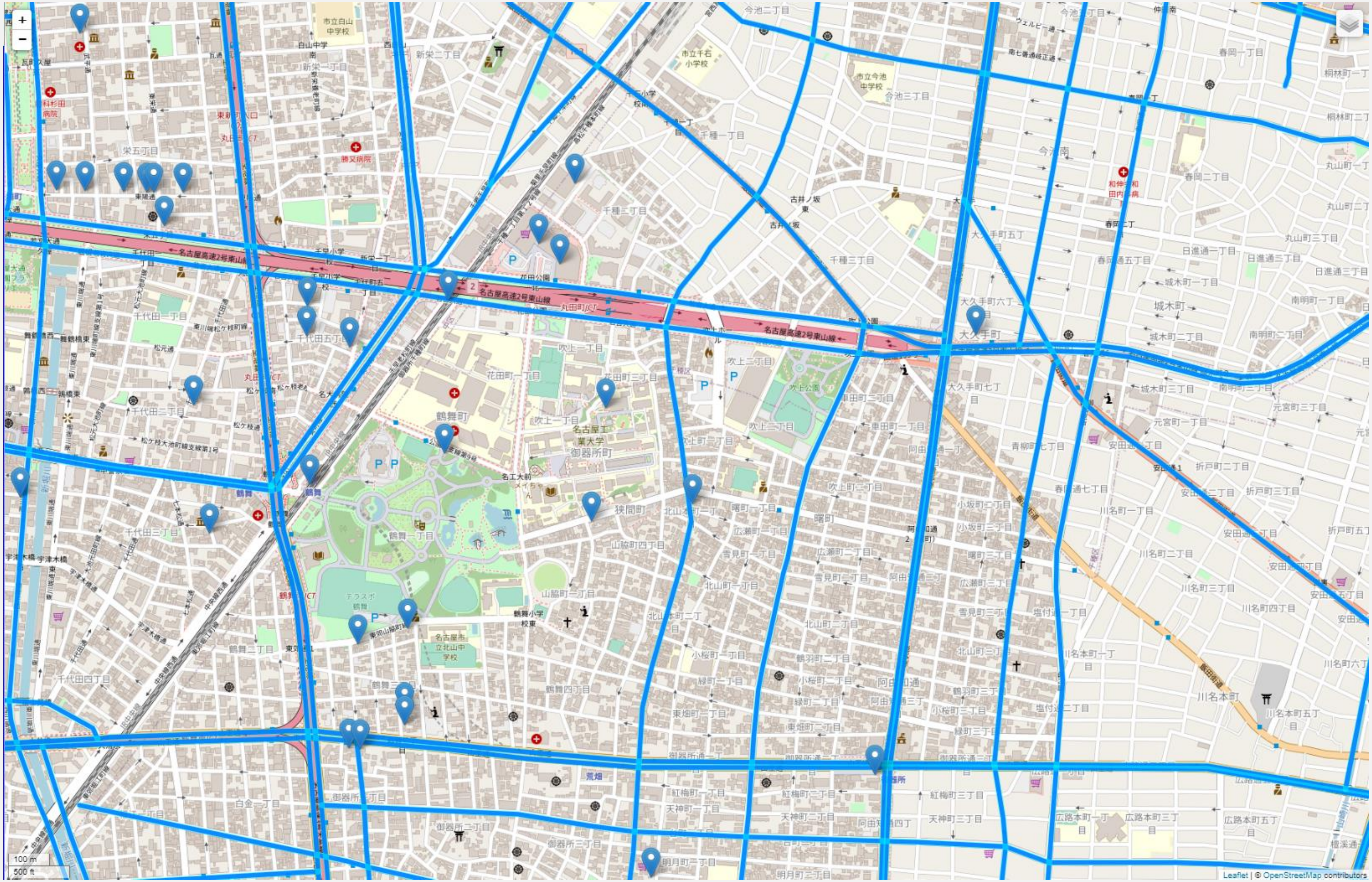


Generating Local SN

1. Access Path Generation
2. Convert the strokes of loop roads into a stroke graph
3. Approximation of the minimum Steiner tree
4. **Determination of local SN**



Demo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鶴舞町
名古屋工業大学
御器所町
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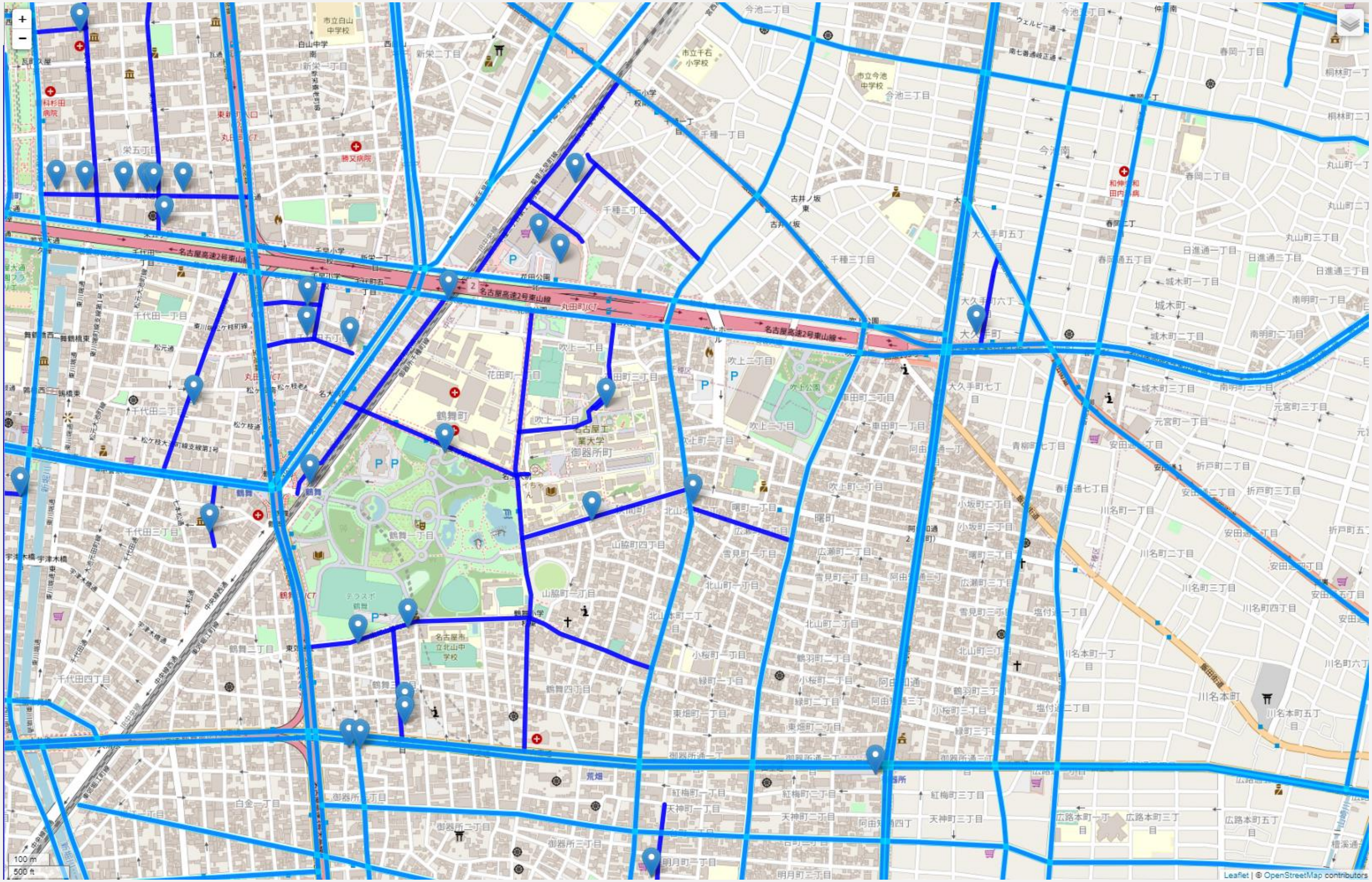
Demo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鶴舞町
名古屋工業大学
御器所町
100 m
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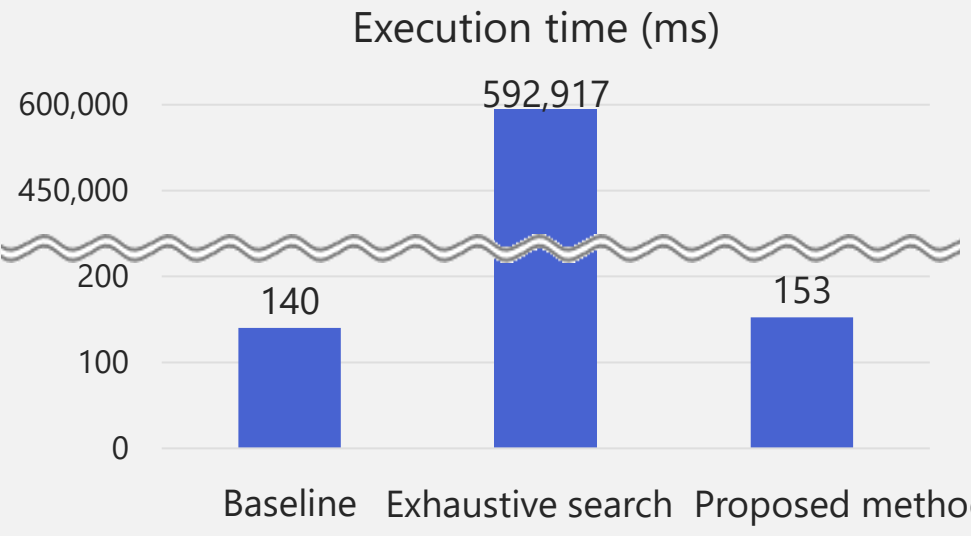
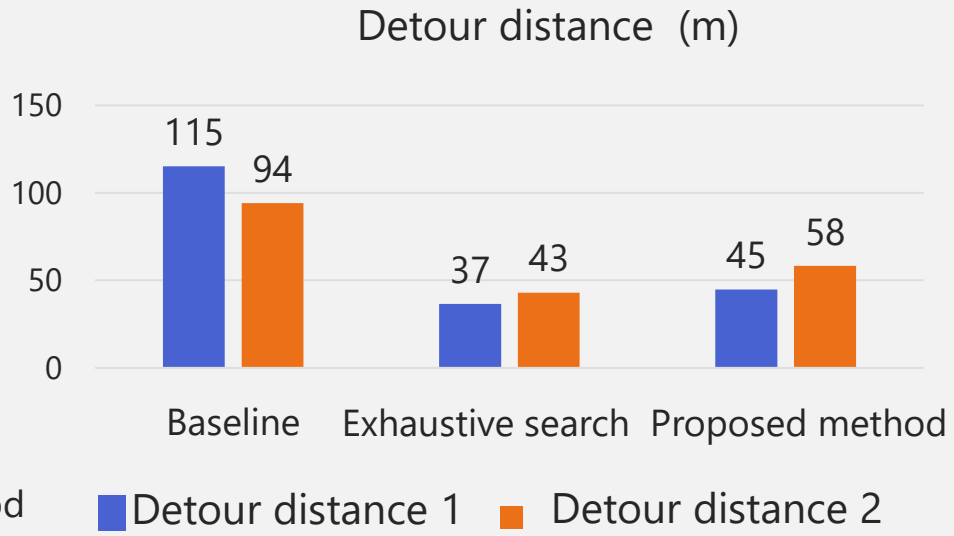
Evaluation Experiment

- **Objective:**
  - Verify the effectiveness of the proposed method.
- **Comparison Methods**
  - **Conventional Method 1**: Baseline (access routes only)
  - **Conventional Method 2**: Exhaustive search
  - **Proposed Method**: Approximation of the minimum Steiner tree
- **Experiment Setup**
  - Comparison of execution time and detour distance
    - **Detour distance 1:** Measures the detour distance within the loop road area
    - **Detour distance 2:** Measures the detour distance for the entire area, including both inside and outside the loop road.

Evaluation Experiment | Experimental Results





The proposed method greatly improved execution time while maintaining a detour distance similar to full exploration.

Suitable for real-time applications such as digital signage.

Conclusion

- **Conclusion**
  - A road generalization method based on an approximation of the minimum Steiner tree was proposed.
  - It significantly reduced computation time while maintaining a certain level of accuracy.
- **Future work**
  - Optimization of the road occupancy rate threshold for Global SN.
  - Enhancing algorithms for acquiring loop roads and improving accuracy.