Categorical Range Queries on Spatial Networks

G8 Rahul Saladi, Xiaofei Zhao, Akash Agrawal and Anuj Karpatne
http://www-users.cs.umn.edu/~rahuls/cs8715/

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Problem Statement

Input for Preprocessing

▶ A spatial/road network.
▶ A set of facilities lying along the edges of the network.

Input for Query

▶ position on the network \((q)\)
▶ query distance \((d_q)\)

Output

▶ All the facilities which are within a network distance of \(d_q\) from \(q\).
Example

Figure: A simple road network. red rectangles are facilities. blue circles are vertices. The query distance is 10 miles. The facilities shown in red lie within 10 miles of Q.
Why is the problem Important/Hard

- **Importance** Extremely useful query in mobile routing apps.

- **Hardness** Existing solutions (RER and RNE) require scan of the entire network in the worst case.

- Running a Djikstra’s or A* algorithm for sparsely populated facilities can lead to poor performance.
Proposed Approach: Notion of Path Neighbourhood

Figure: Example network

<table>
<thead>
<tr>
<th>Vertex</th>
<th>Neighbours</th>
</tr>
</thead>
<tbody>
<tr>
<td>v1</td>
<td>A, C, D</td>
</tr>
<tr>
<td>v2</td>
<td>A, B</td>
</tr>
<tr>
<td>v3</td>
<td>A, C, D</td>
</tr>
<tr>
<td>v4</td>
<td>B, C, D</td>
</tr>
<tr>
<td>v5</td>
<td>B, C, D</td>
</tr>
</tbody>
</table>

Table: Neighbours of each vertex

Figure: Facility neighbourhood graph
Query distance = 10

Dequeue D from Heap
Heap --> B

No entry in the heap is changed
Asymptotic analysis

- **Space occupied** $O(\# \text{ neighbours of all the vertices } + \# \text{ neighbours of all the facilities}).$

- **Query time** $O(\# \text{ neighbours of all the facilities reported}).$
Novelty

- Dijkstra’s algorithm applied on facilities graph. Not on the original network!
- Queries can be posed on any facility group.

**Figure:** Sparse distribution of facilities on a large network.

**Figure:** Facility neighbourhood graph facilitates efficient querying.
Best Case Scenario

> **Space** occupied is linear.

> **Query time** is $O(k)$ where $k$ are the number of facilities reported.

**Figure:** Facilities distributed uniformly on the grid and the Washington Avenue. **Red** rectangles are facilities.
Worst Case Scenario

Figure: Red rectangles are the facilities. Each vertex has all the facilities as its neighbour. How realistic is this road network?

- Space occupied is quadratic.
- Query time is also high.
Future Work (Cost model for Average Case Scenario)

- Perform cost model analysis for our technique as well as RER and RNE technique.
- We considered a simplified network.
- Each vertex has degree less than or equal to four.
- Each edge has unit length.
- Facilities are uniformly distributed on the network.
Future Work (Experimental Evaluation)

- We plan to implement our solution on synthetic and real-world datasets.

- Compare our solution with RER and RNE techniques.
Thank you!