Rendezvous on Street Networks

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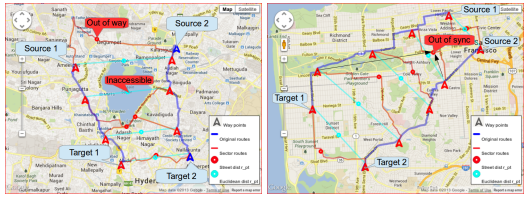
1. Introduction

- **Goal**: Given the initial and target locations for two agents, find the distance optimal rendezvous location on street network with minimum number of queries to the server.
- **Example Scenarios**:
  - meet a friend on your way from office to home
  - rendezvous between automated taxis for load balancing

2. Challenges

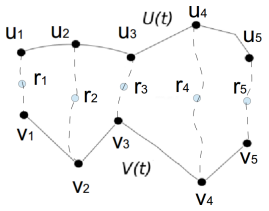
- **Database query challenge:**
  - Minimize number of queries to the server
- **Rendezvous challenges:**
  - Minimize the total travel distance between the agent's original path and rendezvous location
  - Minimize waiting time at rendezvous location
  - Find accessible rendezvous location



Bad examples of rendezvous location

3. Overview

- **Agents**: A_1 and A_2
- **Uniformly discretized way points along the agents' paths:** $U(t) = \{u_1, u_2, \ldots, u_n\}$ and $V(t) = \{v_1, v_2, \ldots, v_n\}$
- **Potential rendezvous locations are selected as mid points along the paths joining the way points**: $R = \{r_1, r_2, \ldots r_n\}$



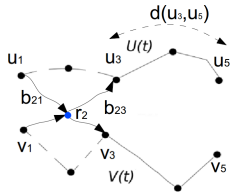
- **Objective:** Find the rendezvous location with minimum number of queries to the server such that:

$$r^* = \underset{r_i}{\text{argmin}} \; D(r_i, j)$$

- $D(r_i, j)$ returns the minimum path length $p^*_{i,j}$ for a given rendezvous point r_i and no. of way points skipped j

$$p^*_{i,j} = \min_k \; p_{i,k}$$

$$p_{i,k} = b_{i,k} + b_{i,(j+k+1)} + d(u_1, u_k) + d(u_{(j+k+1)}, u_n)$$



- **Types of queries to find distance optimal rendezvous location:**
  - **Naive**: Query total number of possible paths $O(n^3) = \frac{n(n-1)}{2} * |R|$
  - **Smart**: Query only bridge distances $b_{i,k}$ and $b_{i,(j+k+1)}$
  - **Euclidean**: Free queries
  - **Hybrid**: Euclidean + Smart queries

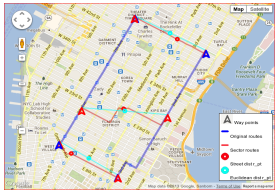
4. Rendezvous Algorithm

- **Propose hybrid algorithm to combine Euclidean and street distance:**

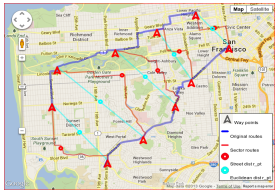
1. Find all path lengths in Euclidean space
2. Sort them in ascending order
   - If the shortest path p^* is not expressed in street network distance then make it so and repeat step 2
   - Else p^* is the true optimal path and the corresponding rendezvous point r^* is the distance optimal rendezvous location

5. Results

Good examples of Euclidean approximation



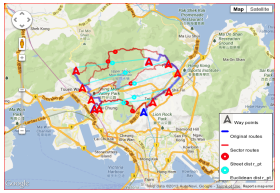
New York



San Francisco

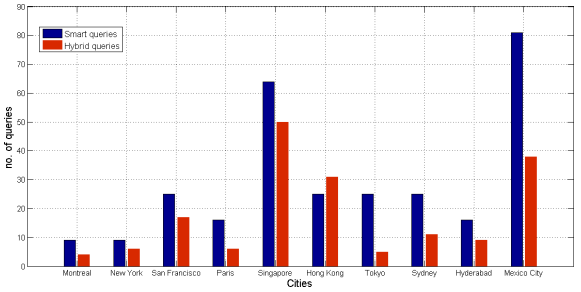
Bad examples of Euclidean approximation

Montreal



Hong Kong

- Comparing number of **smart** and **hybrid** queries for 10 cities



- Hybrid algorithm saved **40%** queries on average compared to the smart queries while obtaining a **distance optimal solution**

- Rendezvous locations obtained using hybrid algorithm were all **accessible**

Cities	Euclidean distance (km)	Real distance (km)	Hybrid distance (km)	No. of queries				Euclidean rpt accessible?
				Naive	Smart	Hybrid	%Saved	
Montreal	2.8	3.4	3.4	27	9	4	**55.55%**	No (Park)
New York	2.9	3.3	3.3	27	9	6	**33.33%**	Yes
San Francisco	6.0	7.4	7.4	125	25	17	**32%**	Yes
Paris	7.3	8.0	8.0	64	16	6	**62.50%**	Yes
Singapore	12.9	15.0	15.0	512	64	50	**21.87%**	Yes
Hong Kong	6.9	11.5	11.5	125	25	31	**-24%**	No (Forest)
Tokyo	8.3	9.2	9.2	125	25	5	**80%**	Yes
Sydney	7.9	9.0	9.0	125	25	11	**56%**	No (Harbor)
Hyderabad	5.5	6.9	6.9	64	16	9	**43.75%**	No (Lake)
Mexico City	19.2	21.4	21.4	729	81	38	**53.08%**	Yes
Average	7.9	9.5	9.5	192.3	29.5	17.7	**40%**	—

6. Conclusion and Future Work

- **Conclusion:**
  - **Leveraged the property that Euclidean distance is the best first approximation** for real street distance
  - **Proposed a hybrid algorithm** for efficient rendezvous by combining Euclidean and real street distances
  - **Reduced query cost** to the server using the proposed hybrid algorithm
- **Future Work:**
  - Online and real-time implementation of the hybrid algorithm
  - Scale the current implementation for multiple agents

7. References

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- **Bast et al.** "Fast routing in very large public transportation networks using transfer patterns", Algorithms – ESA, 2010
- **Papadias et al.** "Group nearest neighbor queries", International Conference on Data Engineering, 2004

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