



GEO
INFORMATION

Methods in Spatial Analysis

PS | LV.Nr. 856.141

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PS Overview and Contents

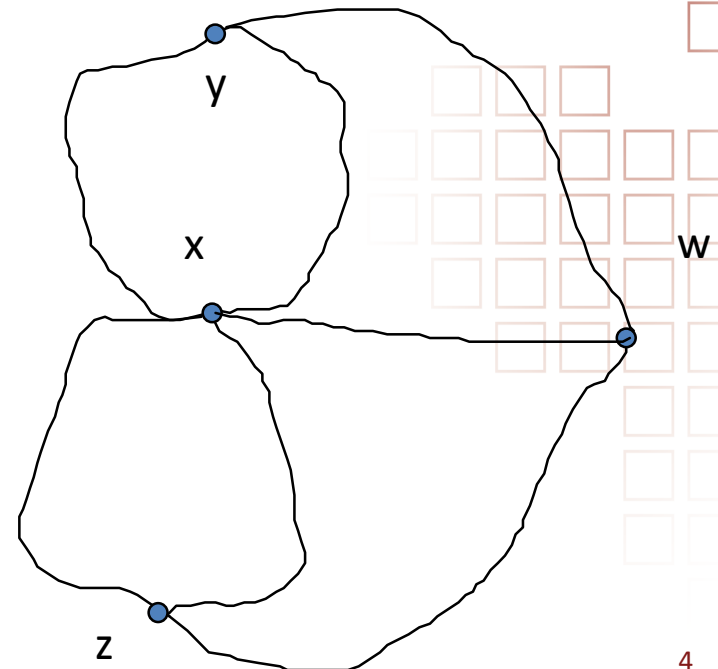
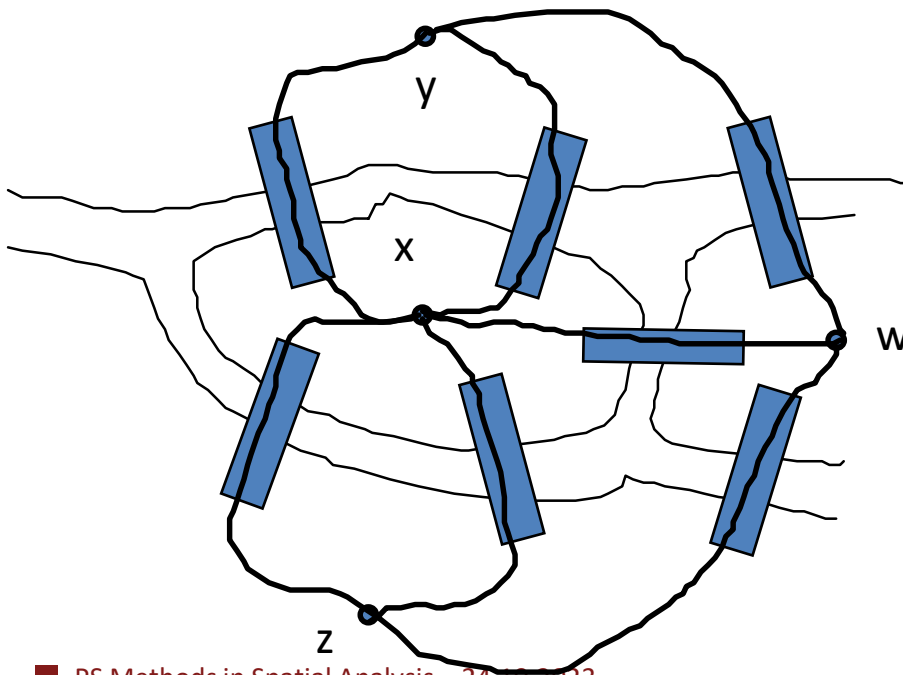
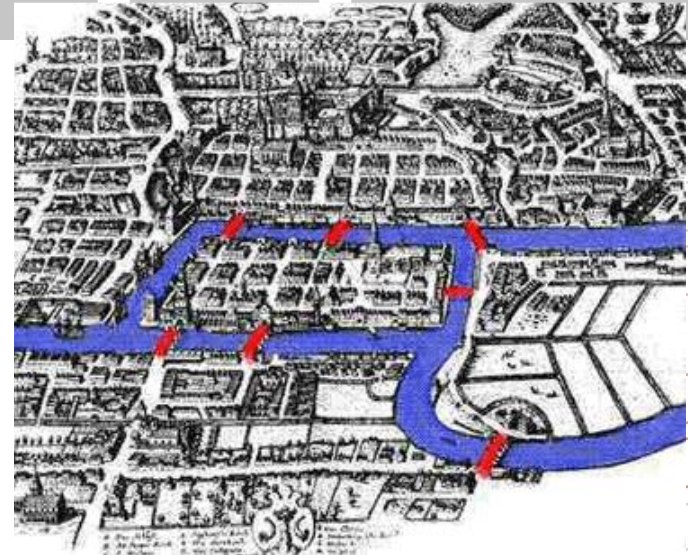
Date	Where & When	Content
10-Oct-2023	GI-Lecture 0900-1500	Administration, Introduction to Spatial Analysis, Basics
17-Oct-2023	GI-Lecture 0900-1500	Distance Analysis Selection & Aggregation
24-Oct-2023	Online 0900-1100	Network Analysis
07-Nov-2023	Online 0900-1100	Spatial Interpolation
14-Nov-2023	Online 0900-1100	Terrain Analysis
21-Nov-2023	Online 0900-1100	Visibility Analysis
28-Nov-2023	Online 0900-1100	Calculating Solar Potential
05-Dec-2023	Online 0900-1100	Hydrological Modelling (Surface Runoff)
12-Dec-2023	Online 0900-1100	Weighted Overlay
09-Jan-2024	GI-Lecture 0900-1500	Cost Surface Analysis, Concluding Remarks

- Important for the following application areas:
 - Supply infrastructure: water, electricity, oil/gas pipeline, sewer system,
 - Transport infrastructure
 - Telecommunication networks

→ Collection of simple geometries (point, line) requires a theoretical concept: **GRAPHS**

Network :: Graphs

- Leonard **Euler**, solved the **Seven Bridges of Königsberg** problem in **1736**;
Euler laid the foundations of graph theory and topology.

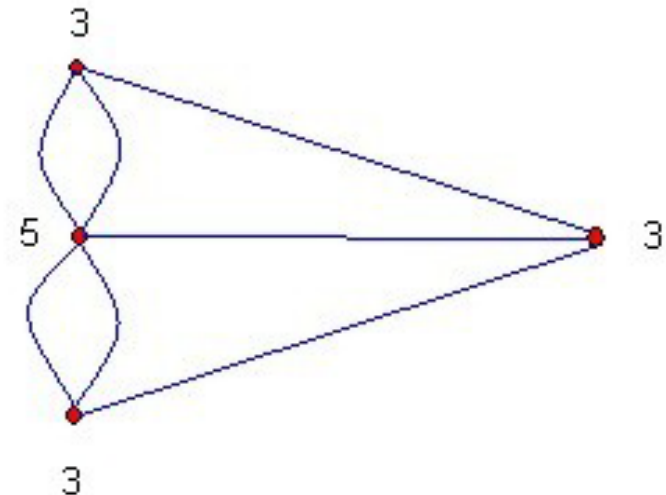
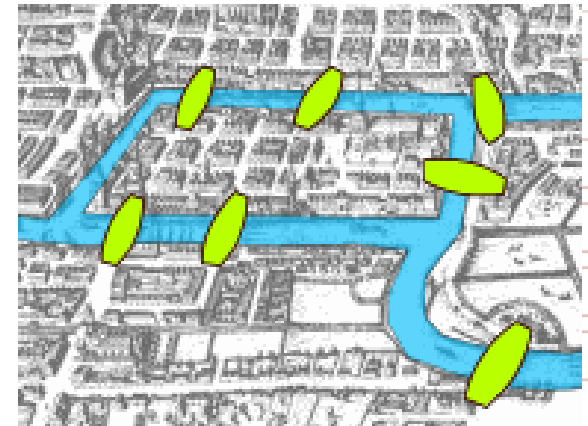


■ Königsberger Brückenproblem cont'd

- Warum ist ein Euler'scher Weg nicht möglich?

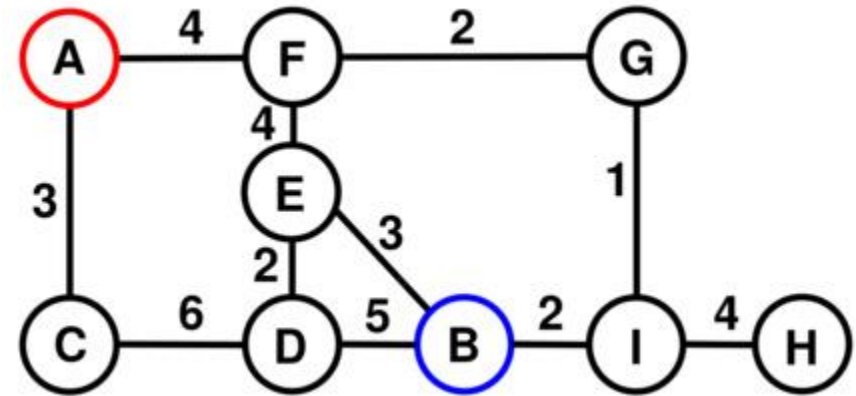
>> zu allen Ufergebieten / Inseln (i.e. Knoten) führt eine ungerade Anzahl an Brücken!

>> es darf maximal zwei Ufer/Inseln/Knoten mit einer ungeraden Anzahl an Brücken geben – der Rest muss gerade sein!



■ Definitions:

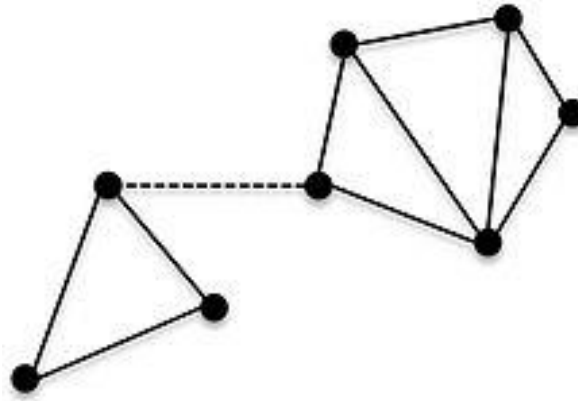
- Vertex/Node
- Edge/Arc
 - Directed vs. undirected
- Graph
 - Contains of nodes & vertices
- Network:
 - Ordered pairs of nodes and edges with attributes (e.g. weights)
- Weights: distance, driving time, energy consumption, ...



■ Examples:

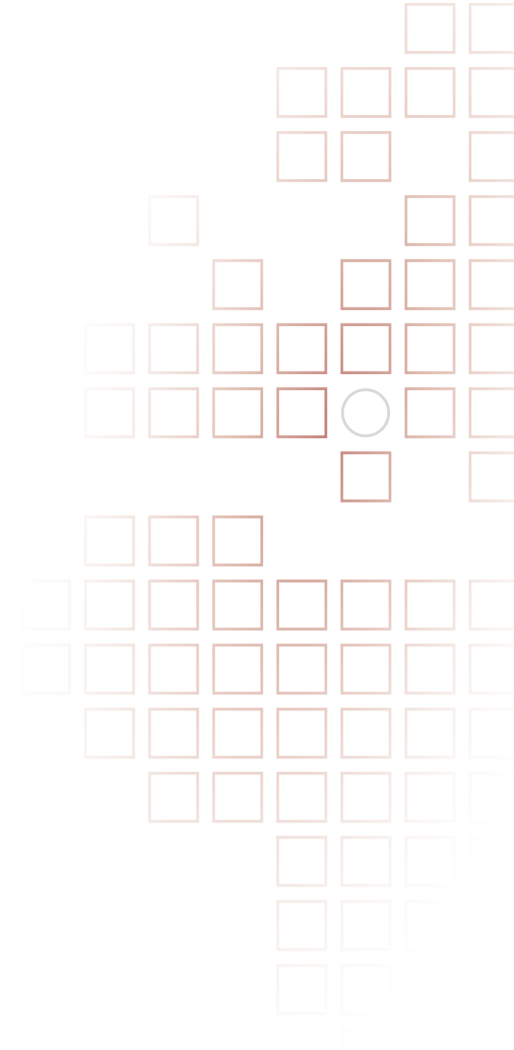
- Road
- Infrastructure (electricity, water,)
- Railway
- ...

- Topological „clean“ Graph (Arc-Node Topology)
 - Nb! Connectivity

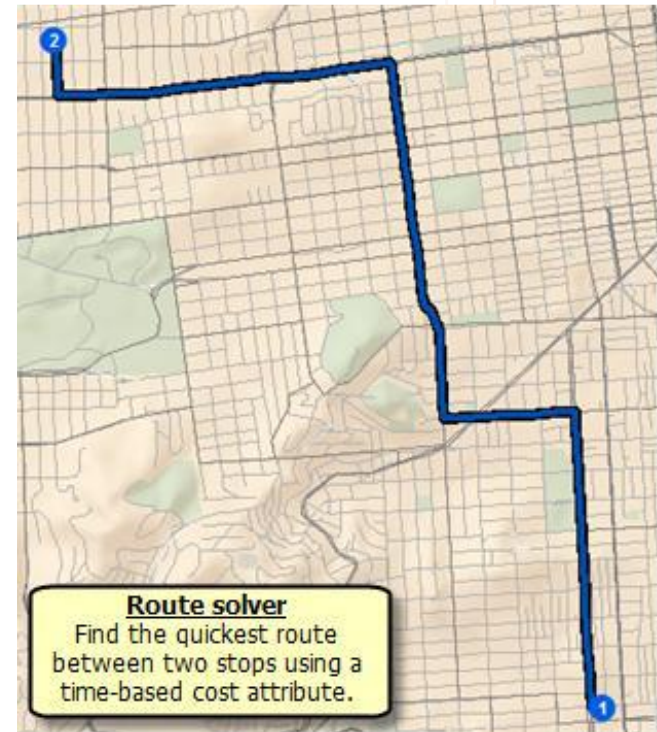


- Definition of any problem in a mathematical language!
- Algorithm to solve a given problem

- Routing/shortest Path Problem
- Traveling Salesman Problem (TSP)
- Vehicle Routing Problem (VRP)
- OD-Cost Matrix
- Location and Service Area Problems
 - Service Area
 - Closest Facility



- Objective: Calculation of a path between start node and target node with respect to a metric
 - time
 - distance
 - ...
- example:
 - SatNav
 - Route planning (Google, Bing, ...)



Routing/shortest Paths

Bing Maps - Opera

Geospatial Analy... x W Shortest path pr... x Bing Maps x +

www.bing.com/maps/#Y3A9NDguMjAyMzY2Njc0ODU2Mzc1fjE2LjM3MTUxMDE3Nzg4ODg3MzIsdmw9MTUmc3R5PXMcnRwPXBvcy40OC4xOTYxNDdMTYyMzY4NzIw Search with Google

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Bing Maps

Caution: This route may not contain sidewalks or pedestrian paths.

Route: 1.7 km, 21 min

1. Depart from **Gusshausstraße 29, 1040 Wien, Austria** < 0.1 km

2. Bear right onto **Erzherzog Johann Platz / Favoritenstraße** < 0.1 km

3. Bear right onto **Wiedner Hauptstraße** 0.1 km

4. Road name changes to **Rilkeplatz** < 0.1 km

5. Road name changes to **Wiedner Hauptstraße** 0.3 km




6. Keep straight onto **Kärntner Straße** 0.8 km

7. Keep straight onto **Stephansplatz / Stock-im-Eisen-Platz** < 0.1 km

8. Turn right to stay on **Stephansplatz** 0.2 km






9. Arrive at **Stephansplatz, 1010 Wien, Austria**
The last intersection is Churhausgasse. If you reach Schulerstraße, you've gone too far.

Reverse

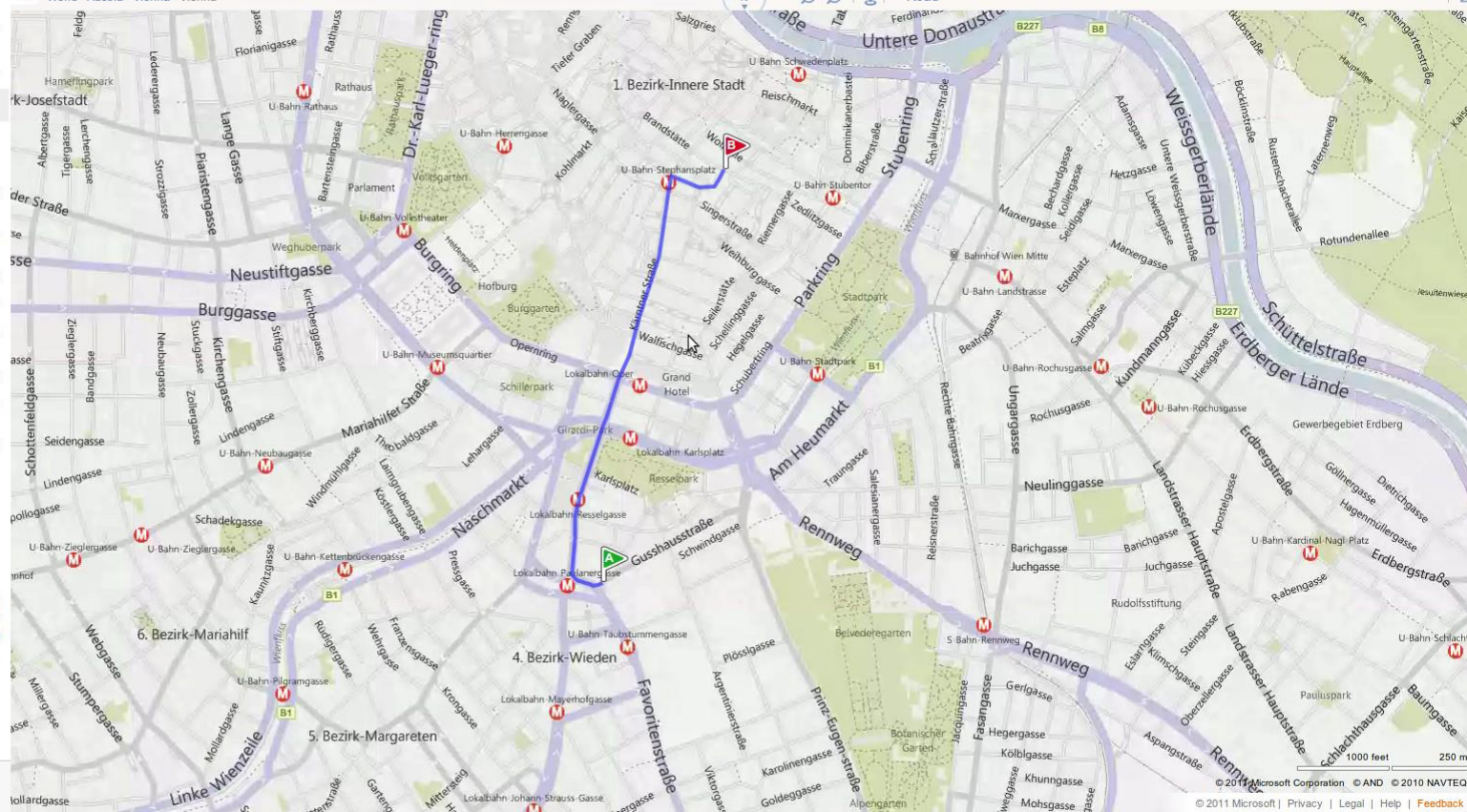
Also available:   

Send to: Email, Mobile, GPS

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WELCOME     

View (100%)



Routing/shortest Paths

Bing Maps - Opera

Geospatial Analy... x W Shortest path pr... x Bing Maps x

www.bing.com/maps/#Y3A9NDguMjAyMzY2NjcxODU2MzctfjE2LjM3MTUxMDE3Nzg4ODg3Mzsdmw9MTUmc3R5PXMcnRwPXBvcy40OC4xOTYxNDdfMTYuMzY4NzI= Search with Google

Web Images News More | MSN Hotmail

Bing Maps

Caution: This route may not contain sidewalks or pedestrian paths.

Route: 1.7 km, 21 min

1 Gusshausstraße 29, 1040 Wien, Austria

2 Depart from Gusshausstraße 29, 1040 Wien, Austria < 0.1 km

3 Bear right onto Erzherzog Johann Platz / Favoritenstraße < 0.1 km

4 Bear right onto Wiedner Hauptstraße 0.1 km

5 Road name changes to Rilkeplatz < 0.1 km

6 Road name changes to Wiedner Hauptstraße 0.3 km

7 Keep straight onto Kärntner Straße 0.8 km

8 Keep straight onto Stephansplatz / Stock-im-Eisen-Platz < 0.1 km

9 Turn right to stay on Stephansplatz 0.2 km

10 Arrive at Stephansplatz, 1010 Wien, Austria

The last intersection is Churhausgasse. If you reach Schulerstraße, you've gone too far.

Stephansplatz, 1010 Wien, Austria

Reverse Also available

Send to: Email, Mobile, GPS

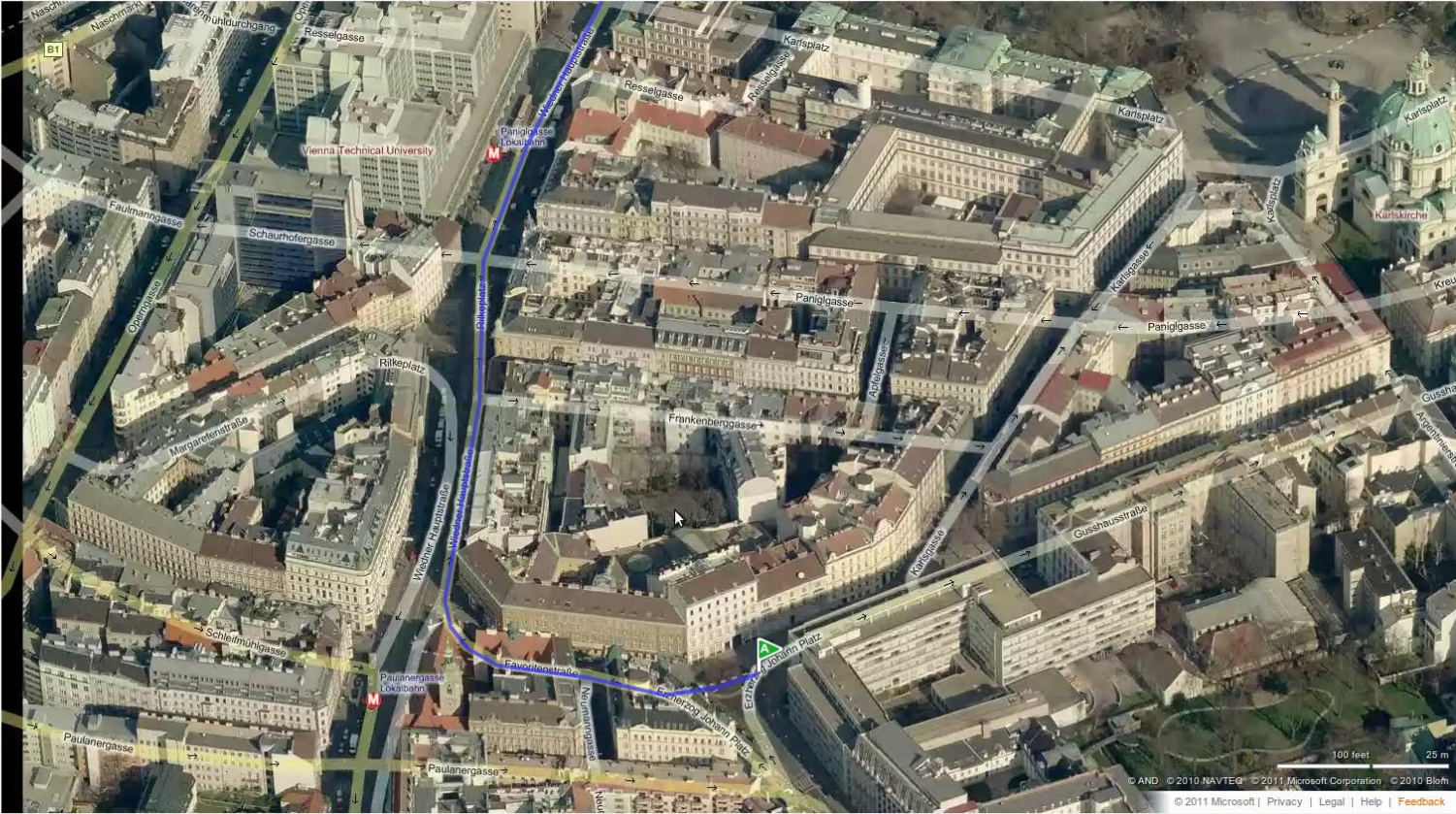
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■ Solution Algorithms:

- Dijkstra Algorithmus (Dijkstra 1956)
- A* Algorithm
- Bellman Ford Algorithm

■ Dijkstra Algorithm (an overview)

1. Assign to every node a distance value: set it to zero for our initial node and to infinity for all other nodes.
2. Mark all nodes as unvisited. Set initial node as current.
3. For current node, consider all its unvisited neighbors and calculate their tentative distance. For example, if current node (A) has distance of 6, and an edge connecting it with another node (B) is 2, the distance to B through A will be $6+2=8$. If this distance is less than the previously recorded distance, overwrite the distance.
4. When we are done considering all neighbors of the current node, mark it as visited. A visited node will not be checked ever again; its distance recorded now is final and minimal.
5. If all nodes have been visited, finish. Otherwise, set the unvisited node with the smallest distance (from the initial node, considering all nodes in graph) as the next "current node" and continue from step 3.

■ Dijkstra Algorithm

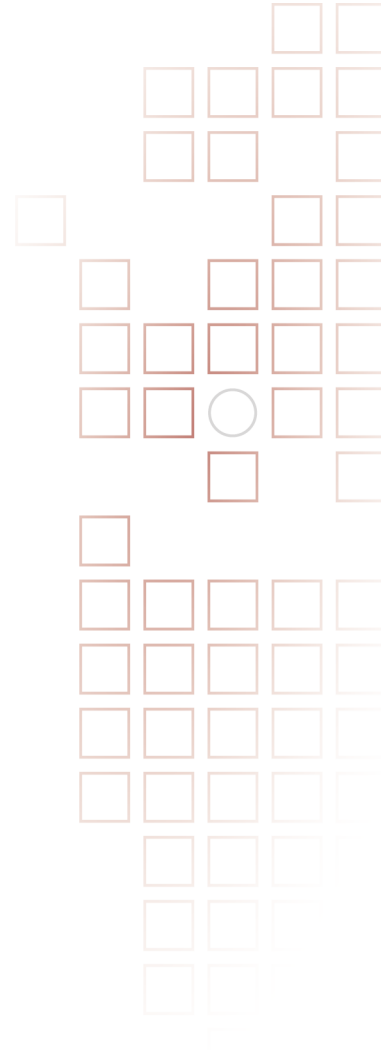
- Solution to single source shortest path problem
- Graph shall not have negative weights!

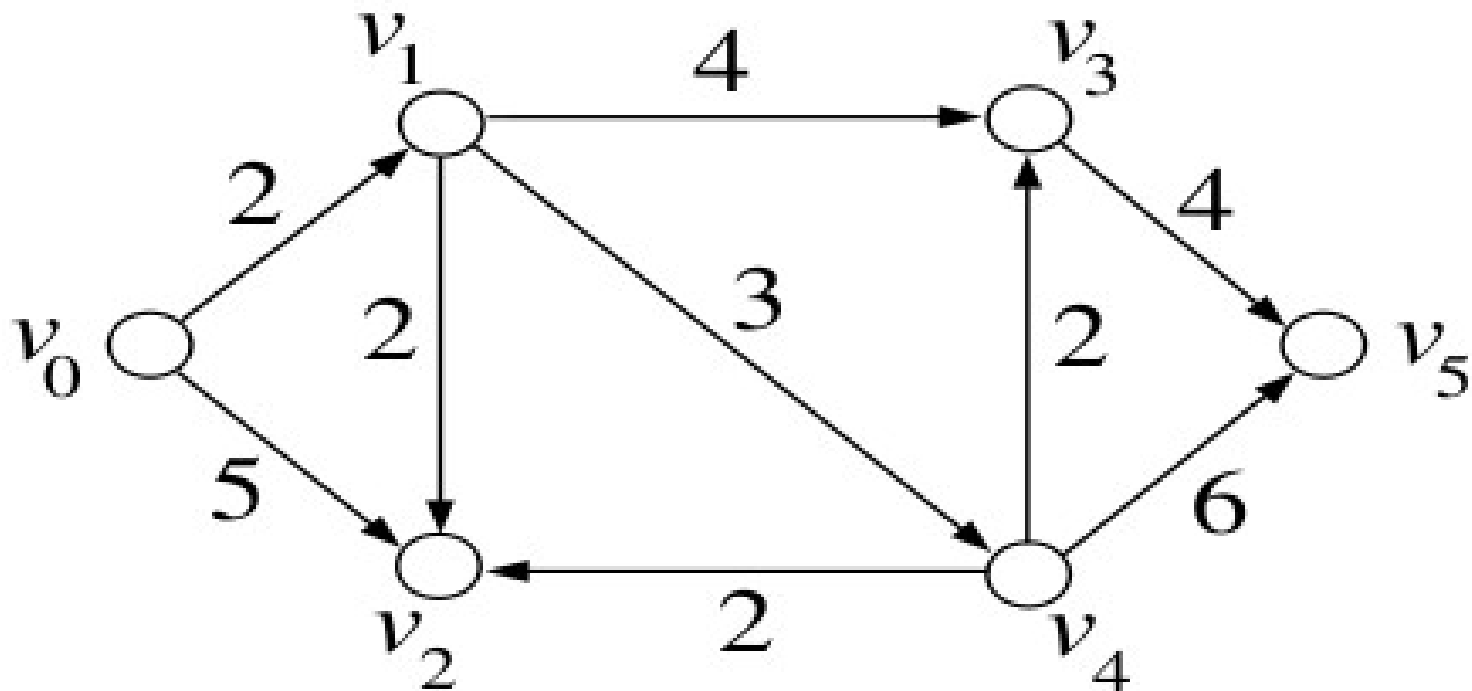
1. $l(v_0) := 0$; for $v \in V \setminus \{v_0\}$ do $l(v) := \infty$ end; $U := \{v_0\}$; $u := v_0$;

2. for $v \in V \setminus U$ do:
 if $(u, v) \in E$ and $l(v) > l(u) + w(u, v)$ then
 $p(v) := u$;
 $l(v) := l(u) + w(u, v)$;
 end if;

3. $m := \min_{v \in V \setminus U} l(v)$, wähle Knoten $z \in V \setminus U$ mit $l(z) = m$;
 $U := U \cup \{z\}$;
 $u := z$;

4. if $U = V$ or $\forall v \in V \setminus U : l(v) = \infty$ then END
 else goto 2;



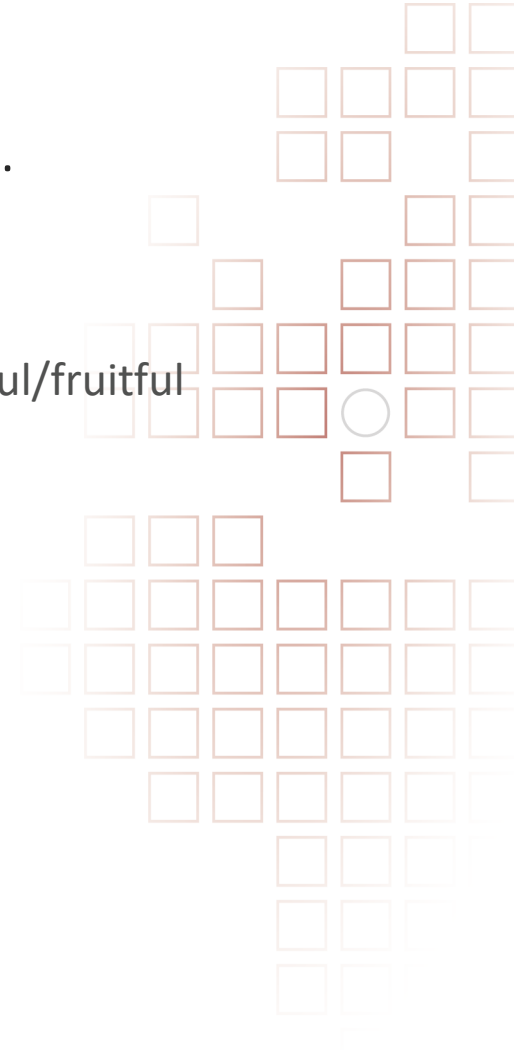


▪ A* Algorithm

- Solution to the single source shortest path problem.
- Graph shall not have negative weights!
- Basic Idea:
 - Investigation only of those nodes that seem successful/fruitful (e.g. that lead to faster solution time - heuristics)
 - Other than that similar to Dijkstra

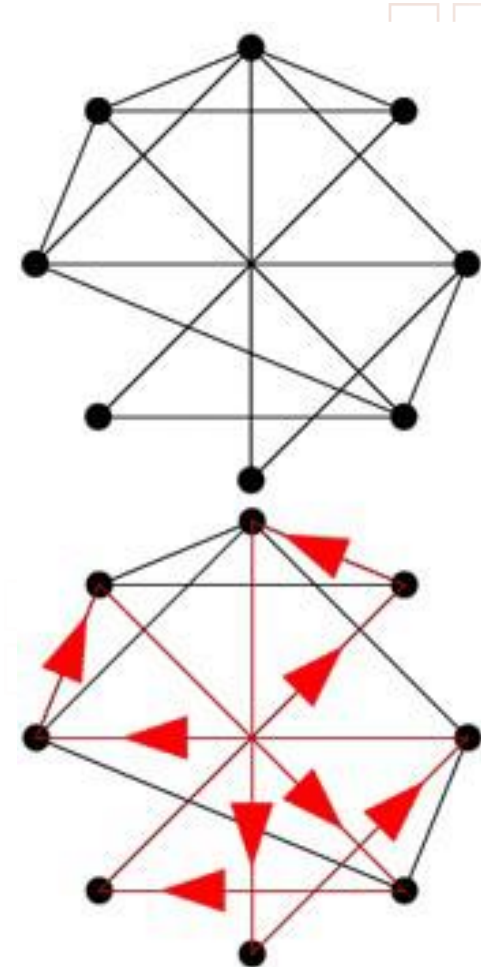
▪ Bellman-Ford Algorithm

- „copes“ with **negative weights**



Traveling Salesman Problem

- Problem:
 - 1 traveling salesman with a given hometown
 - Several cities need to be visited
- Objective:
 - Determination of a path that visits all cities exactly once
 - Optimality: shortest total travel distance or time

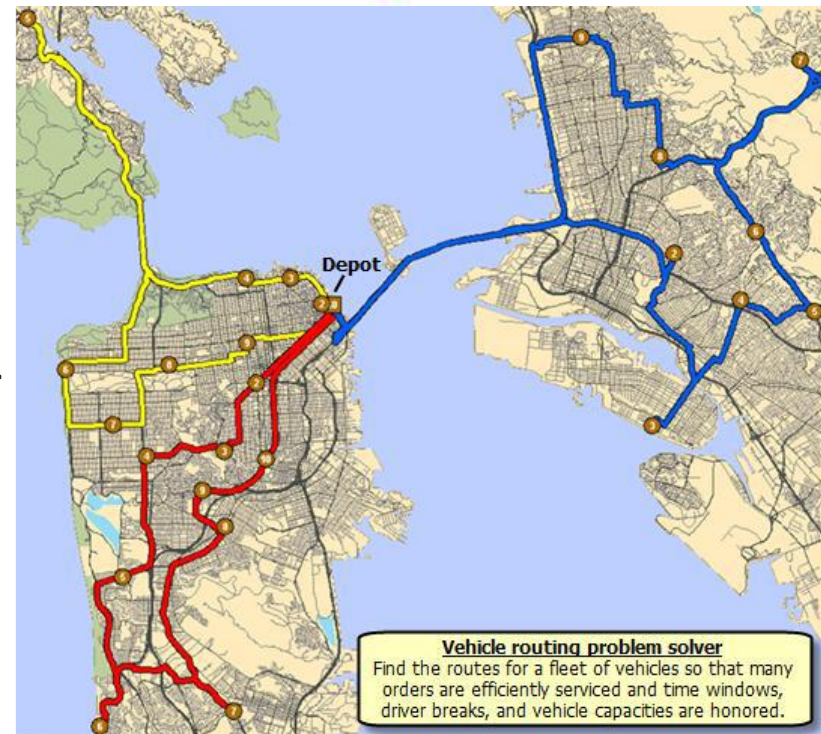
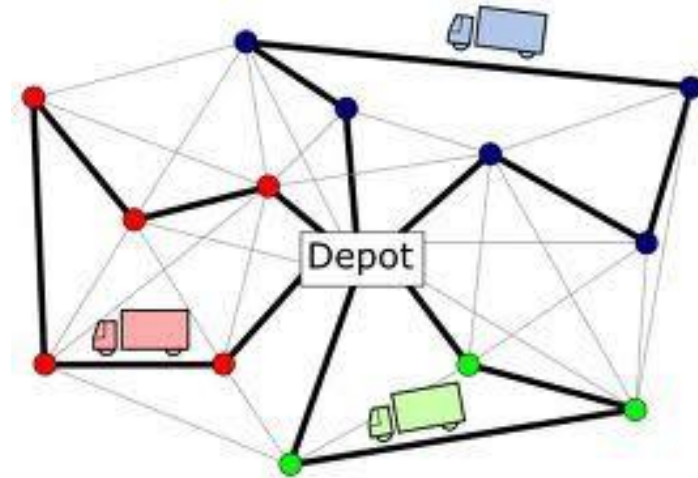


Vehicle Routing Problem

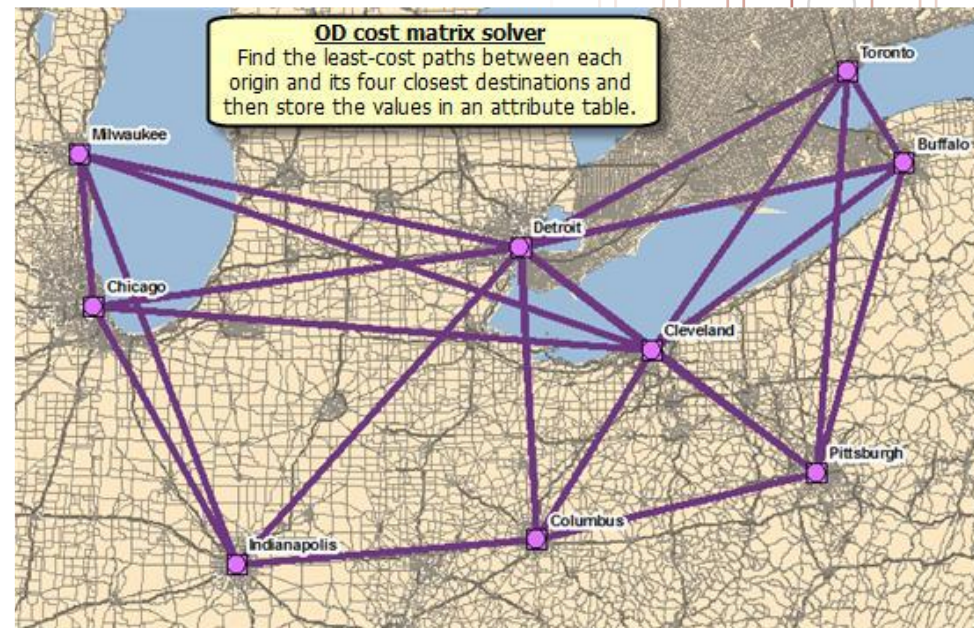
- Problem:
 - Several customers that need to be visited
 - Several vehicles available that visit the customers

>> each customer is visited by exactly one vehicle exactly once

- Objective
 - Determination of routes for each vehicle
 - Optimality: Sum of travel distances or travel time is minimal
 - ... each customer is visited



- Origin-Destination (OD) Cost Matrix
- Problem:
 - Huge number of origins & destinations >> high complexity
- Objective:
 - Calculation of the shortest path between each OD pair

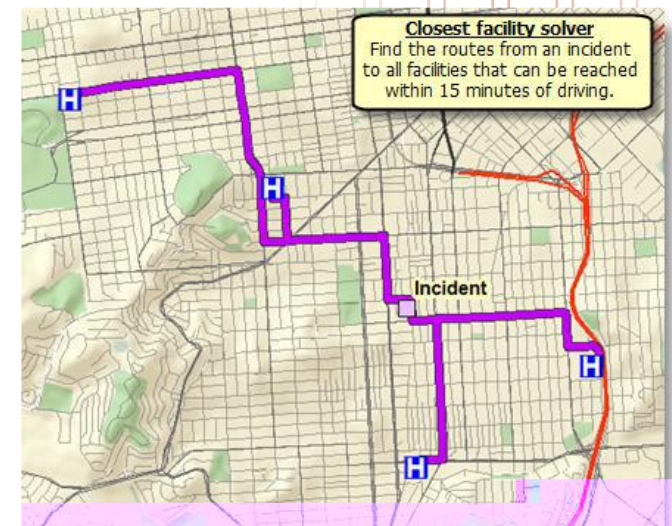
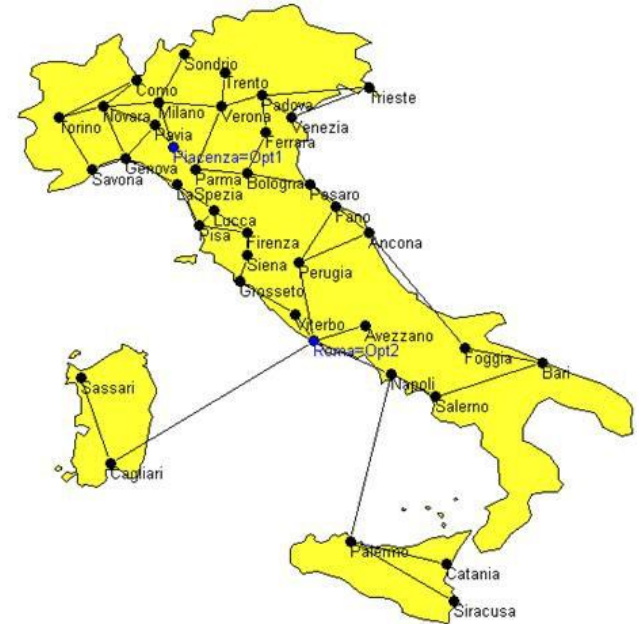


■ Location Problems

- Try to compute the optimal location for an object in space
- >> Decision Support
- zB depot, service points, supermarket, antenna locations ...

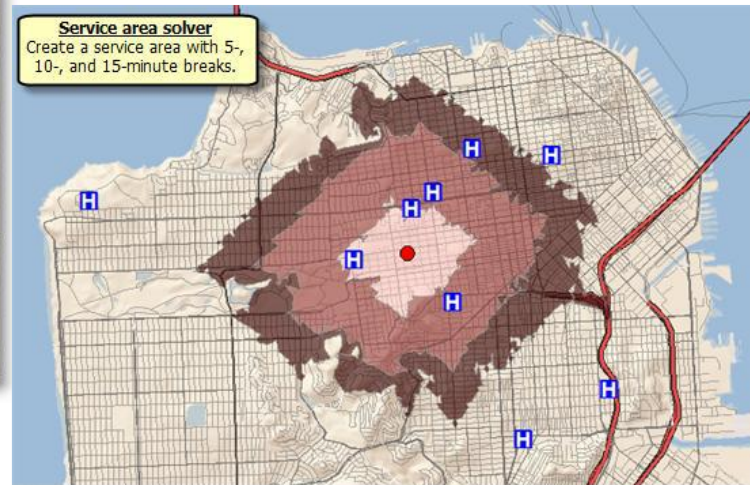
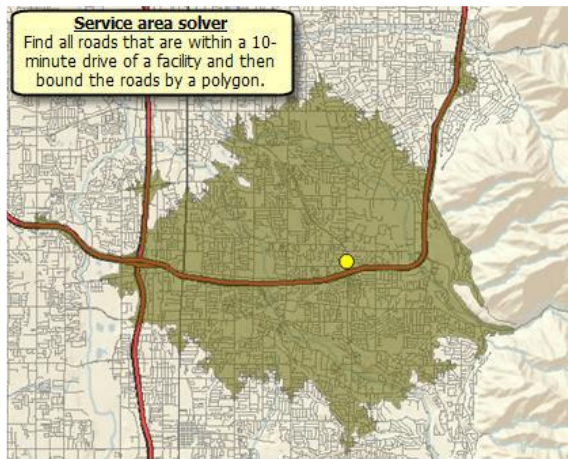
■ Closest Facility

- Calculates which objects are reachable from a single point in space
- Often with respect to a defined distance/time



■ Service Area

- Definition of zones that are reachable from defined points in space
- Often with respect to a time or distance value
- E.g. houses that are reachable within 15min of the fire station





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