Forsvarets forskningsinstitutt

Path planning for autonomous vehicles

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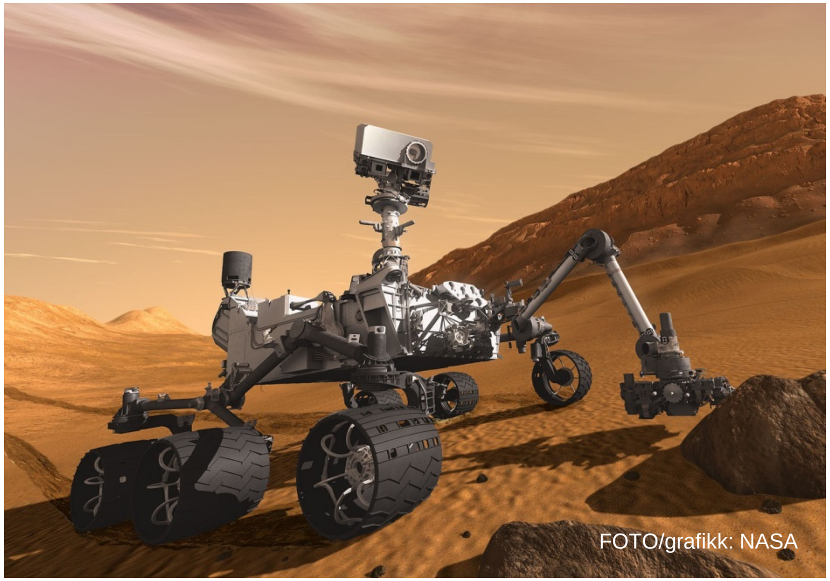
May 19 2016

Mobile robots/autonomous vehicles vs. manipulators

- Manipulators
  - Fixed position
  - Limited workspace

- Mobile robots
  - Position changes
  - Environment changes and may be «unlimited»
  - Uncertainty in position and environment

FOTO: Hyundai Heavy Indutries



FOTO/grafikk: NASA

http://www.ffi.no/no/Aktuelle-tema/Sider/Til-Svalbard-for-å-finne-liv-på-Mars.aspx

Autonomous vehicles

- Where am I?
- What should I do?
- How should I do it?

Autonomous vehicles

- Where am I?
- What should I do?
- How should I do it?

- Where am I?
- Where am I going?
- How should I get there?

Autonomous vehicles consist of

- Sensors
  - What is in my surroundings?
- Payload
  - What I will use to complete my task
- Equipment for movement
  - How I will move while performing my task
- Tools for reasoning
  - Atificial intelligence

Two approaches

- How should the vehicle be constructed to execute these tasks?

- How should we use this vehicle to execute these tasks?

Two approaches

- How should the vehicle be constructed to execute these tasks?

- How should we use this vehicle to execute these tasks?

Should we use this vehicle?

Should we execute this task?

Robots provide new possibilities!

The vehicles consist of:

- Sensors
- Payload
- Equipment for movement
- Tools for reasoning

Sensors

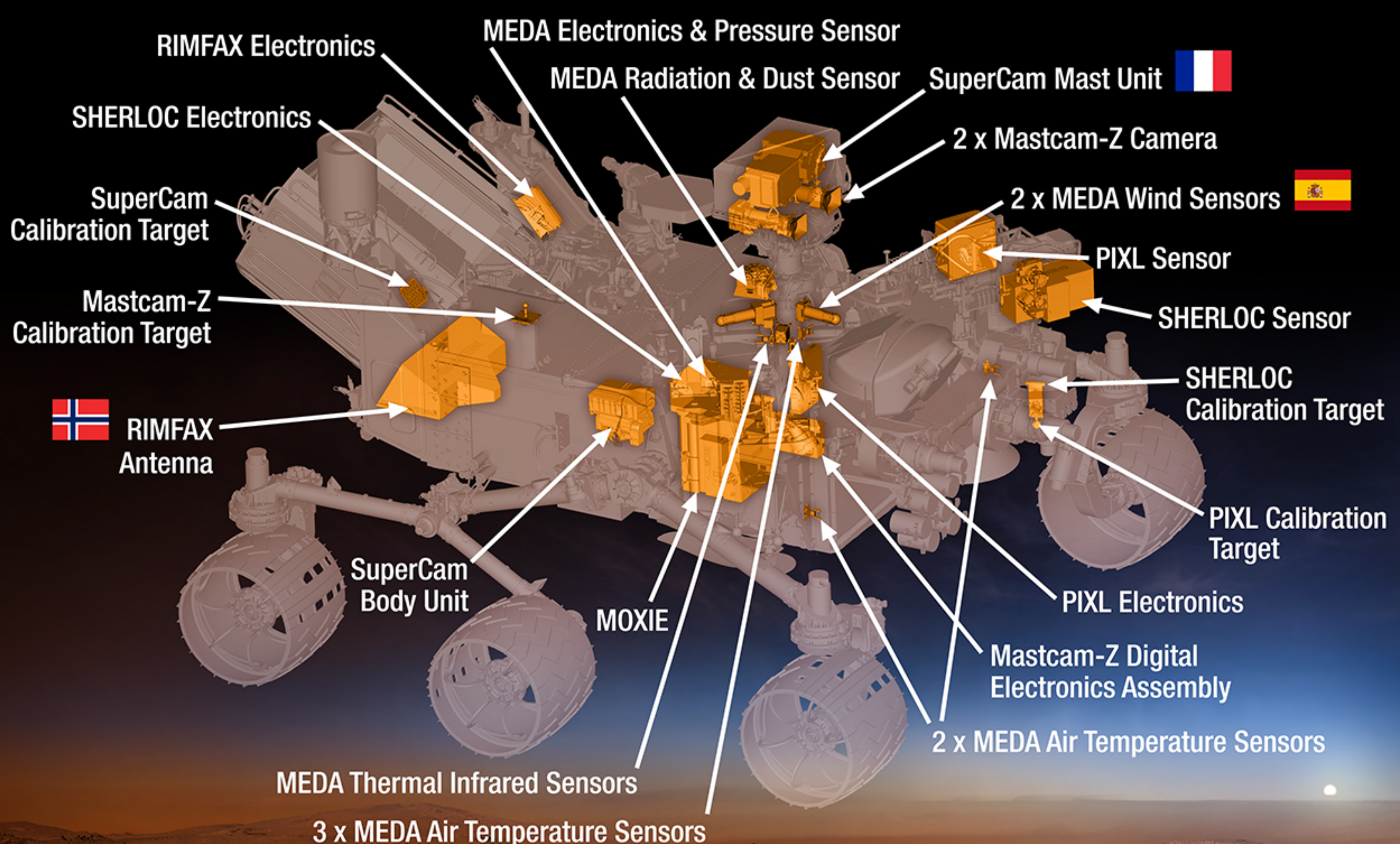
- Depends on the type of vehicle

- Internal and external sensors
- Passive and active sensors

- State monitoring
  - Positioning
  - «Health»

- Perceiving the environment
  - Avoid obstacles
  - Information gathering (of task relevant information)

Mars 2020 Rover



FOTO/grafikk: NASA

Environment model

- Continuous or discrete
- Layers of data
- Discrete hierarchical model to achieve suitable precision

State monitoring

- Sensor functionality
- Position
- Fuel
- Weather
- System failures

Photo: US Air Force

- Alert: Change behavior and/or plan to avoid failure.
  - Complete the task in a different way
  - Abort mission

Autonomous task planning

- How to best use my payload to execute this task in the current environment given my current state?
- Usually involves movement for autonomous vehicles.

Distributed autonomy

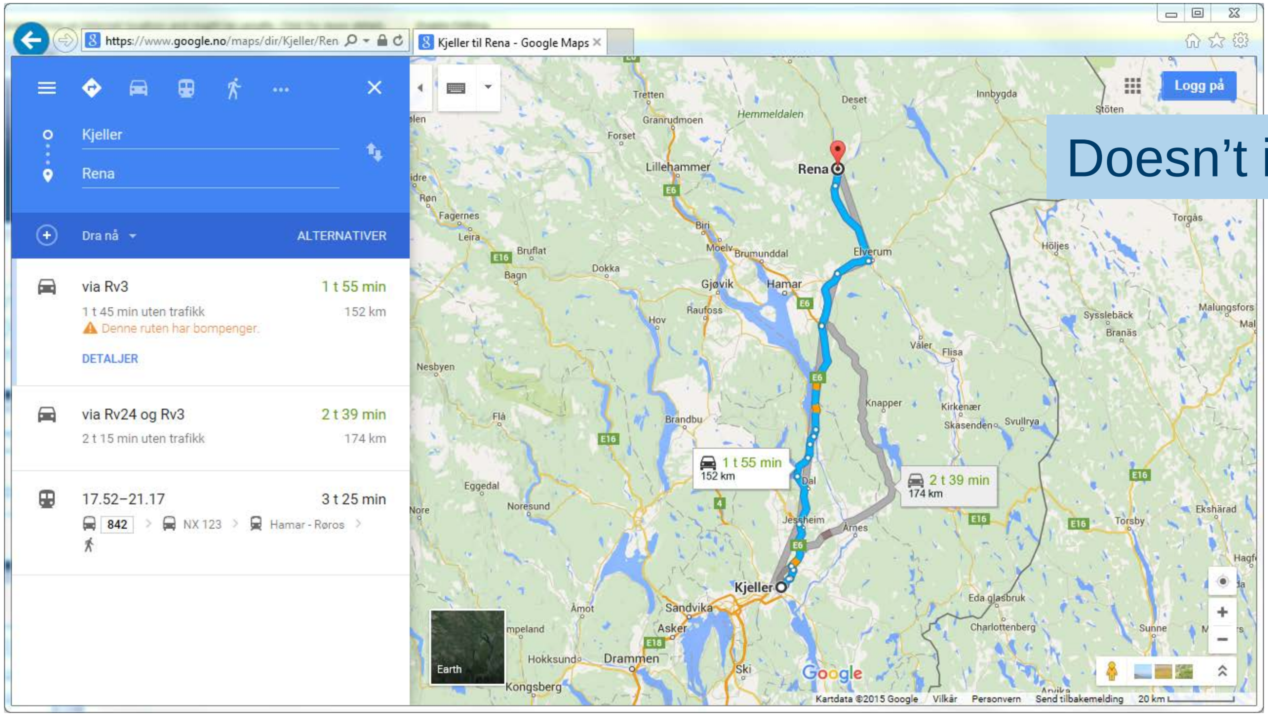
- Am I cooperating with anyone?
  - Equal relationship or master/slave?
  - Same types of vehicles or different properties?

- Communication
  - With other autonomous units
  - With a control station or human

Path planning

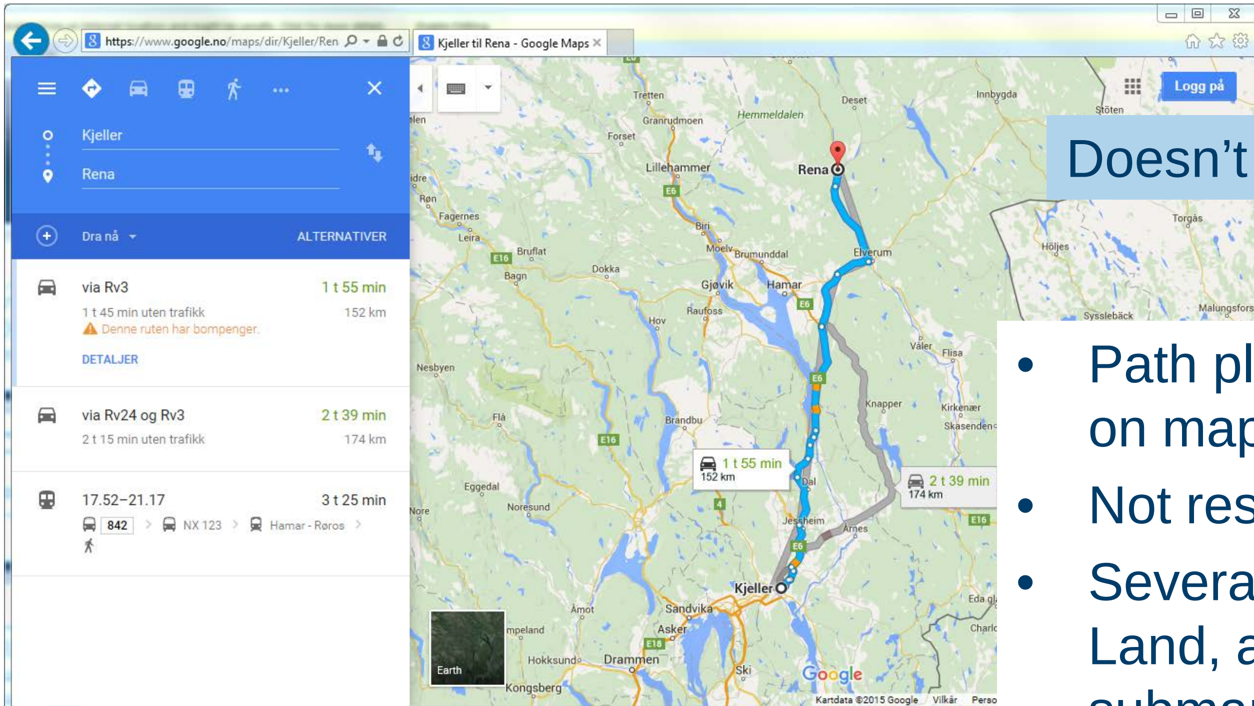
- Positioning and movement of the vehicle in the environment.
- Path planning dependent on task and situation is important.
- Relation to cooperating units.
- Path planning is often done hierarchically.
  - Discrete routes on high levels.
  - Detailed short distance routes can be continuous.

Why do we need a tool for path planning?



Doesn't it exist?

Why do we need a tool for path planning?



Doesn’t it exist?

- Path planning not only based on maps.
- Not restricted to roads.
- Several types of entities: Land, air, surface, and submarines.
- Aspects as threat and task specific needs.

Example terrain

Screenshot from VR-Forces, MÄK

Automatic path planning

Screenshot from VR-Forces, MÄK

- A graph that represents the possible movements through the terrain.
- Weights for the edges in the graph representing the relative accessibility of each edge.
- An algorithm for determining the shortest path through the weighted graph.
  - Often A*, a generalization of Dijkstra.

Examples of path planning methods

- Continuous methods

- Potential fields
- Fast marching methods

- Graph based
  - Visibility graph
  - Tile graph
  - Voronoy diagrams
  - Random/adaptive sampling
  - *Dijkstra, A*, D*..*

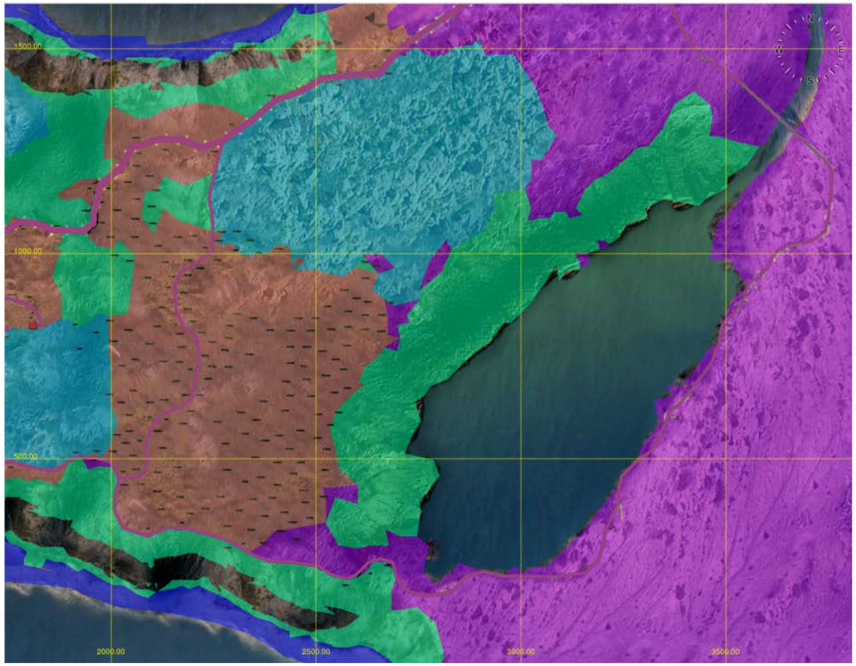
Which method should be used when?

Which properties influence this choice?

Read more:

- Artificial intelligence for games, Ian Millington and John Funge
- Multi-objective Evolutionary Path Planning with Neutrality, Eivind Samuelsen, Master Thesis
- Gomez, Universidad Carlos III de Madrid, https://www.youtube.com/watch?v=wzvEGRznflk

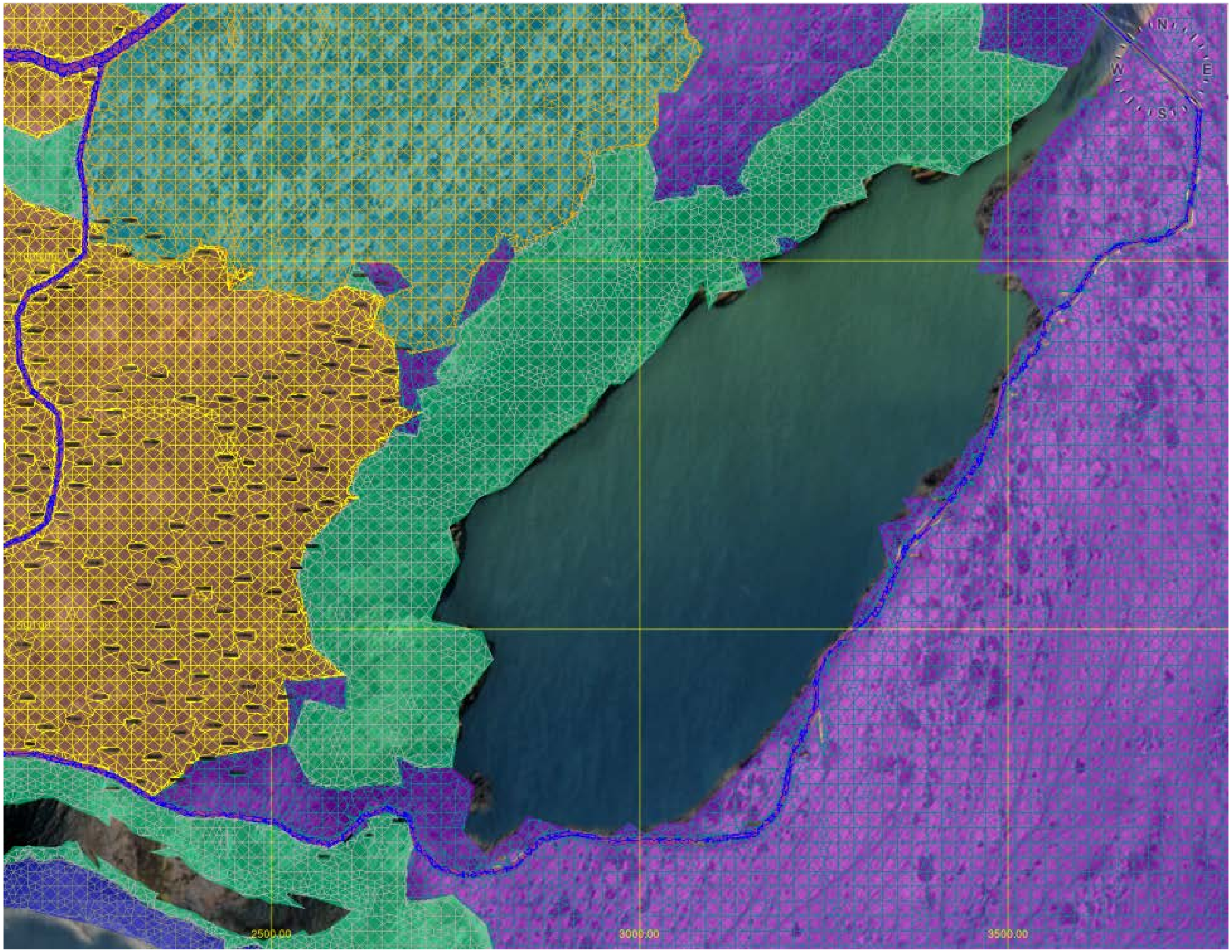
Graph generation



Screenshot from VR-Forces, MÄK

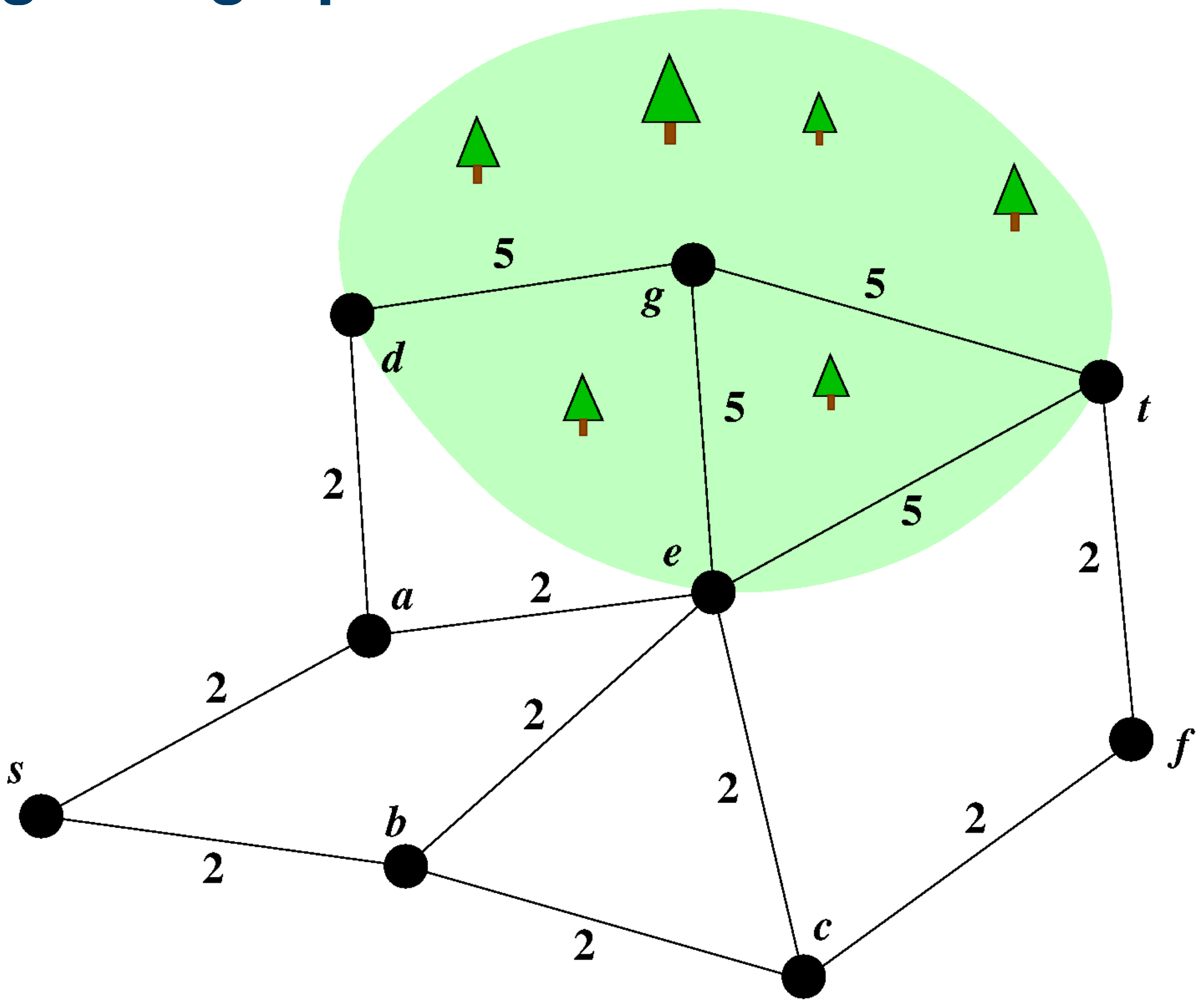
- Areas with accessible terrain types are used to create a navigation mesh.
- A graph is constructed based on the mesh.
- The same graph will be used for several types of vehicles.
  - Only extremely sloped areas are accounted for at this stage.

Graph generation



Screenshot from VR-Forces, MÄK

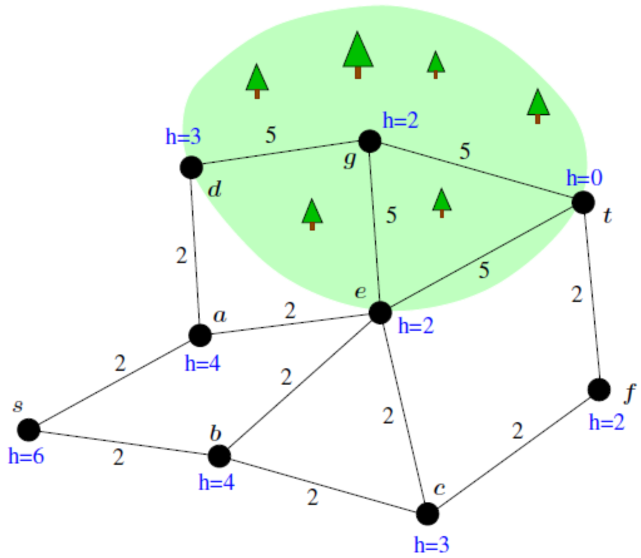
Weighted graph



Path planning algorithm

Dijkstra

- Find the optimal path from a start node to an end node.



A*

- Find the (probably) optimal path from a start node to an end node.
- Introduces a heuristic function to speed up the search.
- The heuristic function determines whether an optimal solution is guaranteed.
- Implementations often terminate the first time the end node is visited.

How does a path depend on the situation?

1. The situation around the entity:
   - Terrain
   - Enemies
   - …

2. Which task the entity is performing

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   - …

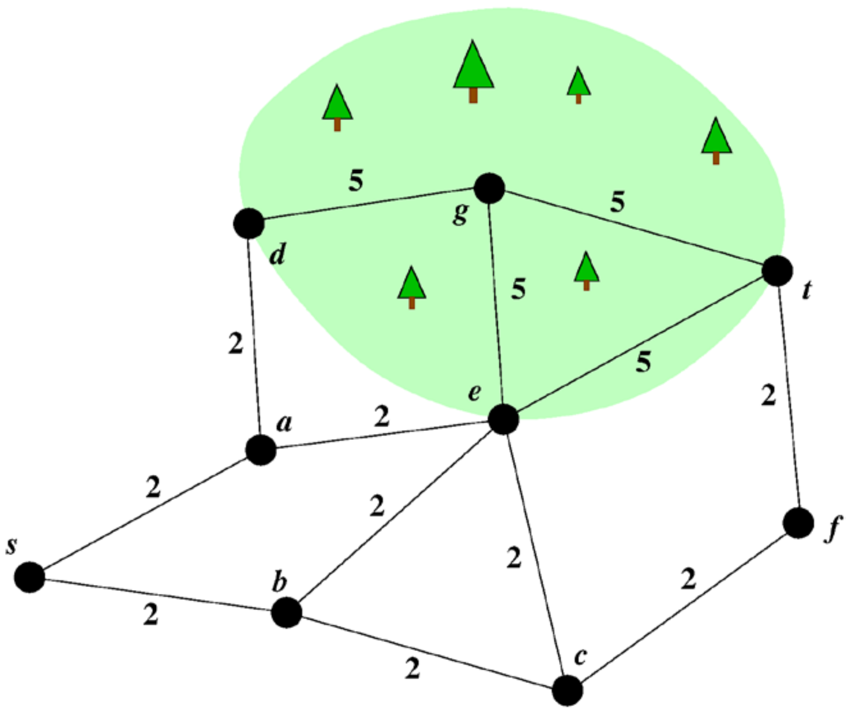
Aspects

2. Which task the entity is performing

Priority

Priority of aspects

1. Time
2. Accessibility
3. Concealment
4. Cover
5. Threat



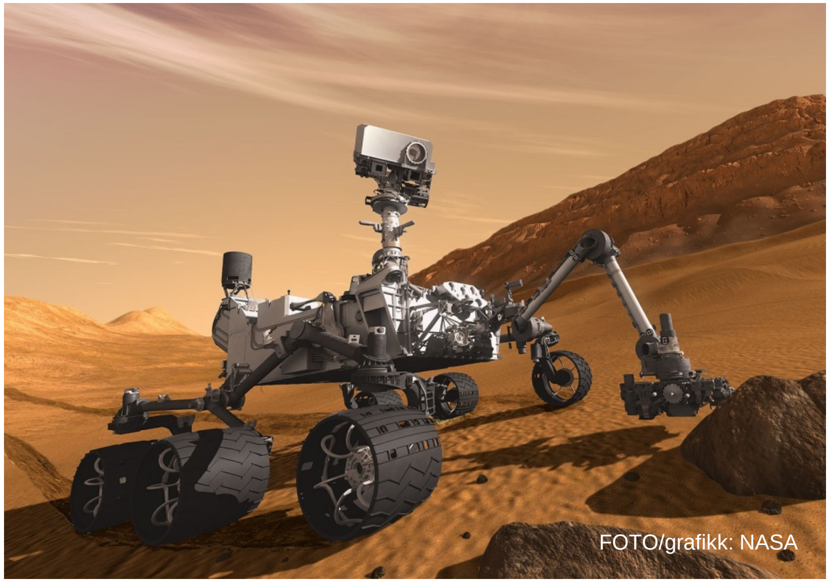
The relative priority of the aspects depends on the task the entity is performing.

Each aspect is assigned a number from 1 to 10, where 10 represents the highest priority.

The aspect weights are combined into a new situation dependent weight.

Our work includes

- Programming
- Optimization
- Mathematics
- Artificial intelligence
- Information security



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