Introduction to Mobile Robotics

Mapping with Elevation Maps

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Mapping for Outdoor Environments

• Autonomous outdoor navigation is a challenging problem
  • outdoor mapping
  • real time path planning
  • real time localization

• One of the key problems:
  efficient data structures for 3D range data
Typical Representations

• Collection of all 3D-Points
  • ≈200,000 Points per scan
  • low utility for navigation

• 3D-Grid
  • huge computational and memory requirements
  + higher accuracy

• 2D-Grid
  + low cost
  + efficient for navigation
  • approximation

Better approach: Elevation Maps
“Herbert” the Outdoor Robot

\[
\begin{align*}
\alpha &= \text{azimuth} \\
\gamma &= \text{tilt} \\
\begin{pmatrix} x \\ y \\ z \end{pmatrix} &= \begin{pmatrix} \left( \frac{\pi}{2} - \gamma \right) z_1 \\ \cos \left( \frac{\pi}{2} - \gamma \right) z_1 \\ \sin \left( \frac{\pi}{2} - \gamma \right) z_1 + z_0 \end{pmatrix} + d \begin{pmatrix} \cos(\alpha) \\ \sin(\alpha) + \sin \left( \frac{\pi}{2} - \gamma \right) \\ - \sin(\alpha) \cos \left( \frac{\pi}{2} - \gamma \right) \end{pmatrix}
\end{align*}
\]
Elevation Maps

**Pros:**
- 2½-D representation (vs. 3D for grids)
- Use a Kalman Filter to estimate the elevation.
- Elevation $h = \mu$.
- Path planning like in 2D

**Cons:**
- No vertical objects
- Only one level
- $\mu$ depends on viewpoint

→ **Extended Elevation Maps**
Typical Elevation Map
Extended Elevation Map

- Cells with vertical objects (**red**)
- Cells with a big vertical gap e.g. windows, bridges, door frames (**blue**)
- Cells, seen from above (**yellow**)
  → store gaps in cells to determine traversibility
Multiple Elevation Maps
Summary

• Data structure with constant time access
• Traversibility and obstacle detection
• Extension of elevation maps to deal with:
  • vertical objects
  • multi-level-extension