Hierarchical Freespace Planning for Navigation in Unfamiliar Worlds

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Motivation

- Autonomous navigation in unfamiliar, complex environments requires
  - careful maneuvering
  - learning from noisy or incomplete perception
  - exploration when needed
  - flexible planning
- Expensive to construct an accurate metric map
- Navigation without a metric map is more difficult


ROSie

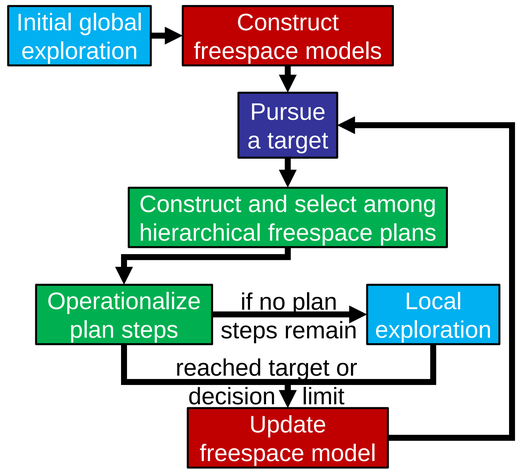

Apollo

Contributions

- Cognitively-based robot control system for autonomous navigation
- Opportunistic exploration globally and locally
- Spatial model focused on where robot can move, not what impedes it
- Hierarchical freespace plans operationalized at execution time

Exploration and planning

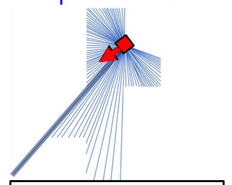
- High-level global exploration seeks long stretches of freespace (highways)
- Time-limited initial search for global connectivity (intersections) generates a freespace model
- Low-level local exploration when plan finishes is decision-limited and target-driven
- Based on experience and the spatial model

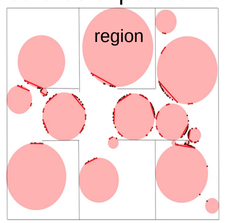


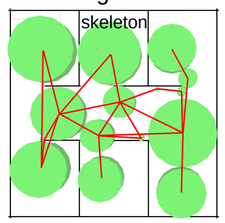
Approach

Models of **connected freespace**
based only on **onboard** range finder data
support **effective planning** in an **unfamiliar world**

Spatial affordances = features expected to facilitate navigation


Laser range finder with long ray highlighted

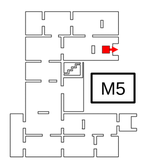


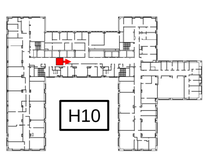


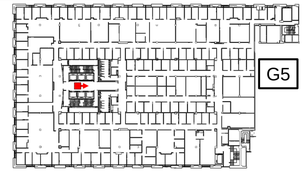
Evaluation

- Simulation in MengeROS with noisy sensors and actuators
- 5 sequences of 40 targets randomly chosen in freespace
- Results average 40 runs with all sequences

Three real-world test environments


M5


H10


G5

	Size (m)	Rooms	Freespace
M5	54 x 62	14	1,585 m^2
H10	89 x 58	75	2,627 m^2
G5	110 x 70	180	4,021 m^2

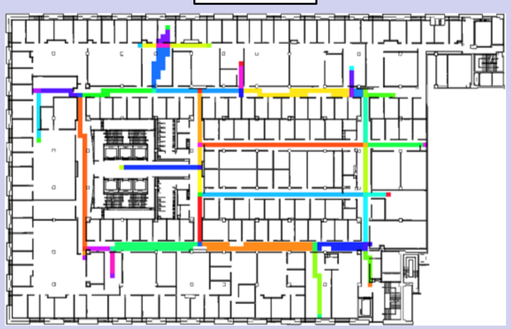
Versions	Exploration		Global Planning
	Global	Local	
Greedy	No	No	No
Wander	Yes	No	No
Skeletal	No	No	Skeleton
ExSk	Yes	Yes	Skeleton
SemaFORR	Yes	Yes	Highways

Freespace-based planning: hierarchical sequence of spatial affordances

Plan directly in learned freespace models

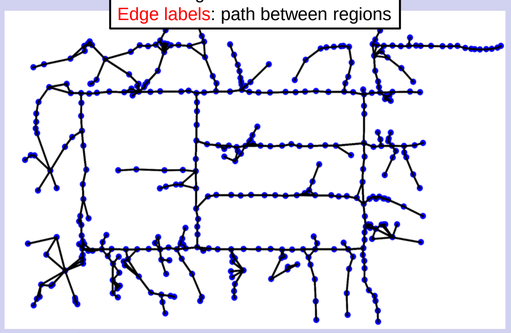
Skeleton

Highways

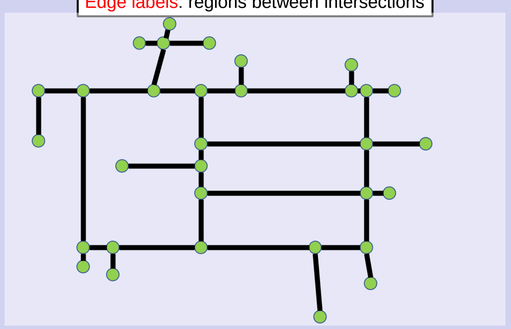


Transform freespace models to graphs

Skeleton Graph
Nodes: regions
Edge labels: path between regions



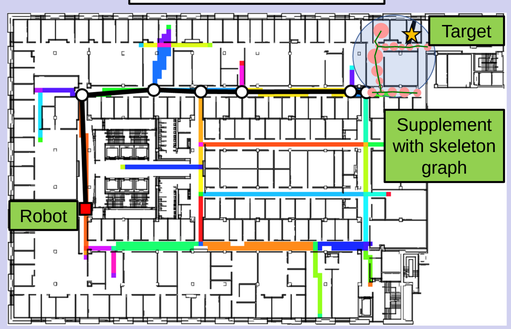
Highway graph
Nodes: intersections
Edge labels: regions between intersections



Construct hierarchical plans in graphs
Operationalize plan at execution time

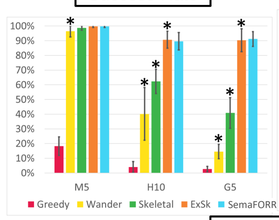
Plan through regions

Plan in highway graph

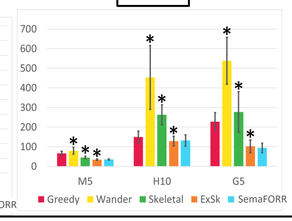


Results

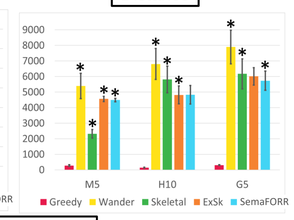
Success Rate



Time



Distance



* difference is statistically significant ($p < 0.05$)

Conclusion

A robot controller that explores when needed, focuses on freespace, and plans hierarchically supports robust navigation in complex, unfamiliar worlds