Metrics for Efficient Environment Exploration in Robot Motion Planning

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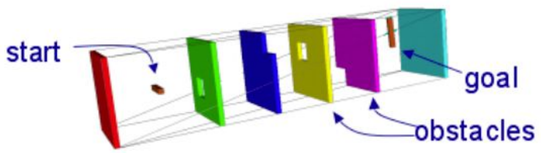
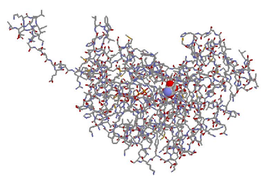
Motion Planning

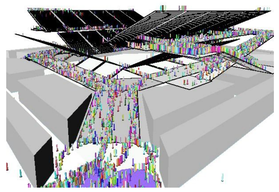
Motion Planning refers to the process of finding a collision-free path for a robot given a starting point and a goal destination in an environment containing obstacles.



Applications



Computational Biology
(Ligand binding)



Group Behaviors
(Evacuation)

Robotics
(Mobile Robots)

Motivation

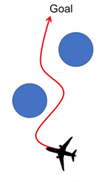
Research Problem

We need more efficient methods and metrics that biases workspace exploration based on desired properties of the robot and its environment

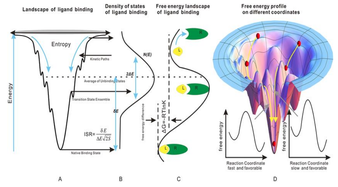
Approach

Clearance-Biased Exploration - A method that guides exploration based on the size of free space between obstacles in the workspace

Climbing Robot
(Narrow clearance between obstacles)



Mobile Robot
(Wide clearance between obstacles)

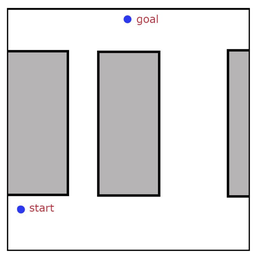


Ligand Binding
(Energy Level)

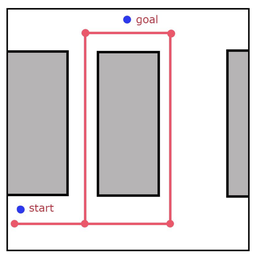
Clearance-Biased Exploration

Clearance-Biased Exploration - a method of targeting workspace exploration based on the free-space between obstacles in the workspace. Particularly applied to Dynamic Region-biased Rapidly Exploring Random Trees (DR-RRT)

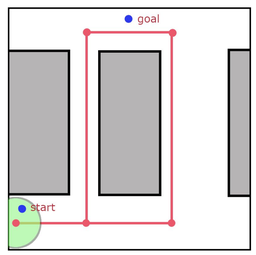
Example Execution



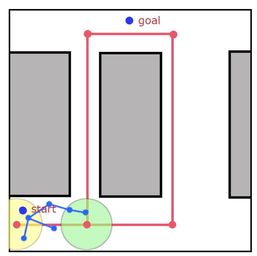
Environment with query



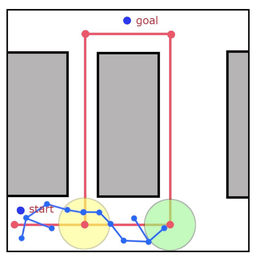
Query Skeleton



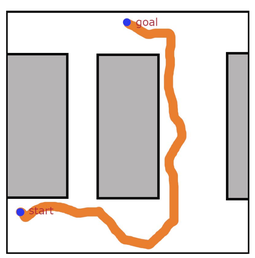
Dynamic Sampling Region near start



Grow RRT



Clearance-biased Exploration



Roadmap

Algorithm

Input: *env*, the environment

Output: *g*, the free-space roadmap

Procedure:

WS ← **BuildWorkspaceSkeleton(***env***)**

QS ← **GetQuerySkeleton(***WS***)**

PM ← **GeneratePropertyMap(***QS***)**

curRegion ← **CreateDynamicSamplingRegion(**$PM_{\{0\}}$**)**

While !*done* **do**

g ← **RRT(** *curRegion* **)**

children ← **curRegion.GetChildren()**

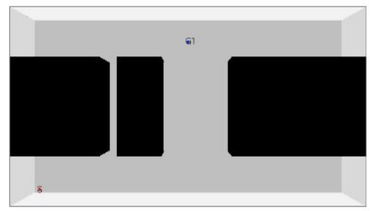
curRegion ← **maxvar(children.Clearance())**

end while

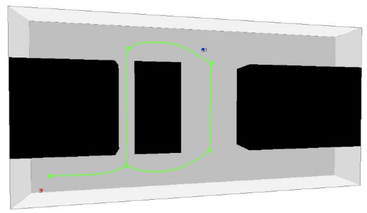
- **DR-RRT** - is a sampling-based planner that uses the Workspace Skeleton to guide RRT exploration in the workspace.
- **Property Map** - an unordered map of workspace node and edge clearance
- **Query Skeleton** - an undirected graph of the query that represents the workspace topology
- **Region** - a node in the Workspace Skeleton

Results

Test Environment

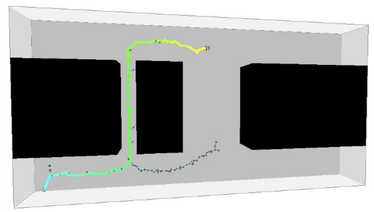


A 3D environment with obstacles with query

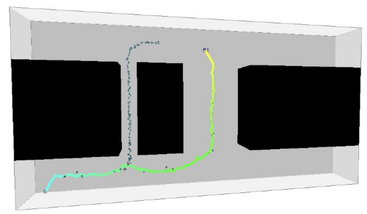


Query Skeleton

Results



Regular DR-RRT Path



Clearance-Biased DR-RRT Path

- Clearance-Biased DR-RRT guides exploration towards regions with higher clearance values

Conclusion

Although DR-RRT is one of the state-of-the-art sampling methods, there is still room for improvement. More efficient property metrics can be developed to exploit the Workspace Skeleton and guide exploration.

Future Work

- Use properties such as edge length to improve clearance value exploration
- Design and Implement more efficient metrics and methods based on the robot and environment properties for different motion planning problems
  - Energy Threshold - Protein Binding Accessibility

Acknowledgment & References

Acknowledgment

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References

[1] J. Denny, R. Sandstrom, A. Bregger, and N. M. Amato, "Dynamic Region-biased Rapidly-exploring Random Trees," In. *Proc. of the Twelfth International Workshop on the Algorithmic Foundations of Robotics* (WAFR), San Francisco, CA, USA, Dec. 18–20, 2016.