Metrics for Efficient Exploration of Narrow Passages in Robot Motion Planning

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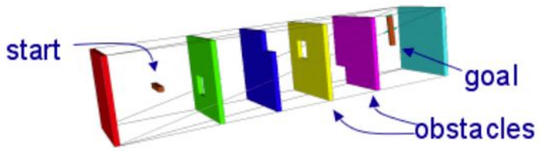
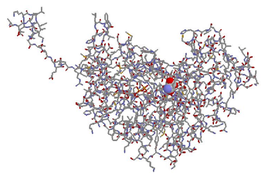
Motion Planning

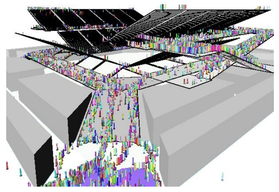
Motion Planning refers to the process of finding a collision-free path for a robot given a starting point and a goal destination in an environment containing obstacles.



Applications



Computational Biology
(Ligand binding)



Group Behaviors
(Evacuation)

Robotics
(Mobile Robots)

Motivation

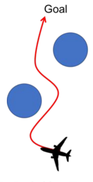
Research Problem

- State of the art sampling-based planning methods has difficulty in narrow passages. We need methods for efficiently exploring environments based on properties of the robot and the environment

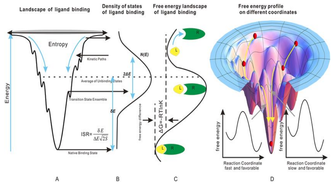
Approach

- **Exploration Based On Clearance Value**
  - A method that biases exploration based on the value of the obstacle-free space between the boundary box and the free space in the environment

Climbing Robot
Narrow clearance between obstacle



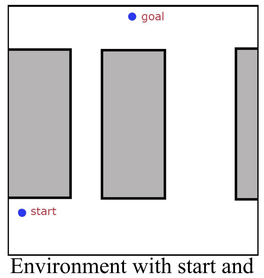
Mobile Robot
Wide clearance between obstacle



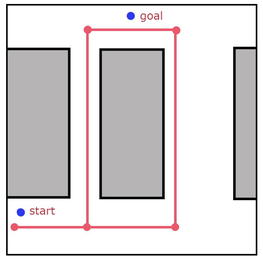
Ligand Binding
Energy Level

Exploration Based on Clearance Value

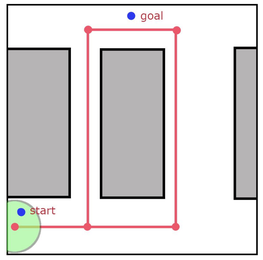
Dynamic Region-biased Rapidly Exploring Tree (DR-RRT) is a sampling-based planner that encodes the environment topology to guide the exploration in the workspace



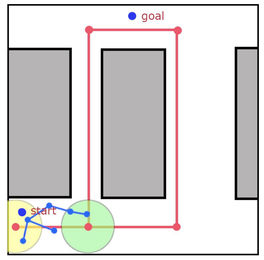
Environment with start and goal configuration



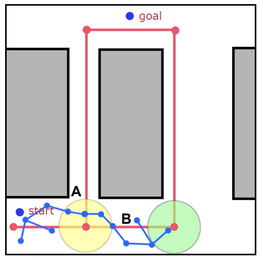
Workspace skeleton



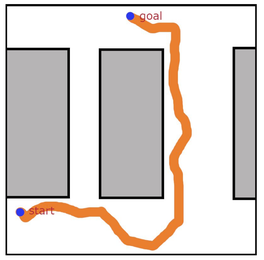
Dynamic Sampling Region near start configuration



Randomly sample till it reaches the next region



Compare the clearance value of A and B and explore B



Roadmap

Pseudocode

Input: Env, the environment

Output: G, the c-space roadmap

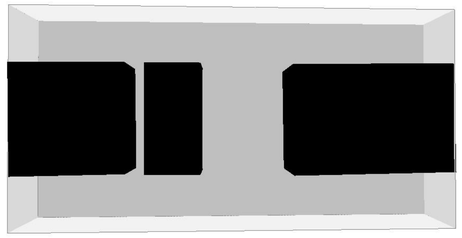
Procedure:

WS = *BuildWorkspaceSkeleton(Env)*
CM= *GenerateClearanceMap(WS)*
CurRegion = *CreateRegion(CM*$_{\{0\}}$*)*
While (!done) {
  G = *RRT(curRegion)*
  Children = curRegion.getChildren
  curReg = maxvar(Children.clearance)
}
return G

- **Dynamic Sampling Region** - Nodes in the workspace skeleton to guide RRT exploration
- **RRT** - a sampling-based planner that grows a tree by randomly generating points in the obstacle-free space
- **Clearance** - the obstacle free space between the boundary box and obstacles in the environment
- **Workspace Skeleton** - an undirected graph that represents the environment's topology

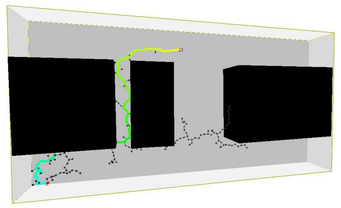
Results

Test Environment:

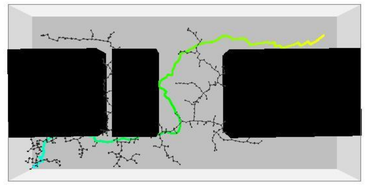


A 3D environment with block obstacles

Results:



Regular DR-RRT



DR-RRT with Clearance biasing

- Exploration is biased towards regions with wider clearance

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 guide exploration based on the type of problem the planners are applied to.

Future Work

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

Acknowledgment & References

Acknowledgement

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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.