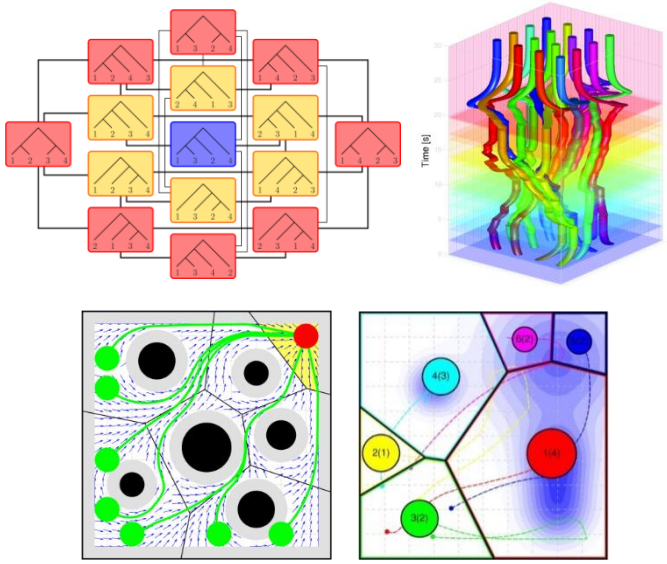
Penn
University of Pennsylvania

icra STOCKHOLM 2016 SWEDEN
ICRA 2016 IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION

Clustering-Based Robot Navigation and Control

Omur Arslan, Dan P. Guralnik and Daniel E. Koditschek
University of Pennsylvania



Closing the Gap

in Modeling Configuration Spaces

[Choset et al., 2005][LaValle, 2006]

Configuration Space Motion Planning

"Explicit Configuration Space Construction"

Sampling-Based Motion Planning

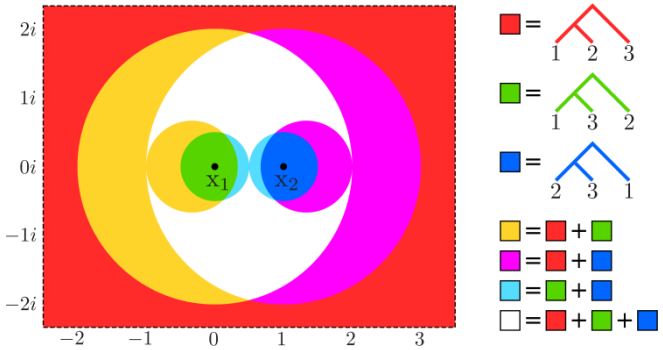
"Sample Configurations Connected by Simple Paths"

Clustering-Based Motion Planning

"Configuration Clusters & Their Adjacencies"

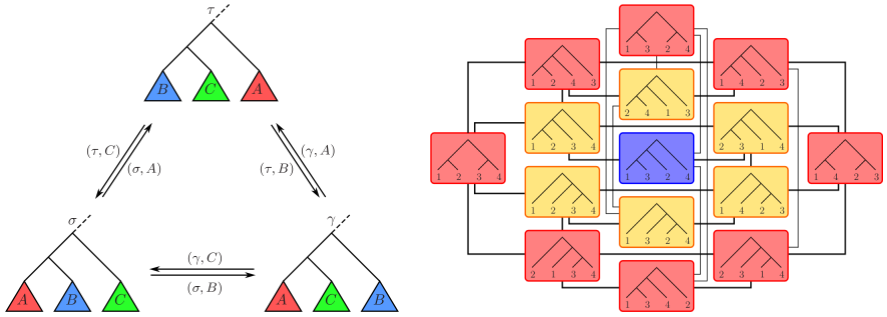
What Does Clustering Offer? [Jain,Dubes,1988]

Automated tools to discover coherent groups in configuration spaces



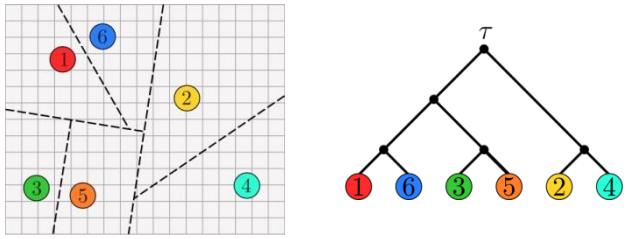
Quotient space of three point robots on a plane

Explicit relations between clustering models



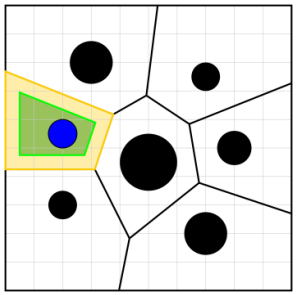
The nearest neighbor interchange (NNI) moves between cluster hierarchies and the NNI graph

Symbolic abstractions relating conf. spaces to the space of clustering models

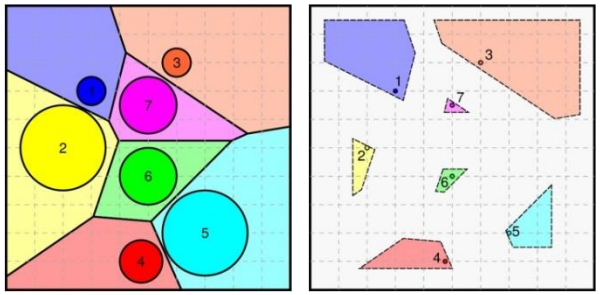


A multirobot configuration and its cluster hierarchy

Locality identification (e.g., collision-free neighborhood)



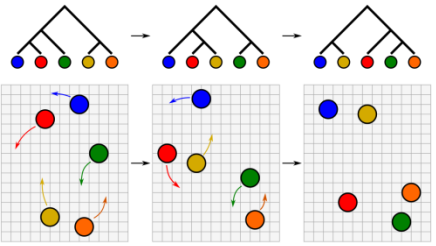
Single robot in cluttered environments



Noncolliding Disks

Coordinated Robot Navigation via Hierarchical Clustering

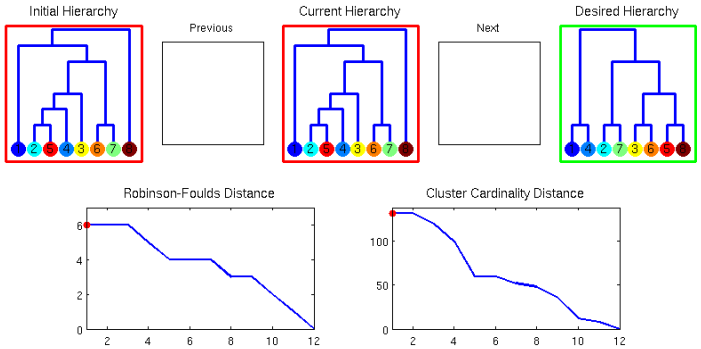
[Arslan, Guralnik, Koditschek, TRO'16]



Navigation in Tree Space

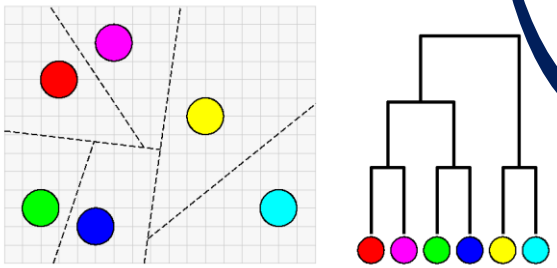
High-level discrete planner

[Arslan, Guralnik, Koditschek, DAM'16,Conditionally Accepted]



Hierarchical Abstraction

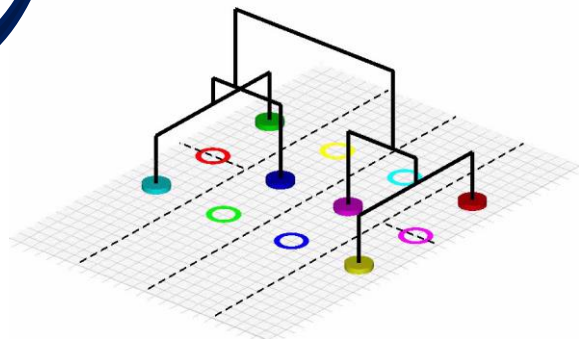
A relation from the continuous configuration space to the abstract space of binary hierarchies



Hierarchical Portals

Geometric realizations of discrete hierarchical transitions in the continuous configuration space

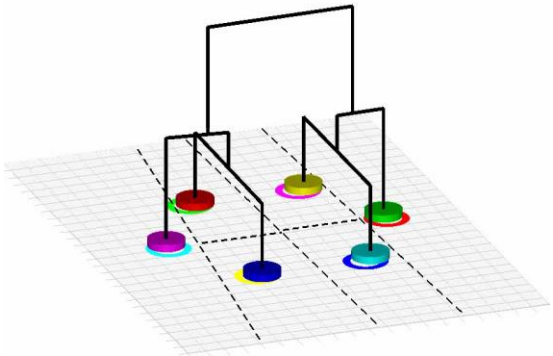
[Arslan, Guralnik, Koditschek, WAFR'14]



Hierarchy Preserving Navigation

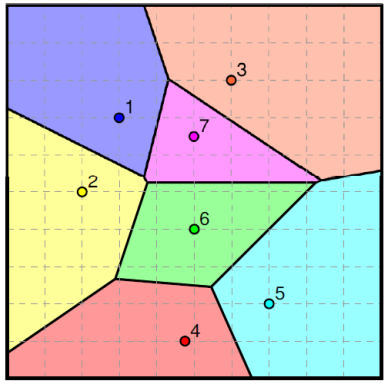
Low-level continuous vector field planner

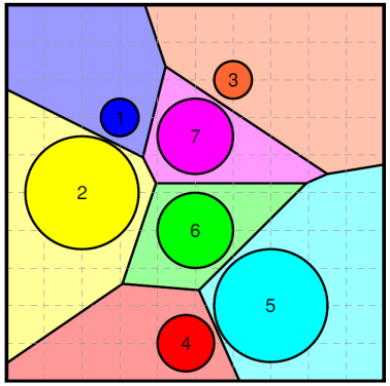
[Arslan, Guralnik, Koditschek, Allerton'12]



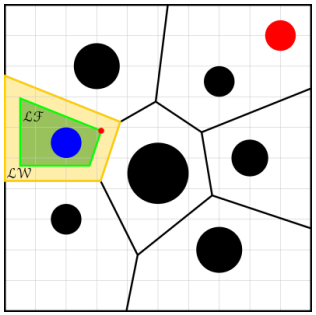
Encoding Collisions via Robot-Centric Voronoi Diagrams

Power Diagram [Aurenhammer, SIAM JC'87]

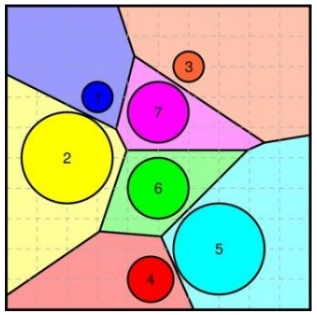


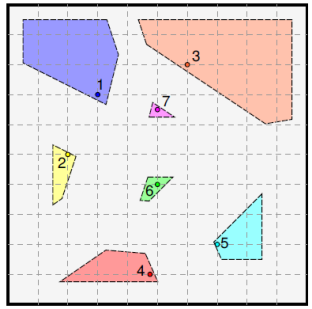


Local Free Space



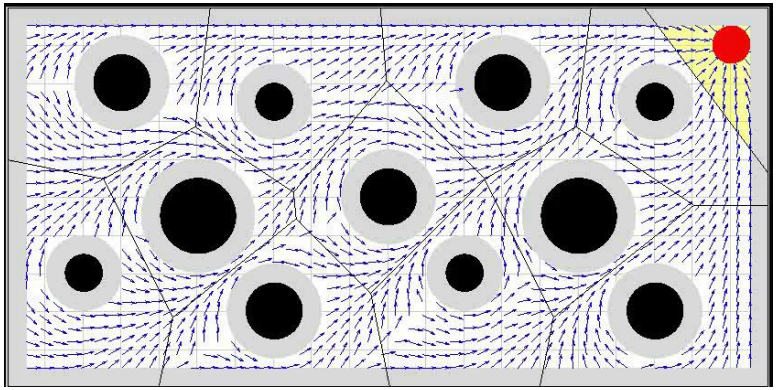
Single robot in a cluttered environment





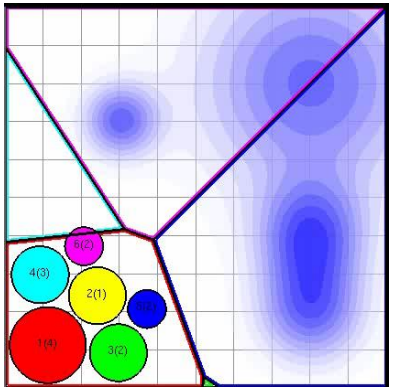
Noncolliding Disks

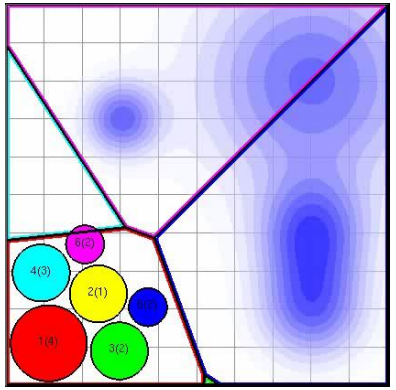
The "move-to-projected-goal" law



[Arslan,Kod, ICRA'16A]

The "move-to-constrained-centroid" law





[Arslan,Kod, ICRA'16B]

Contributions

- The use of clustering for modelling configuration spaces and for design of provably correct motion planners

- Potential applications of clustering to the problem of feedback motion planning and control
  - Coordinated Robot Navigation via Hierarchical Clustering
  - Encoding Collisions via Robot-Centric Voronoi Diagrams
    - Reactive robot navigation in forest-like environment
    - Safe coverage control of heterogeneous disk-shaped robots

References

[1] O. Arslan, Y. Baryshnikov, D. P. Guralnik, and D. E. Koditschek, “Hierarchically clustered navigation of distinct euclidean particles,” in *Communication, Control, and Computing (Allerton), 2012 50th Annual Allerton Conference on*, 2012, pp. 946–953.

[2] O. Arslan, D. P. Guralnik, and D. E. Koditschek, “Navigation of distinct Euclidean particles via hierarchical clustering,” *Algorithmic Foundations of Robotics XI, Springer Tracts in Advanced Robotics*, vol. 107, pp. 19–36, 2015.

[3] O. Arslan, D. P. Guralnik, and D. E. Koditschek, “Discriminative measures for comparison of phylogenetic trees,” *(accepted to) Discrete Applied Mathematics*, 2016.

[4] O. Arslan, D. P. Guralnik, and D. E. Koditschek, “Coordinated robot navigation via hierarchical clustering,” *Robotics, IEEE Transactions on*, vol. 32, no. 2, pp. 352–371, 2016.

[5] O. Arslan and D. E. Koditschek, “Exact robot navigation using power diagrams,” in *Robotics and Automation, 2016 IEEE International Conference on (in press)*, 2016.

[6] O. Arslan and D. E. Koditschek, “Voronoi-based coverage control of heterogeneous disk-shaped robots,” in *Robotics and Automation, 2016 IEEE International Conference on (in press)*, 2016.

[7] F. Aurenhammer, “Power diagrams: Properties, algorithms and applications,” *SIAM Journal on Computing*, vol. 16, no. 1, pp. 78–96, 1987.

[8] H. Choset, K. M. Lynch, S. Hutchinson, G. A. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun. Principles of Robot Motion: Theory, Algorithms, and Implementations. MIT Press, Cambridge, MA, 2005.

[9] A. K. Jain and R. C. Dubes, *Algorithms for clustering data*. Prentice-Hall, Inc., 1988.

[10] S. M. LaValle. Planning Algorithms. Cambridge University Press, Cambridge, UK, 2006.