Disclaimer

These slides are intended as presentation aids for the lecture. They contain information that would otherwise be to difficult or time-consuming to reproduce on the board. But they are incomplete, not self-explanatory, and are not always used in the order they appear in this presentation. As a result, these slides should not be used as a script for this course. I recommend you take notes during class, maybe on the slides themselves. It has been shown that taking notes improves learning success.

Reading for this set of slides

- Planning Algorithms (Steve LaValle)
  - 4 The Configuration Space (4.1 – 4.3)
  - 5 Sampling-based Motion Planning (5.1, 5.5, 5.6, also skim the remaining sections)

Please note that this set of slides is intended as support for the lecture, not as a stand-alone script. If you want to study for this course, please use these slides in conjunction with the indicated chapters in the text books. The textbooks are available online or in the TUB library (many copies that can be checked out for the entire semester. There are also some aspects of the lectures that will not be covered in the text books but can still be part of the homework or exam. For those It is important that you attend class or ask somebody about what was covered in class.

Robotics

Motion Planning – Some History

TU Berlin

Oliver Brock

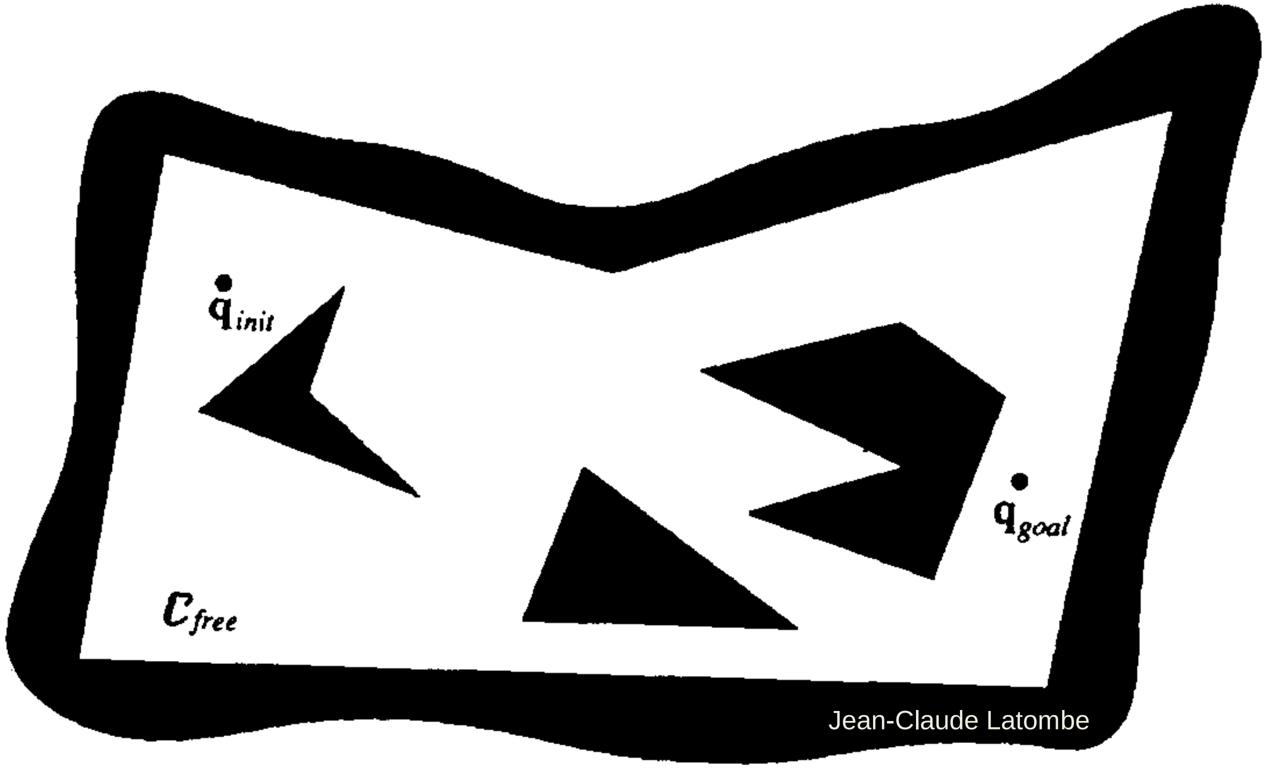
Origins of Motion Planning

- Tomás Lozano-Perez and M.A. Wesley: "An Algorithm for Planning Collision-Free Paths Among Polyhedral Obstacles", 1979.
- Introduced the notion of C-space to robotics
- Many approaches have been devised since then in C-space

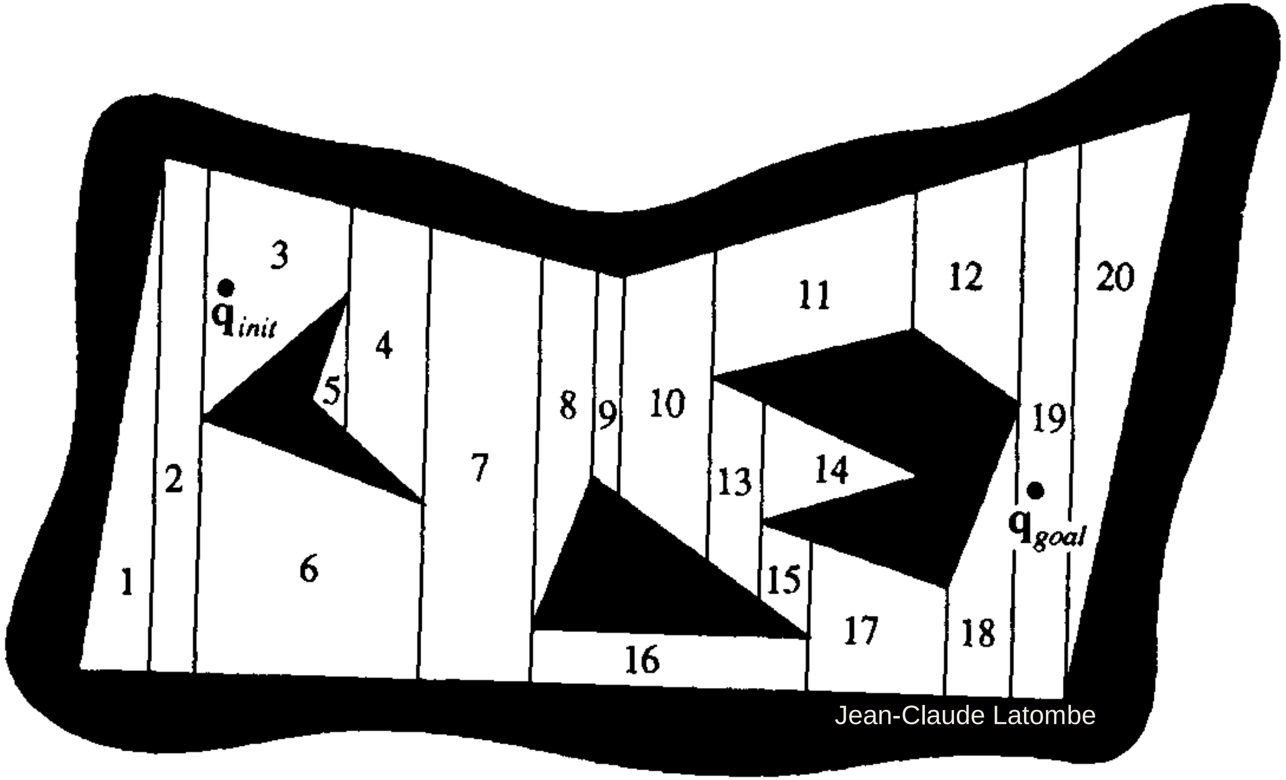
4 Basic Categories of Motion Planning Methods

- Exact Cell Decomposition
- Approximate Cell Decomposition
- Roadmap Methods
- Potential Field Methods

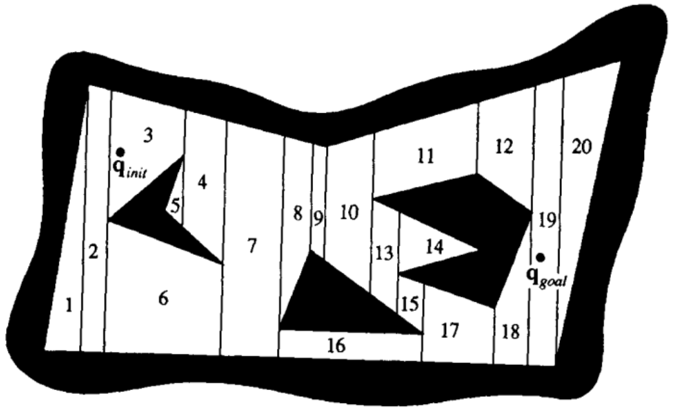
Exact Cell Decomposition

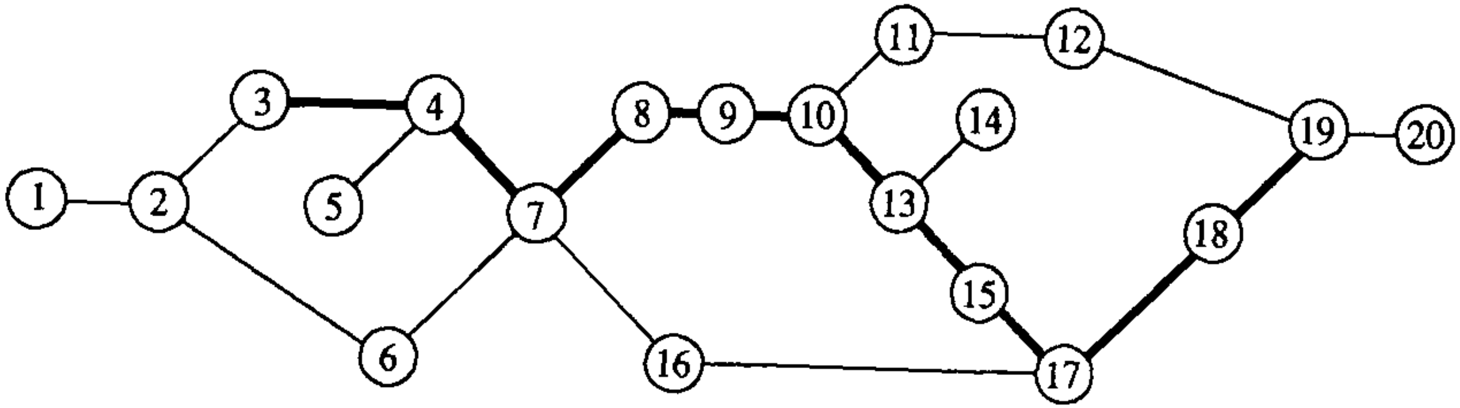


Exact Cell Decomposition cont.



Exact Cell Decomposition cont.





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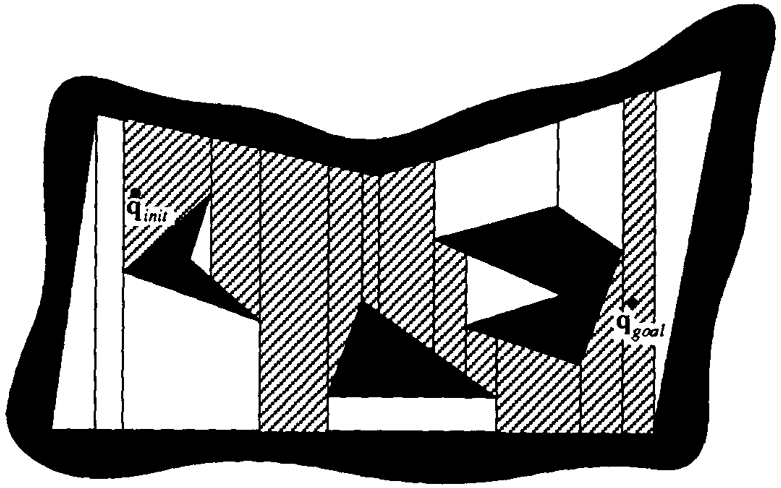
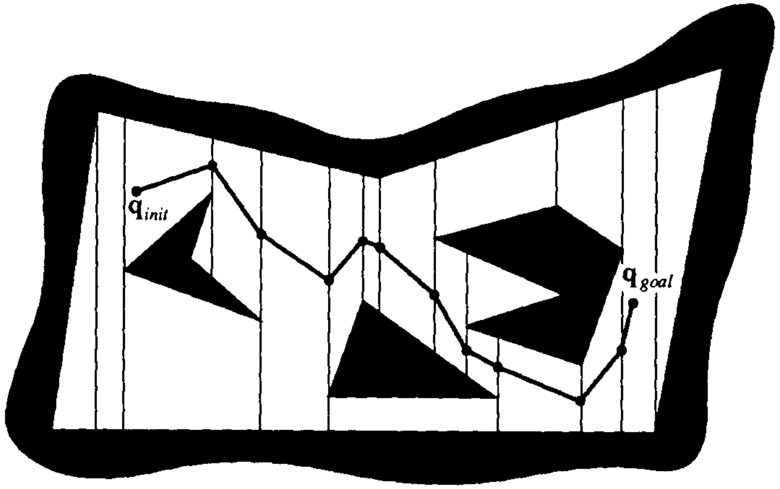
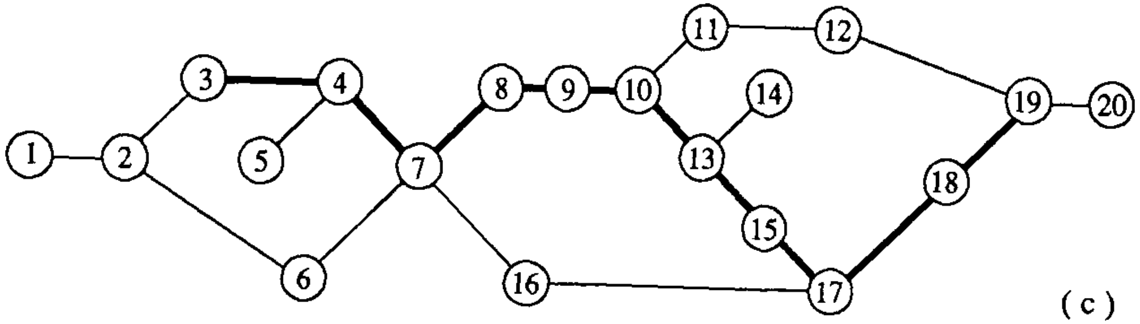
Exact Cell Decomposition cont.







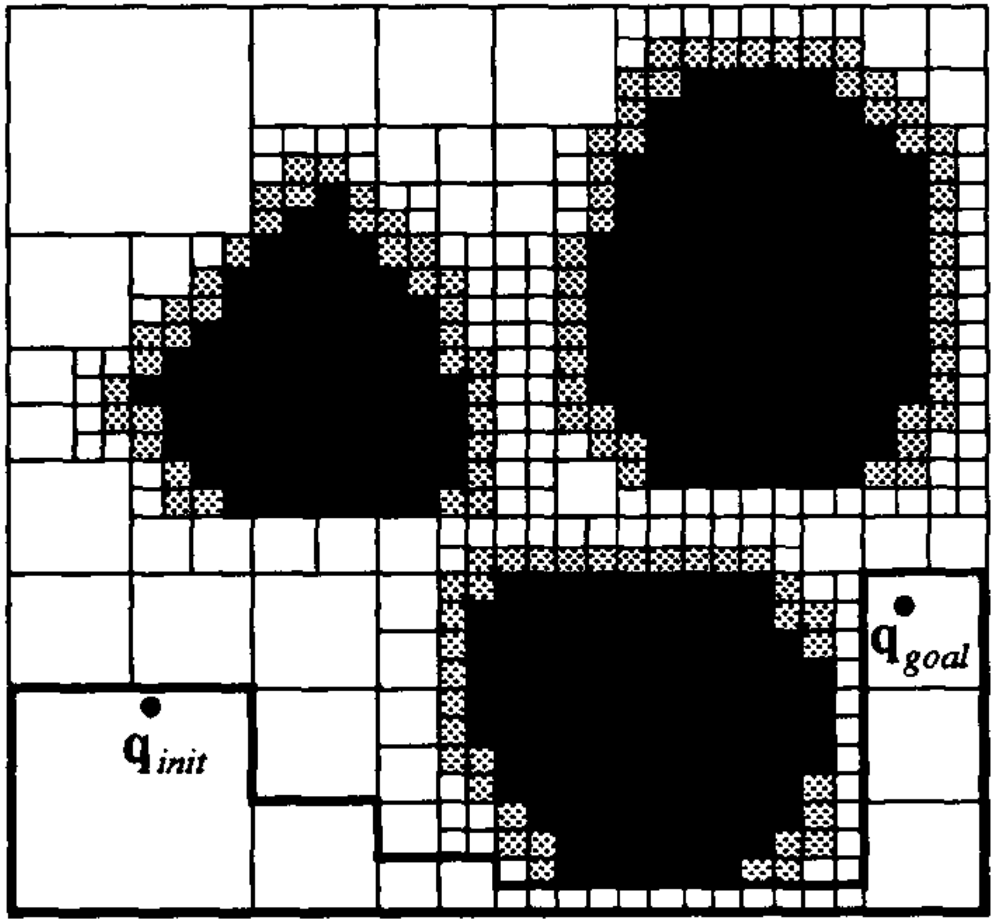
Additional Exact Cell Decomp. Methods

- Stick robot (line segment) in the plane
- General case
  - "…makes use of a well-known result established by Collins ('75) for deciding the satisfiability of Tarski sentences."
- We'll pass…
  - (Often) complicated
  - Impractical
  - Computationally complex
  - But theoretically very appealing and elegant!

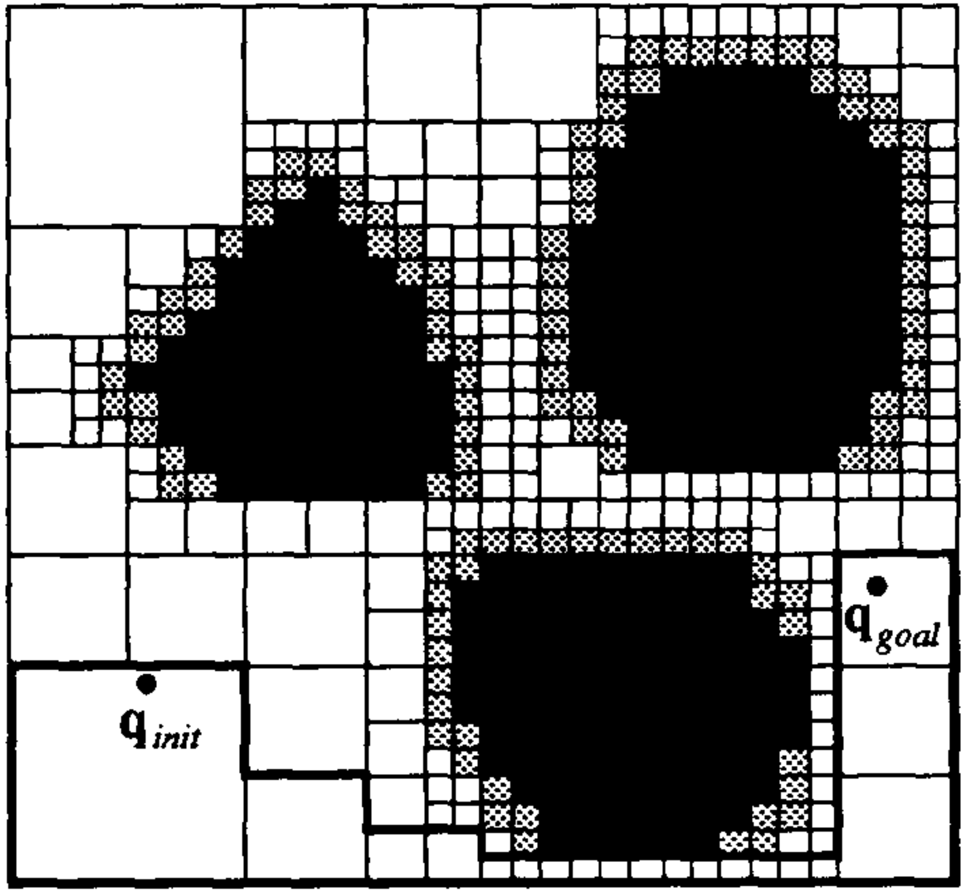
From Exact to Approximate

- Maybe we don’t even need to know **everything** there is to know…
- Incremental refinement of our understanding until we find a solution

2^n-Tree



Approximate Cell Decomposition



Again: we build a graph and search it to find a path!

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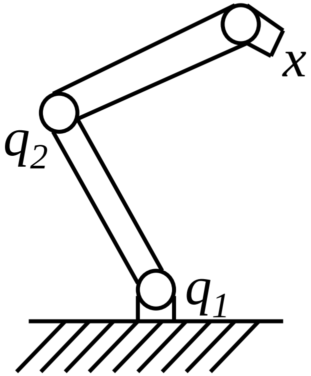
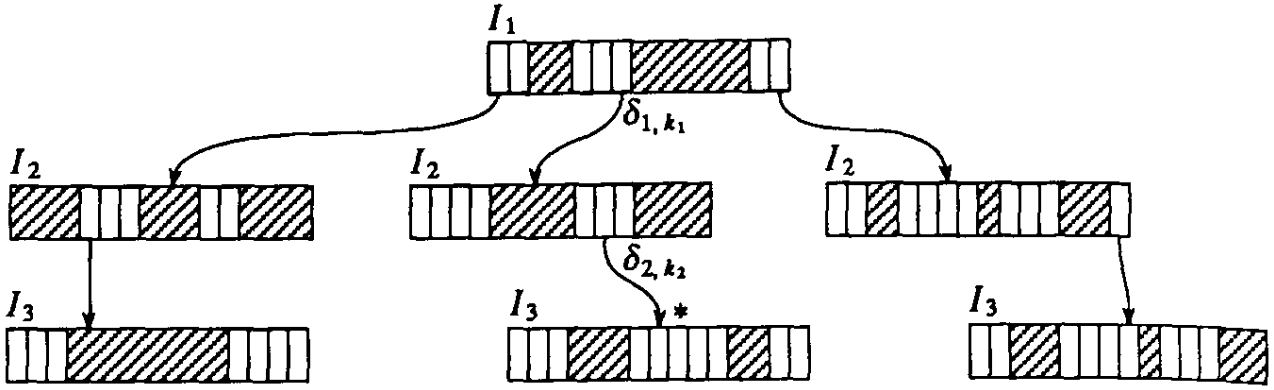
Approximate Cell Decomposition in Higher Dimensions





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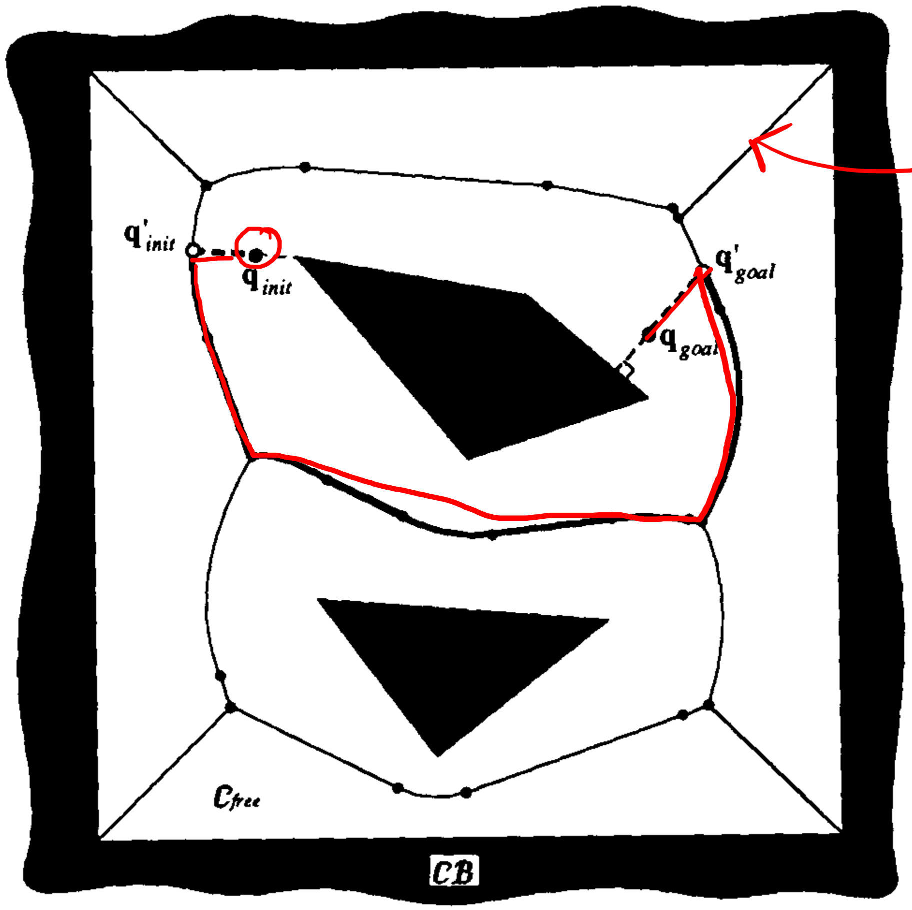
So far:

- Cell decomposition methods:
  - exact
  - approximate
- General approach:
  - decompose C-space into simple cells
  - represent adjacency of cells as a graph
  - search graph to obtain path

Generalized Voronoi Diagram



ROADMAP

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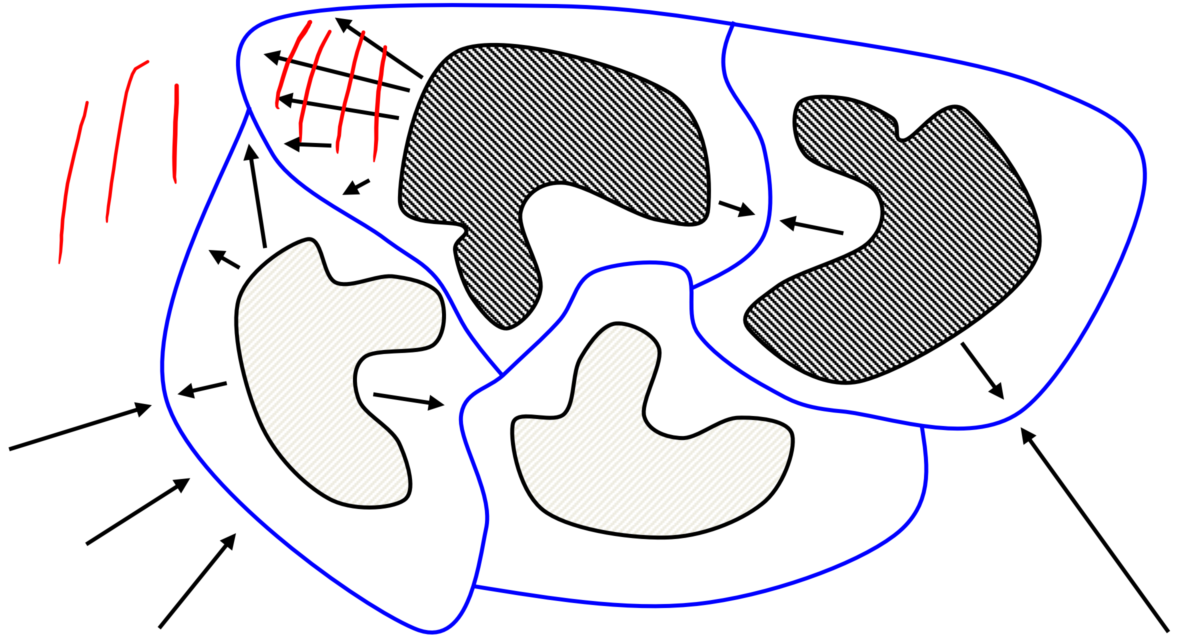
Retraction

A retraction is a continuous mapping of C_{free} onto a one-dimensional network of curves $R \subset C_{free}$.



Voronoi = Retraction

Four Categories

- Exact Cell Decomposition ✓
- Approximate Cell Decomposition ✓
- Roadmap Methods; examples:
  - Visibility ✓
  - Voronoi ✓
  - PRM LATER !
- Potential Field Methods ✓✓

Completeness of Planning Algorithms

- A planner is **complete,** if it will find a path whenever one exists
- Resolution complete APPR. CELL DEC.
  - Complete up to a given resolution
- Probabilistic Completeness → SAMPLING-BASED
  - Complete with a certain probability
- Most global methods exhibit some form of completeness
- Local methods are incomplete (local minima, saddle points, …)

Global Motion Planning is Difficult

- Most efficient *complete* and *general* algorithm so far:
  - Silhouette Method by Canny in 1988
  - Roadmap method
  - C-space with d dimensions
  - DOUBLE Exponential in d

COMPLETE

- *PSPACE*-hardness has been shown for many simple problems:
  - Planar arm among polygonal obstacles
  - Rectangles in the plane

Comparison of Planning Methods