CS686: Classic Motion Planning Methods

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(윤성의)

Course URL:
http://sglab.kaist.ac.kr/~sungeui/MPA

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Class Objectives

- Classic motion planning approaches
  - Roadmap
  - Cell decomposition
  - Potential field

Classic Path Planning Approaches

- Roadmap
  - Represent the connectivity of the free space by a network of 1-D curves
- Cell decomposition
  - Decompose the free space into simple cells and represent the connectivity of the free space by the adjacency graph of these cells
- Potential field
  - Define a function over the free space that has a global minimum at the goal configuration and follow its steepest descent

Classic Path Planning Approaches

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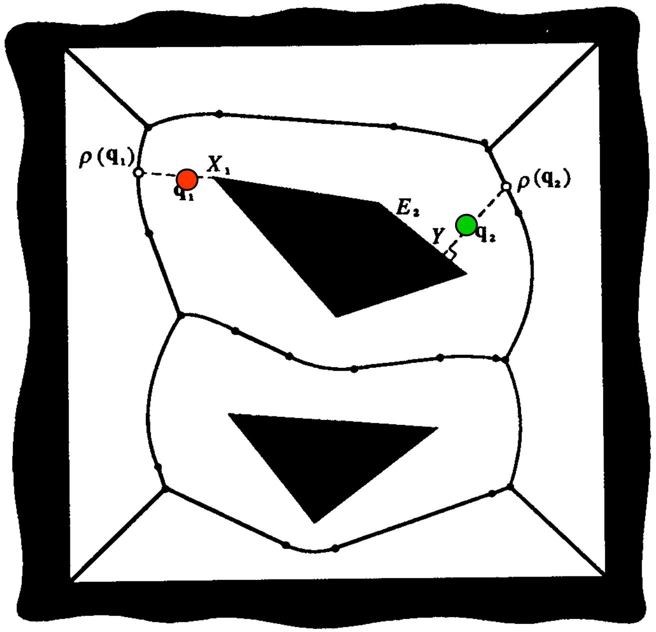
Roadmap Methods

- Visibility Graph
  - Shakey project, SRI [Nilsson 69]
- Voronoi diagram
  - Introduced by computational geometry researchers
  - Generate paths that maximize clearance
  - O(n log n) time and O(n) space for 2D points

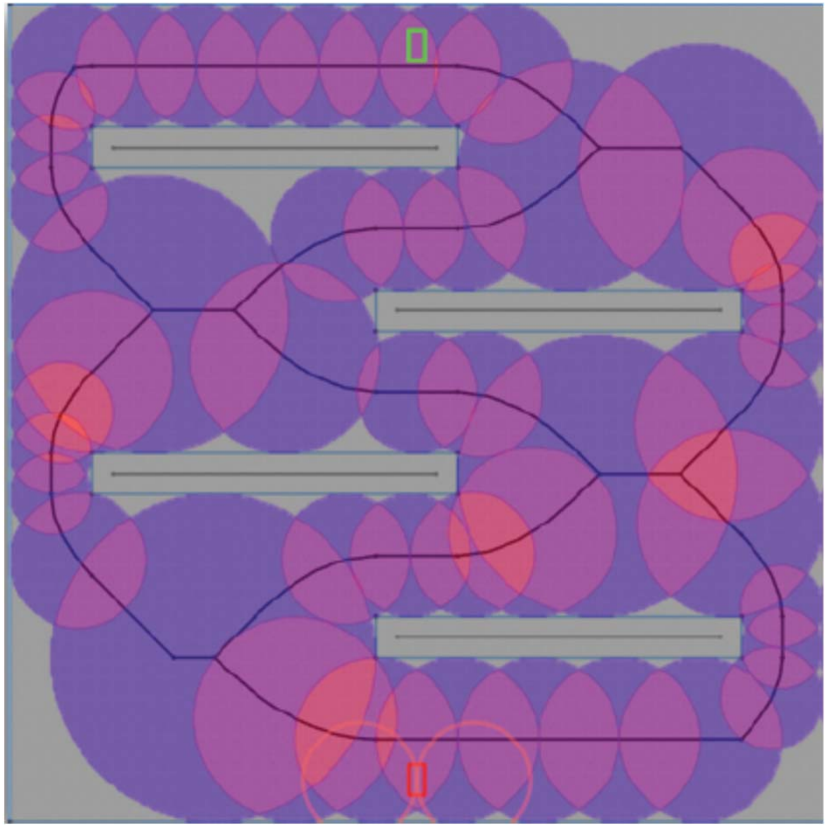


Other Roadmap Methods

- **Visibility graph**
- **Voronoi diagram**
- **Silhouette**
  - **First complete general method that applies to spaces of any dimension and is singly exponential in # of dimensions [Canny, 87]; e.g., $O\left(n^{2^{f(k)}}\right) \rightarrow O(n^k)$**
- **Probabilistic roadmaps**

Cloud RRT* [Kim et al., ICRA]

- **Use Voronoi diagram to bias sampling for achieving better convergence to optimal path**



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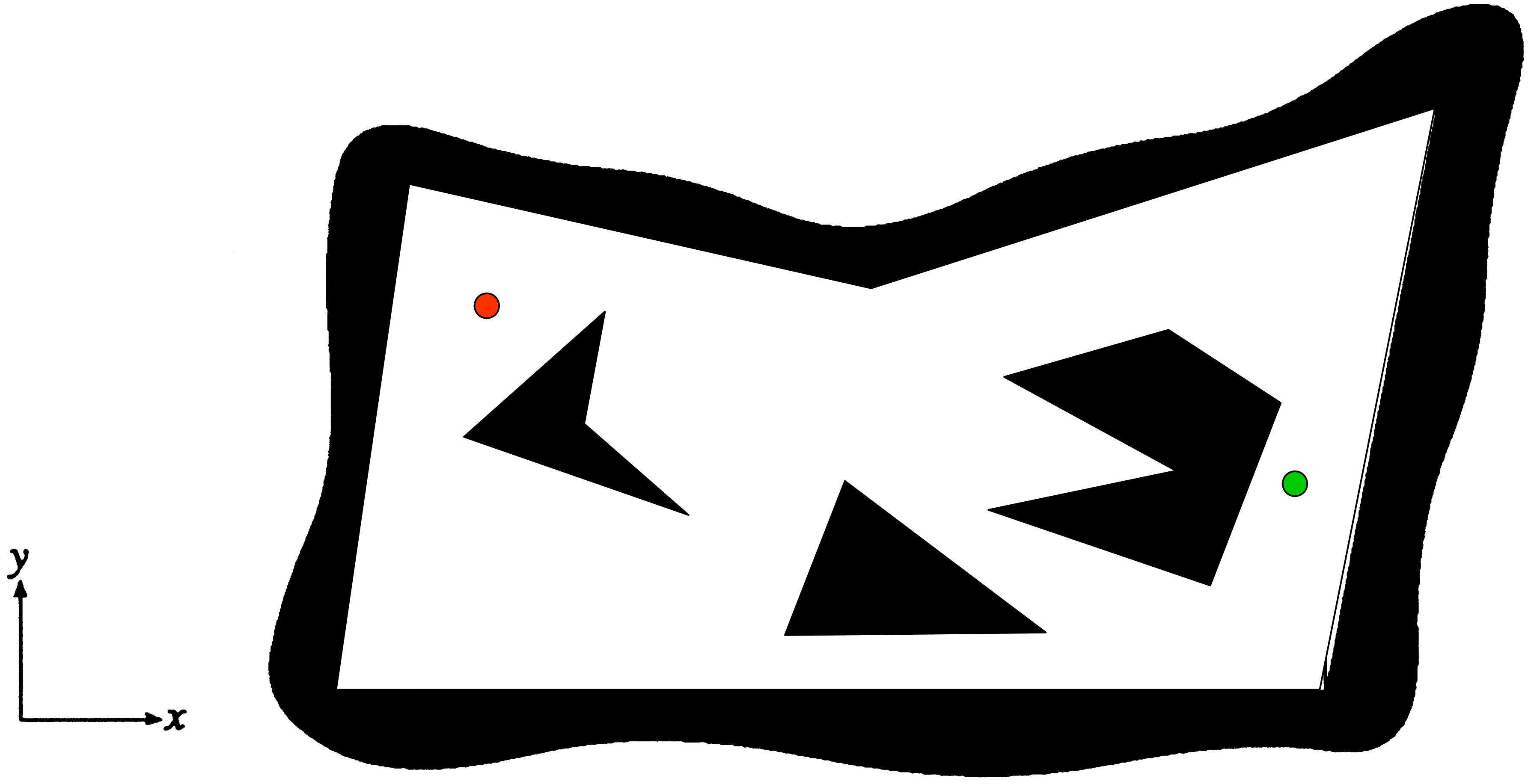
Cell-Decomposition Methods

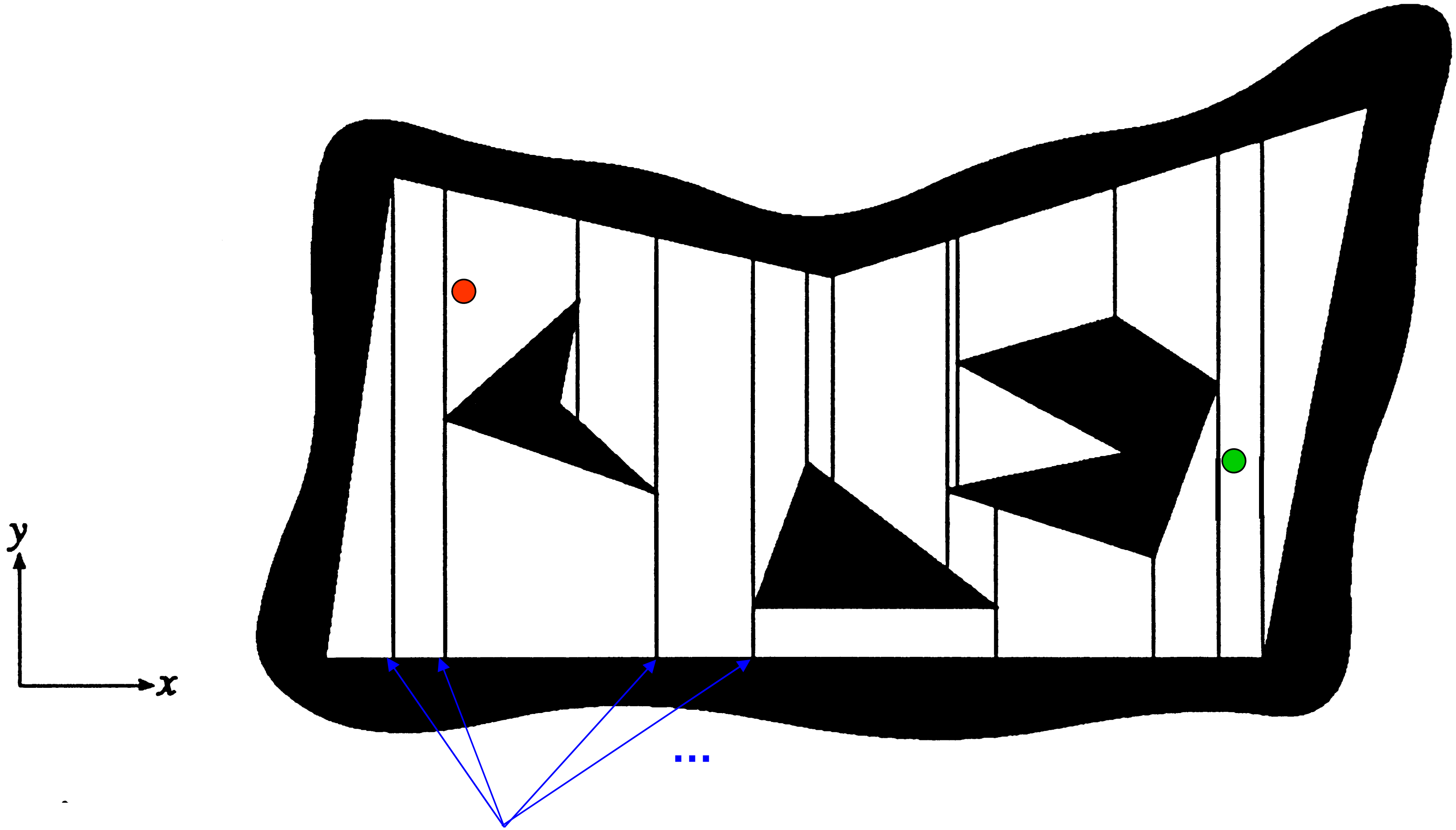
- **Two classes of methods:**
  - **Exact and approximate cell decompositions**

- **Exact cell decomposition**
  - **The free space F is represented by a collection of non-overlapping cells whose union is exactly F**
  - **Example: trapezoidal decomposition**

Trapezoidal Decomposition



Trapezoidal Decomposition



critical events → criticality-based decomposition

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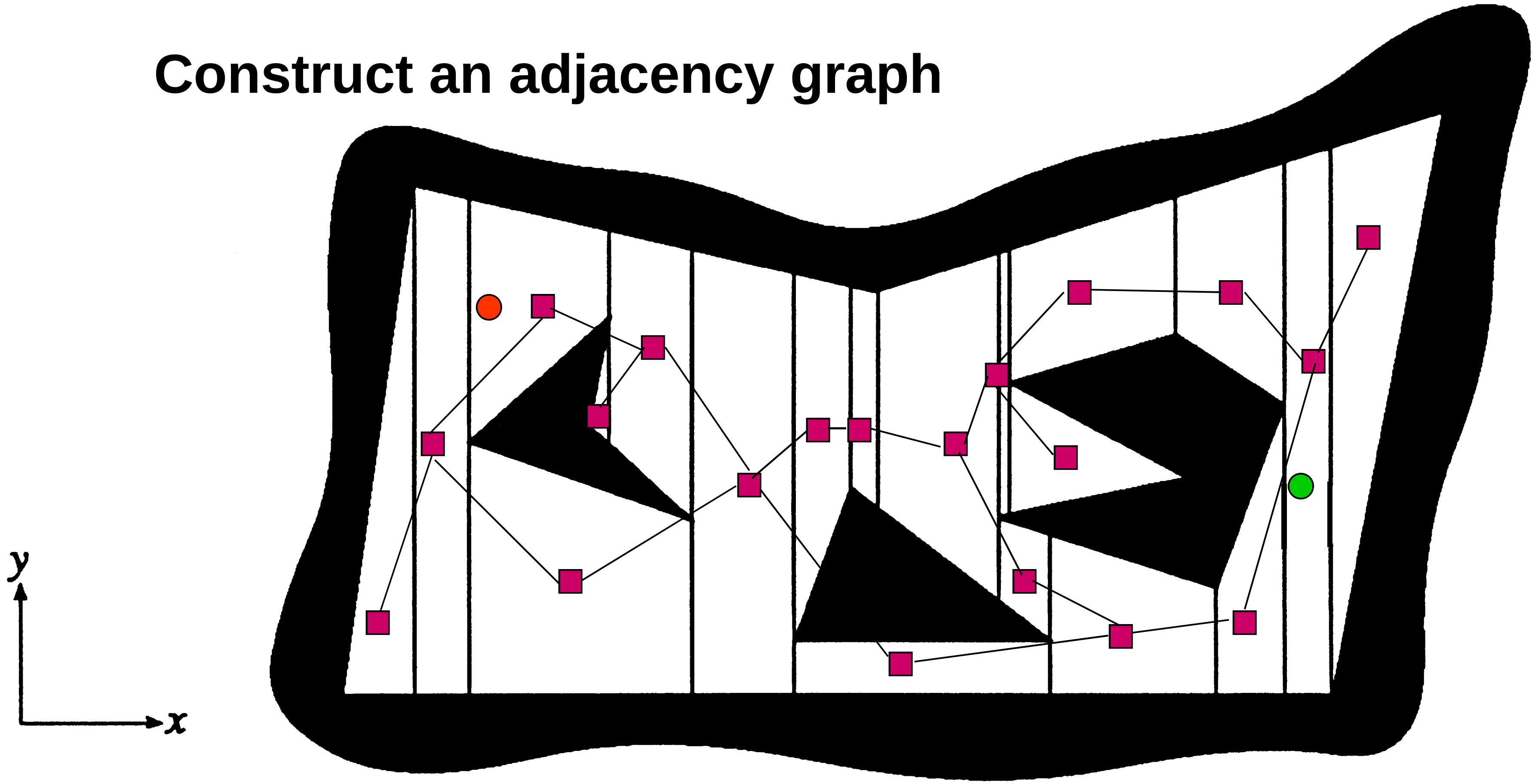
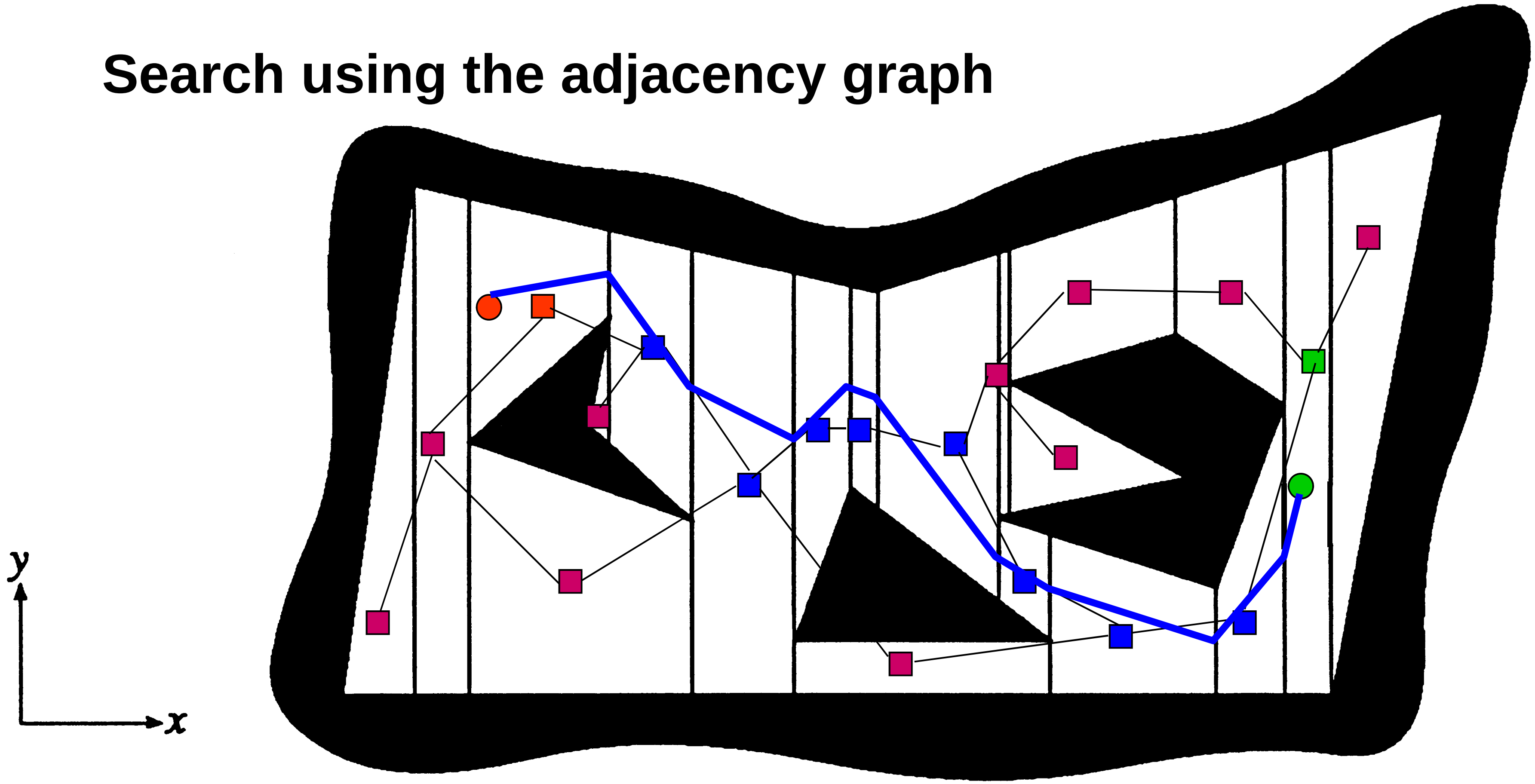
Trapezoidal Decomposition

Construct an adjacency graph



Trapezoidal Decomposition

Search using the adjacency graph



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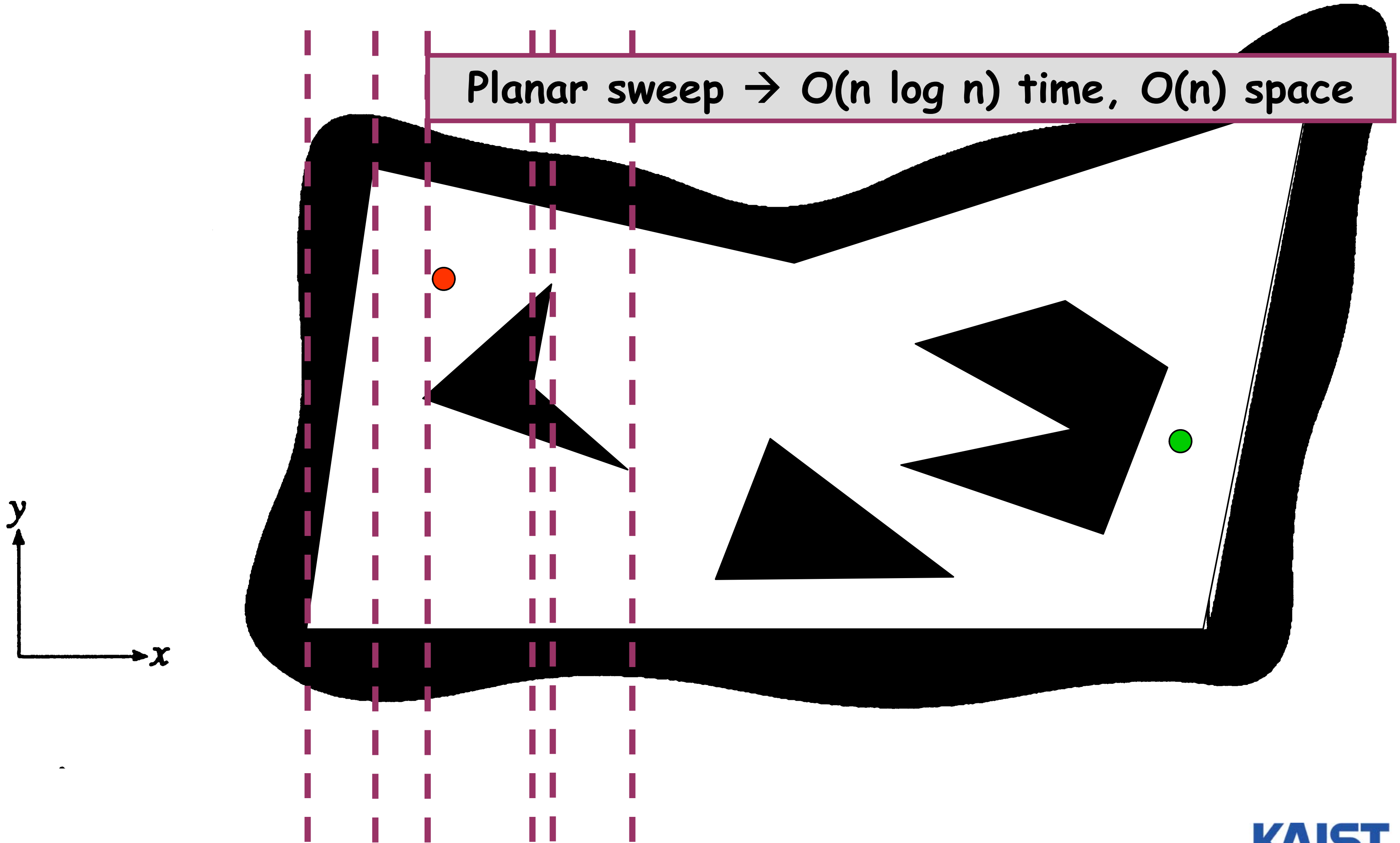
Trapezoidal Decomposition

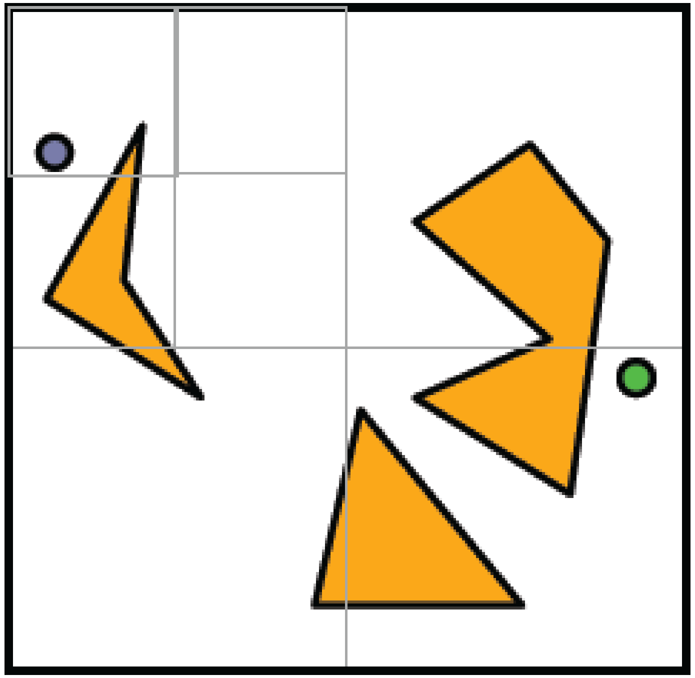


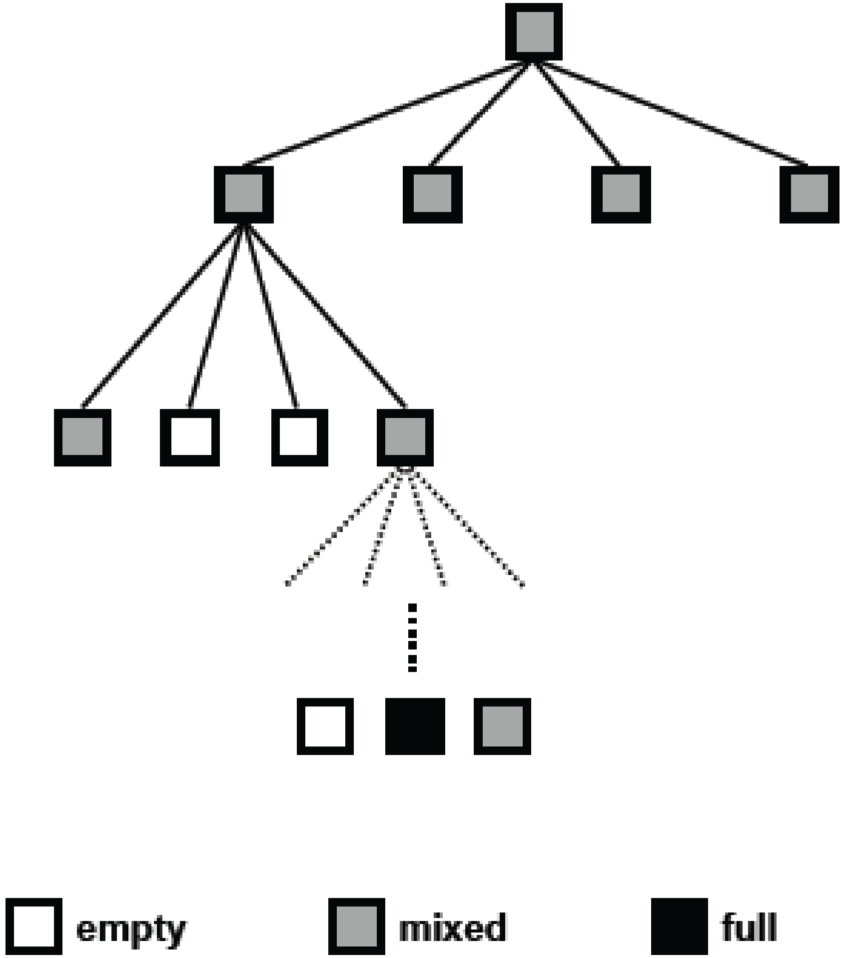
Cell-Decomposition Methods

- Two classes of methods:
  - Exact and approximate cell decompositions

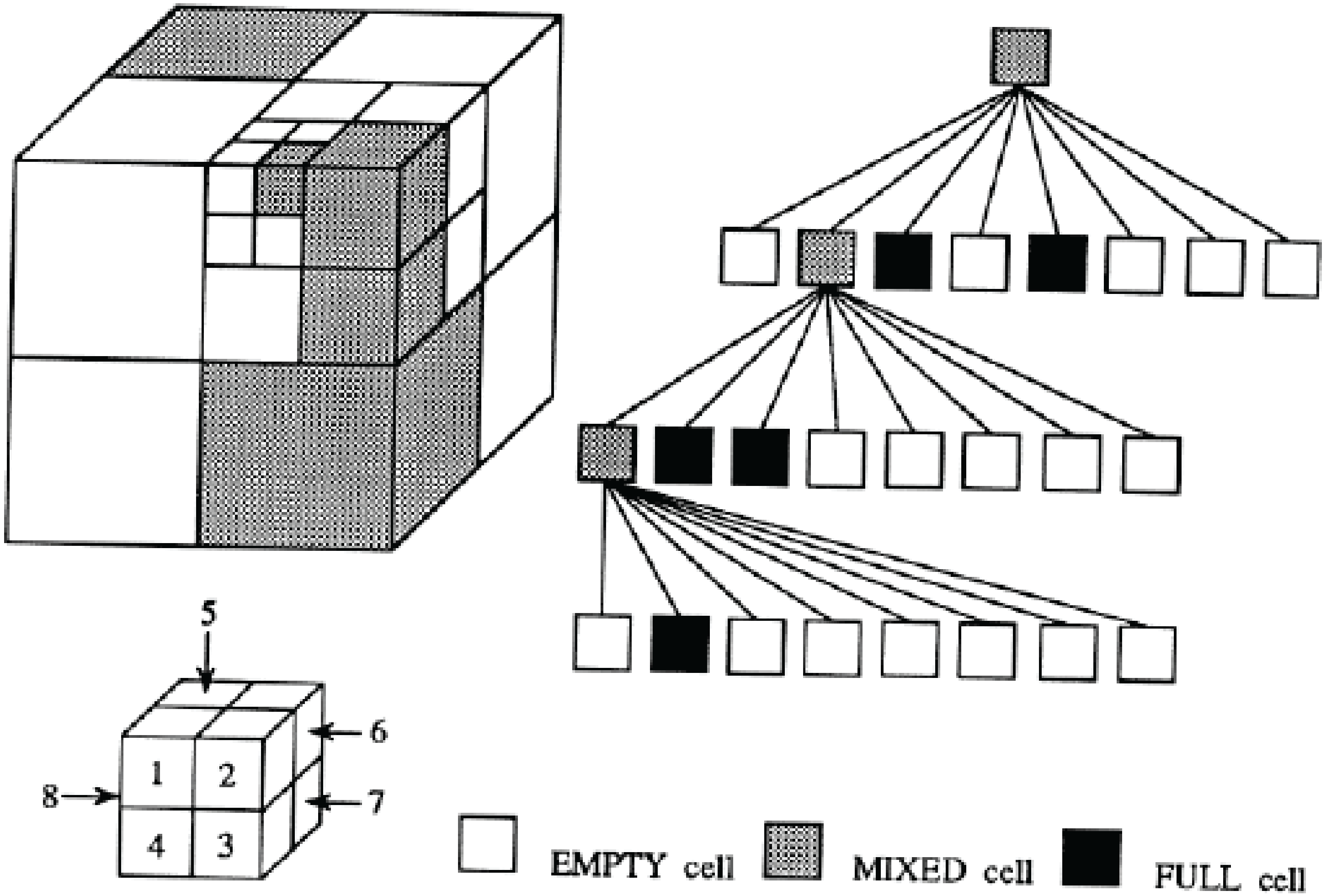
- Exact cell decomposition
- Approximate cell decomposition
  - The free space F is represented by a collection of non-overlapping cells whose union is contained in F
  - Cells usually have simple, regular shapes (e.g., rectangles and squares)
  - Facilitates hierarchical space decomposition

Quadtree decomposition



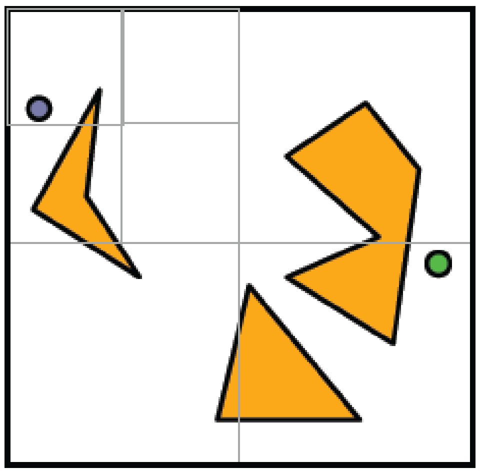


Octree decomposition



Sketch of Algorithm

1. Decompose the free space F into cells
2. Search for a sequence of mixed or free cells that connect that initial and goal positions
3. Further decompose the mixed
4. Repeat 2 and 3 until a sequence of free cells is found



Classic Path Planning Approaches

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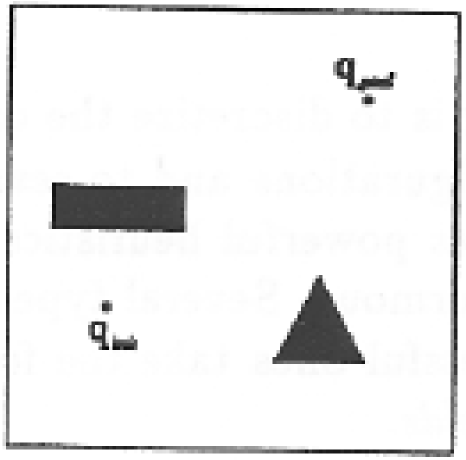
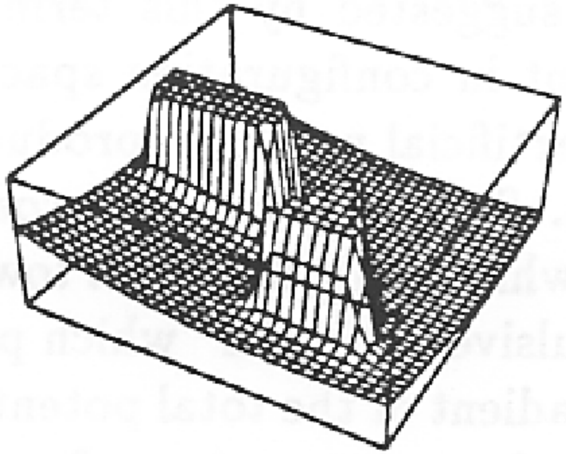
Potential Field Methods

- Initially proposed for real-time collision avoidance [Khatib, 86]
  - Use a scalar function, potential field, over the free space
  - Compute a force proportional to the negated gradient of the potential field



Workspace



A potential field

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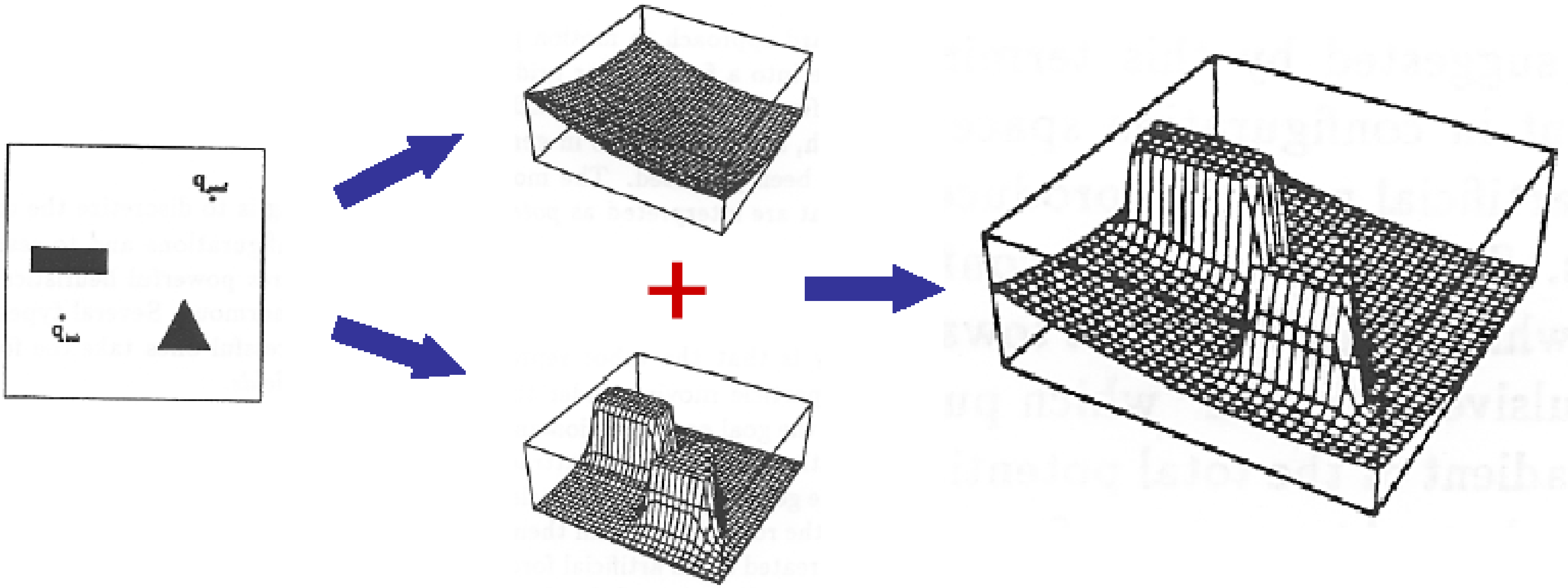
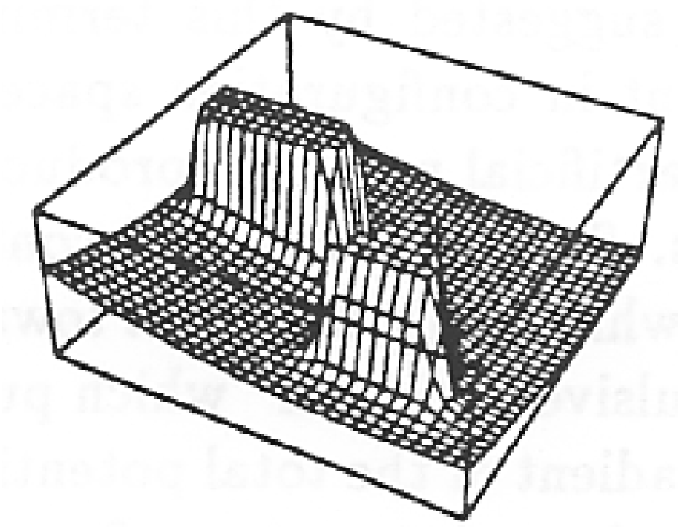
Attractive and Repulsive fields

Attractive field towards the goal



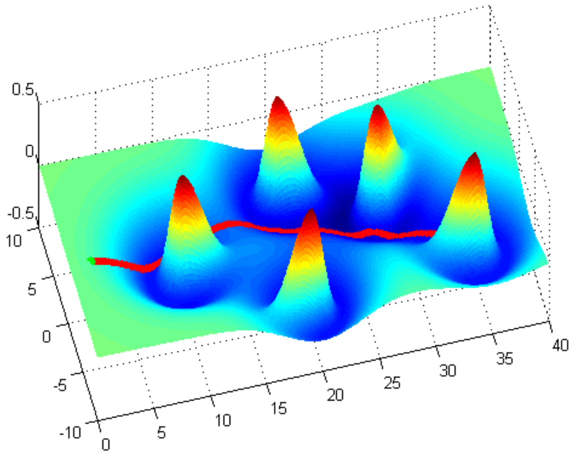
Repulsive field away from obstacles

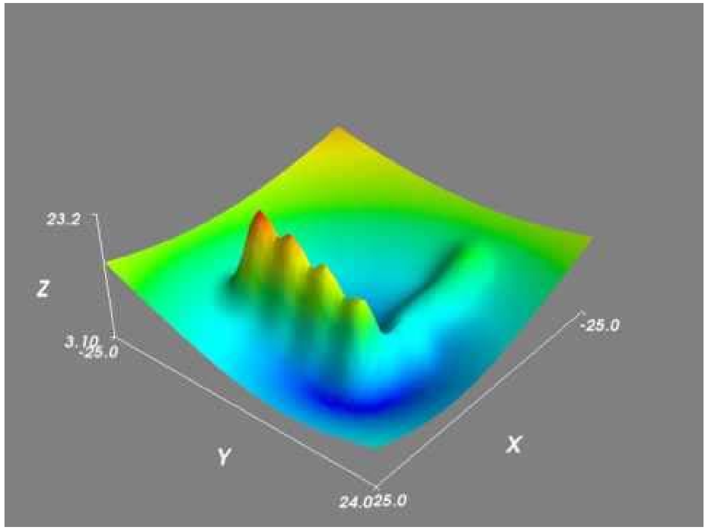
Ideal Potential Field



- The ideal one
  - Has the global minimum at the goal
  - Has no local minima
  - Grows to infinity near obstacles
  - Is smooth
- Can we compute the one?

Local Minima





Svenstrup

- **What can we do?**
  - **Escape from local minima by taking random walks**

Sketch of Algorithm

- Place a regular grid G over the configuration space
- Compute the potential field over G
- Search G using a best-first algorithm with potential field as the heuristic function

Completeness

- A complete motion planner always returns a solution when one exists and indicates that no such solution exists otherwise
  - Is the visibility algorithm complete? Yes
  - How about the exact cell decomposition algorithm and the potential field algorithm?

Class Objectives were:

- **Classic motion planning approaches**
  - **Roadmap**
  - **Cell decomposition**
  - **Potential field**

Homework

- Browse 2 ICRA / IROS / RSS / WAFR / TRO / IJRR papers
  - Prepare two summaries and submit at the beginning of every Tue. class, or
  - Submit it online before the Tue. Class

- Example of a summary (just a paragraph)

  Title: XXX XXXX XXXX
  Conf./Journal Name: ICRA, 2015
  Summary: this paper is about accelerating the performance of collision detection. To achieve its goal, they design a new technique for reordering nodes, since by doing so, they can improve the coherence and thus improve the overall performance.

Homework for Every Class

- **Go over the next lecture slides**
- **Come up with one question on what we have discussed today and submit at the end of the class**
  - **1 for typical questions**
  - **2 for questions with thoughts or that surprised me**

- **Write a question at least 4 times before the mid-term exam**

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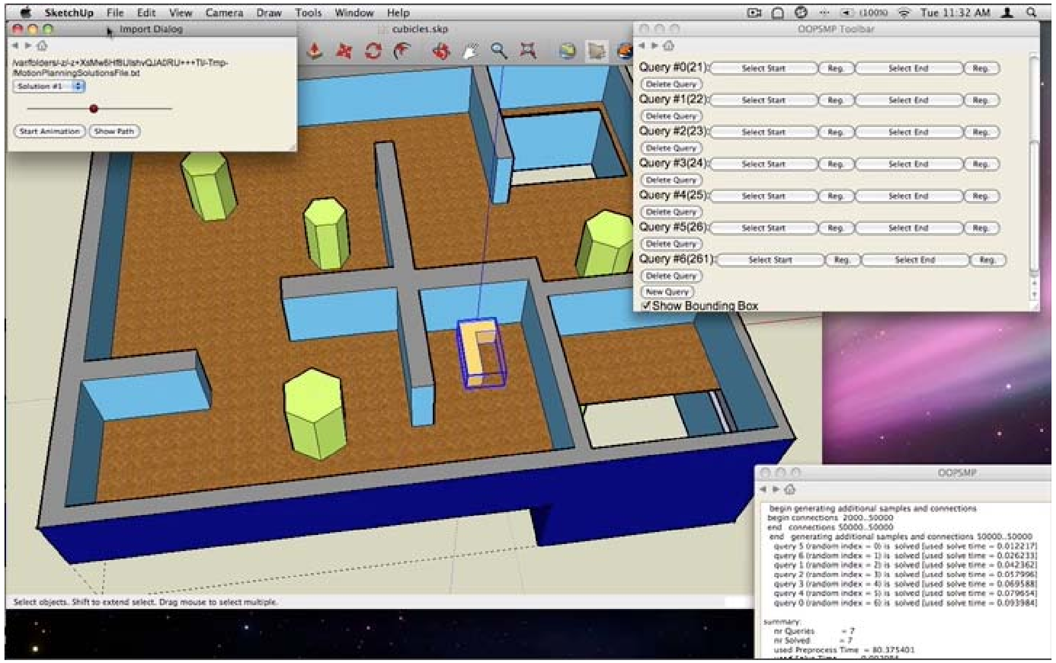
Homework: PA1

- Install Open Motion Planning Library (OMPL)
- Create a scene and a robot
- Find a collision-free path and visualize the path



Homework

- **Deadline: 11:59pm, Mar.-28**
- **Delivery: send an email to TA that contains:**
  - **An image that shows a scene with a robot with a computed path**
- **TA info:**
  - **SooMin Kim**
  - **See the homepage**

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Conf. Deadline

- **ICRA: Sep.-15 2017**
- **RSS: Jan, 2018**

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Next Time….

- Configuration spaces