CS686:
Classic Motion Planning Methods

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(윤성의)

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

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Class Objectives

- **Classic motion planning approaches**
  - **Roadmap**
  - **Cell decomposition**
  - **Potential field**
  - **Ch. 2 of my draft: https://sgvr.kaist.ac.kr/~sungeui/mp/**

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**

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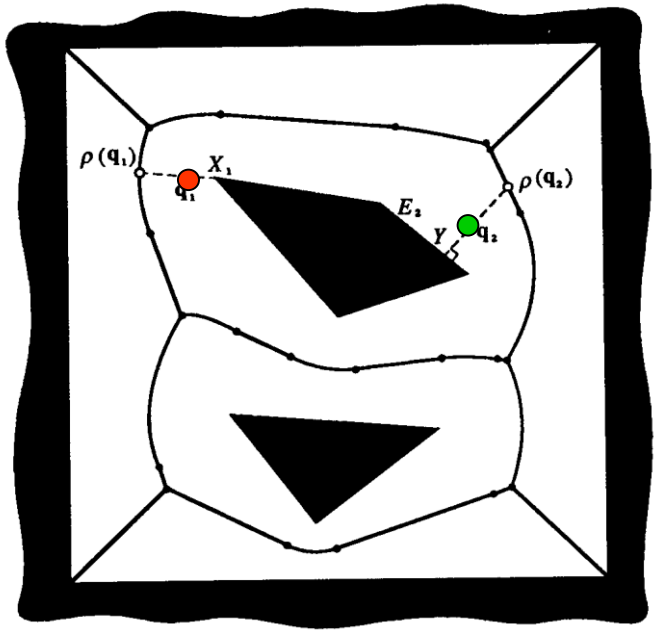
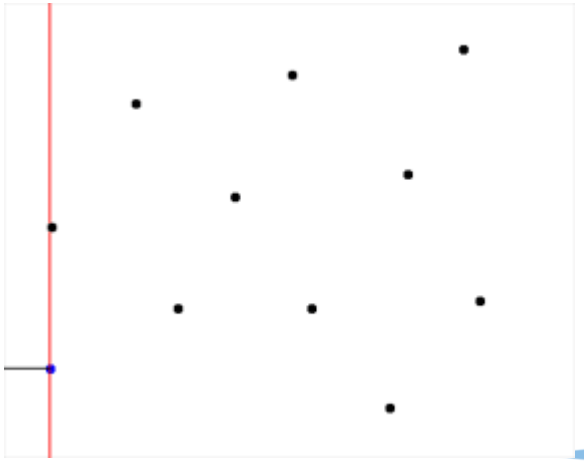
Roadmap Methods

- 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**
  - **GPU computation is possible**



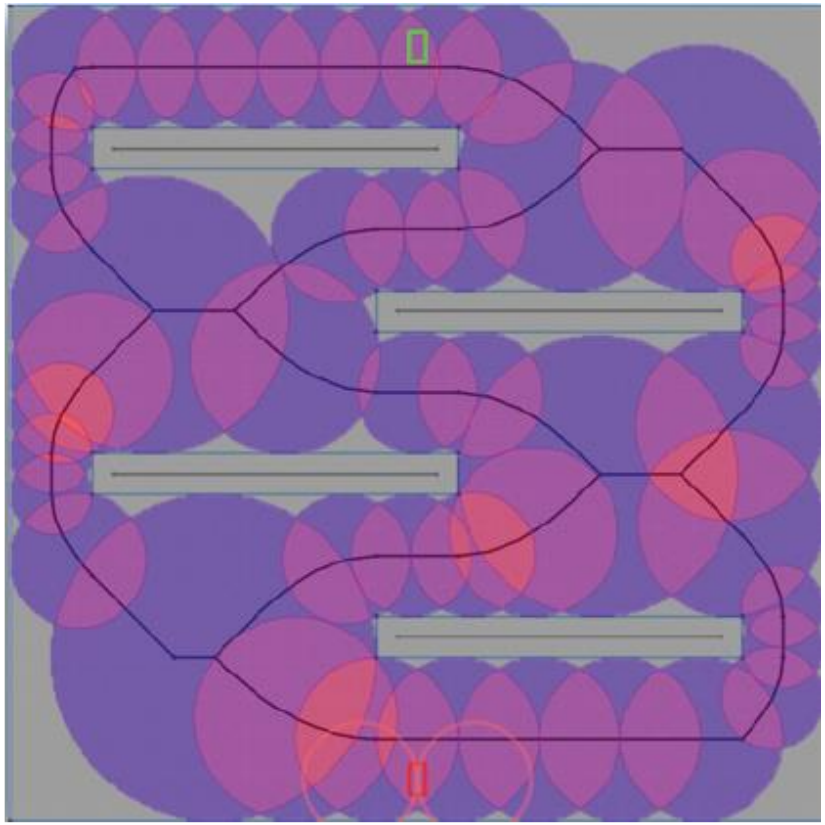


Other Roadmap Methods

- **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**



https://www.youtube.com/watch?v=NSuDtd1amC4

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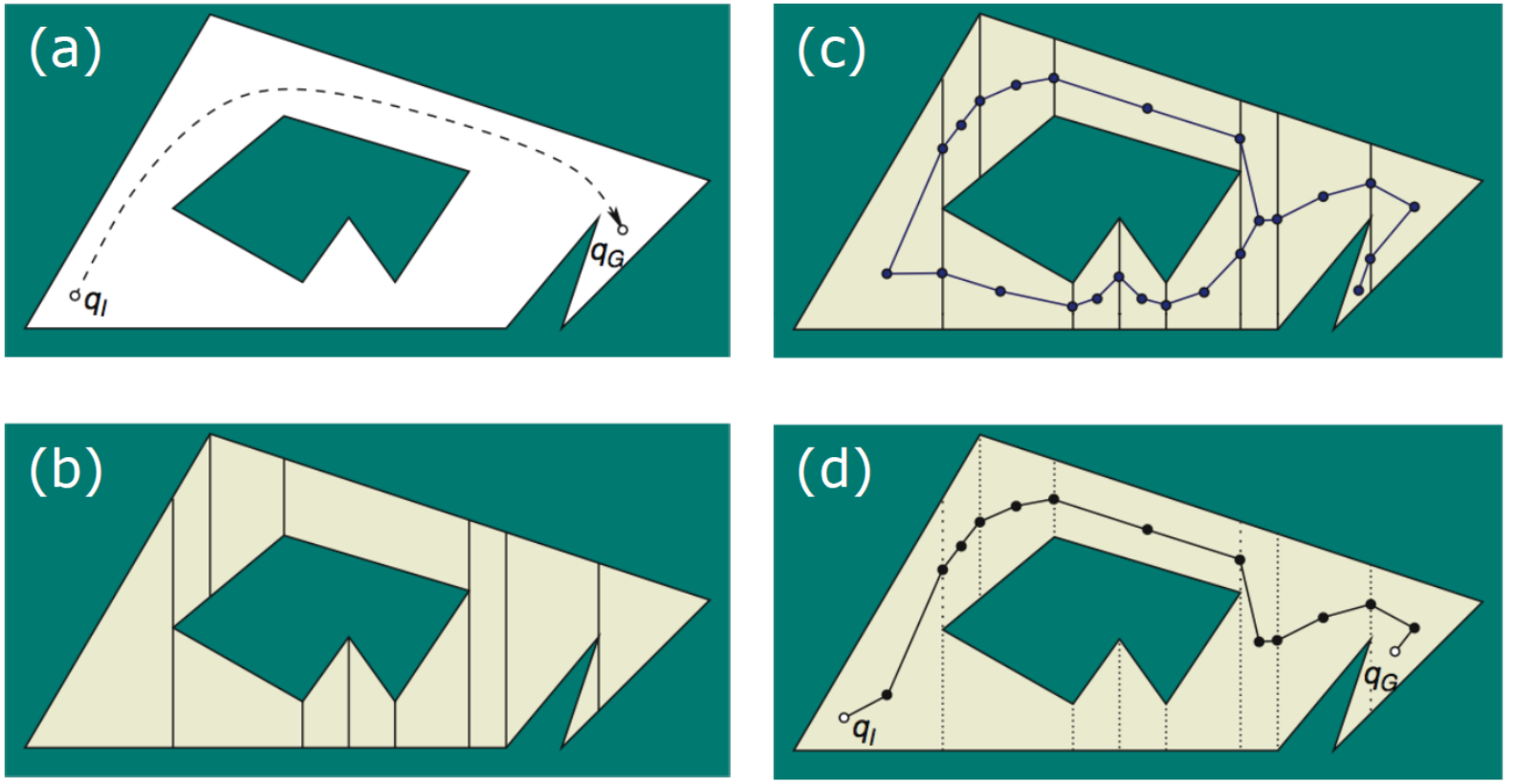
Cell-Decomposition Methods

- **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



Credit: Arras

Criticality-based (e.g., vertices) decomposition
→ Planar sweep → O(n log n) time, O(n) space

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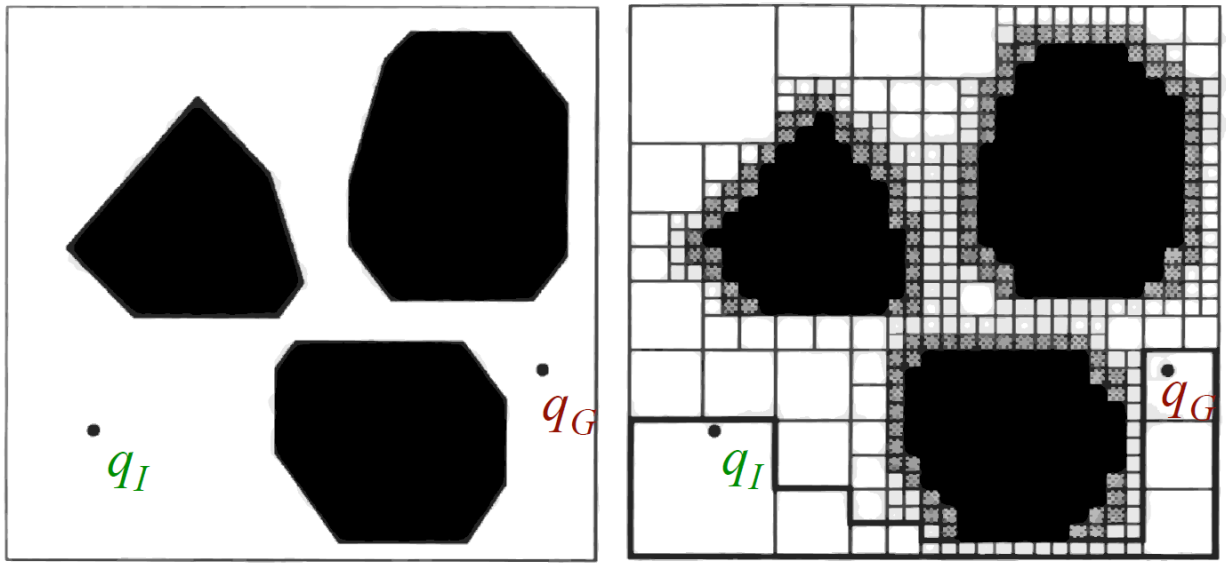
Cell-Decomposition Methods

- **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

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



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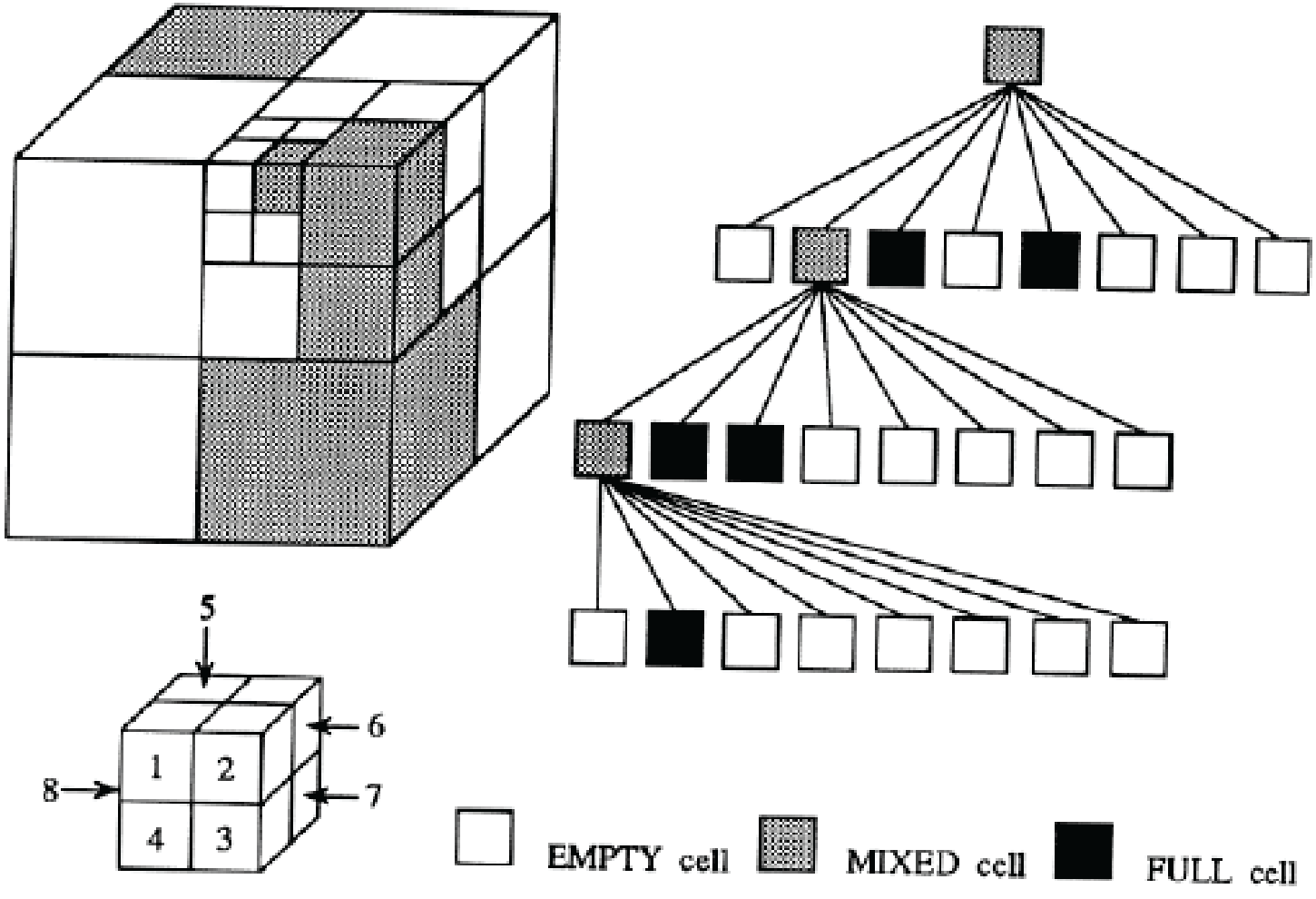
Octree decomposition



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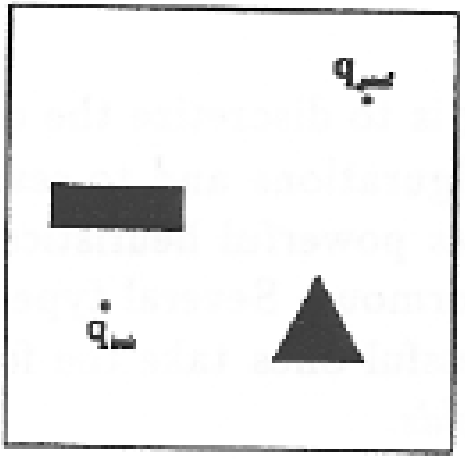
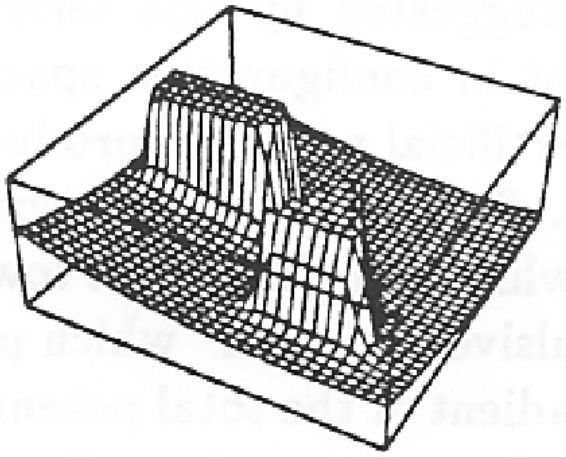
Potential Field Methods

- **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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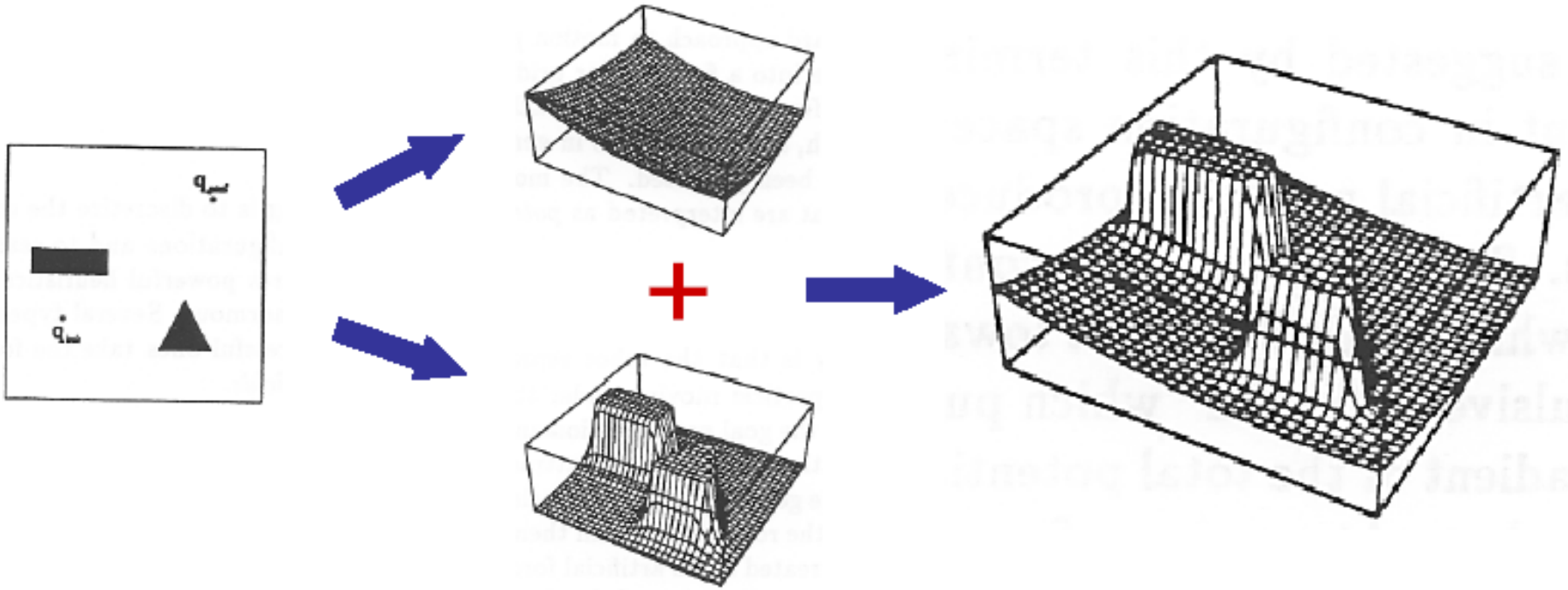
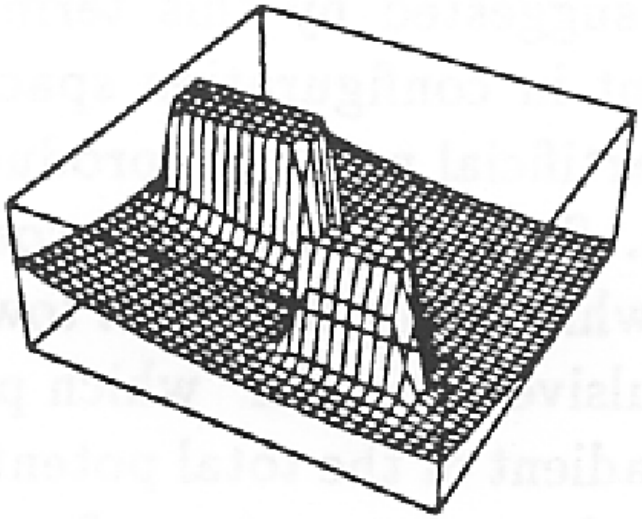
Attractive and Repulsive fields

Attractive field towards the goal



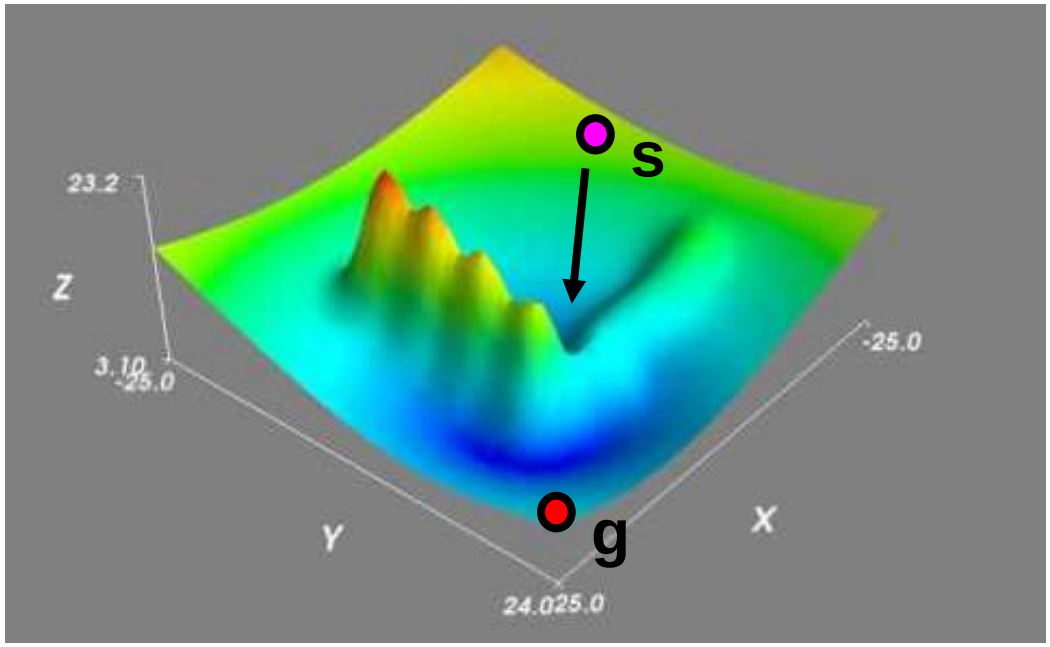
Repulsive field away from obstacles

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**

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Sketch of Algorithm

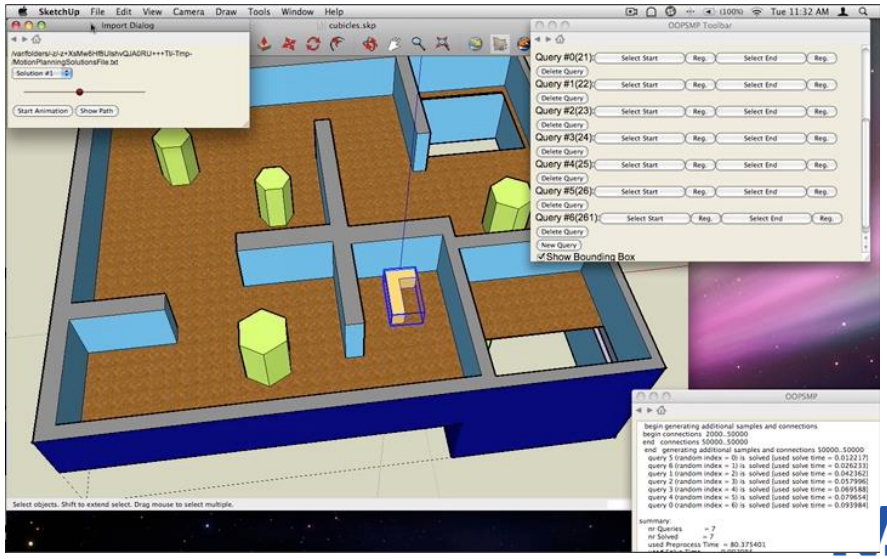
- **Place a regular grid G over the configuration space**
- **Compute the potential field over G**
- **Search G using a best-first algorithm with potential field as the heuristic function**

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?

Homework: PA1

- **Install Open Motion Planning Library (OMPL)**
  - **Create a scene and a robot**
  - **Find a collision-free path and visualize the path**
- **See KLMS announcement**
  - **Submit an image showing a scene with a robot with a computed path**



Conf. Deadline

- **ICRA: Sep.-15 2023**
- **IROS: Jan, RSS, etc..**

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Homework

- **Browse 2 ICRA/IROS/RSS/CoRL/TRO/IJRR papers**
  - **Submit it online before the Tue. Class**
  - **https://forms.gle/2jdXkgYu5snyAb3s8**

- **Example of a summary (just a paragraph)**

  Title: XXX XXXX XXXX
  Conf./Journal Name: ICRA, 2020
  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.

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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**

- **Write a question two times before the mid-term exam**
  - **https://sgvr.kaist.ac.kr/~sungeui/MPA/**

Next Time….

- **Configuration spaces**