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. 3 of my draft:**
    https://sgvr.kaist.ac.kr/~sungeui/mp/

- **Last time**
  - **Configuration space, i.e., C-space**
  - **Discretization, e.g., visibility graph**
  - **Best-first search and A* search**

Questions

- **I'm still in Italy, my home country, which is seven hours behind KST**
  - **Do that homework in your time zone**

- **Can you send me some background publications in this field?**
  - **Go over my draft, which I'm trying to improve it now.**

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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

- **Roadmap**
  - **Represent the connectivity of the free space by a network of 1-D curves**
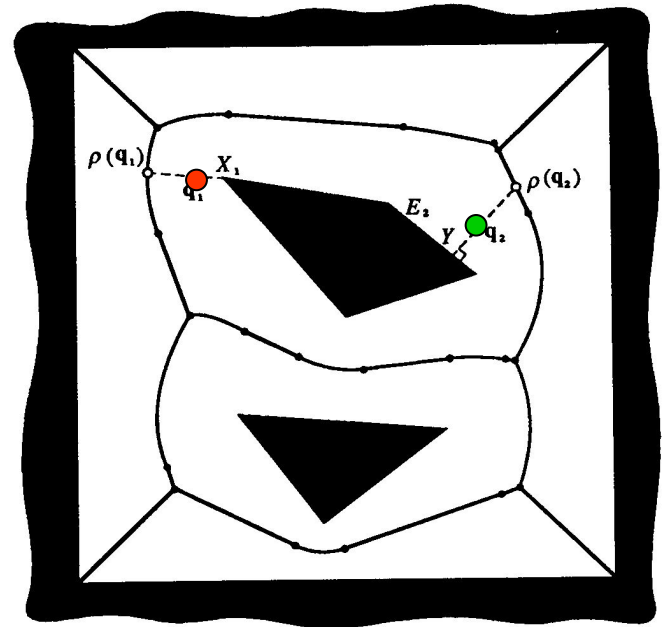
- **Cell decomposition**
  - **Decompose the free space into simple cells and represent the connectivity of the free space by the adjacency graph of these cells**

- **Potential field**
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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**
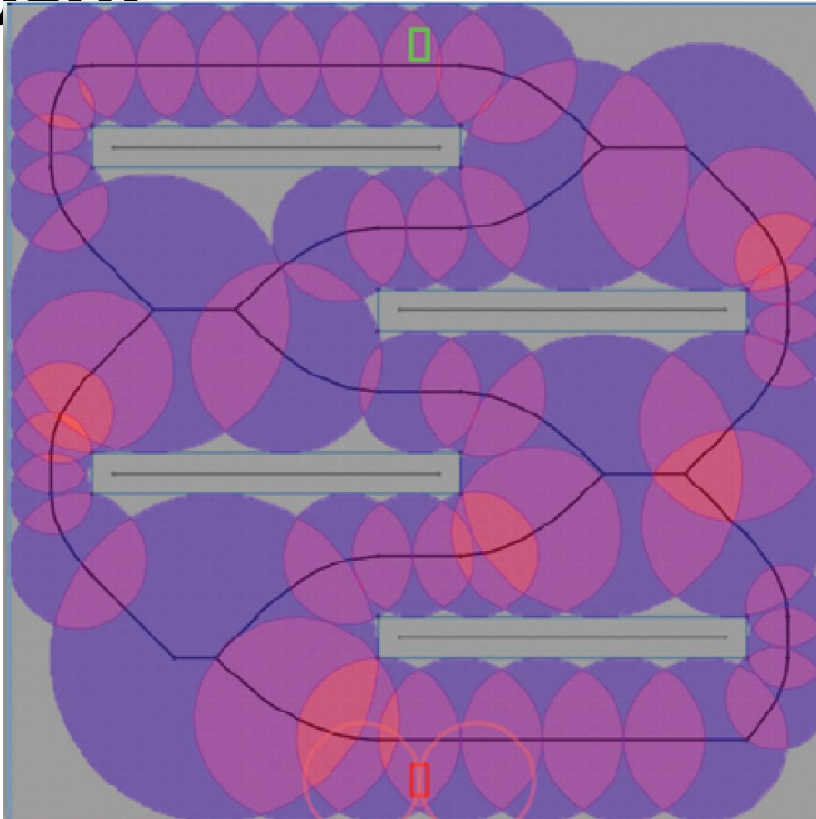 - **GPU computation is**

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**

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Trapezoidal Decomposition
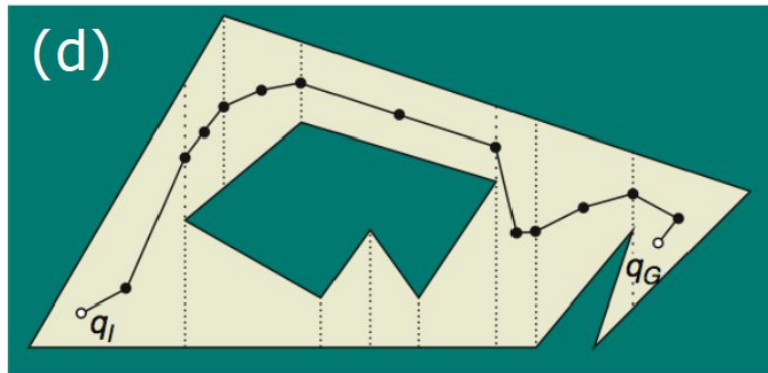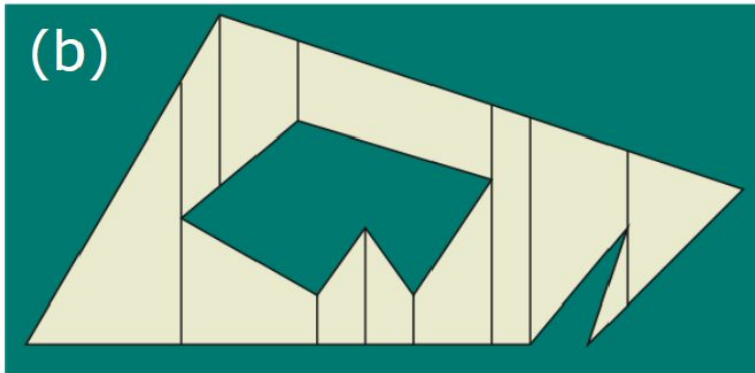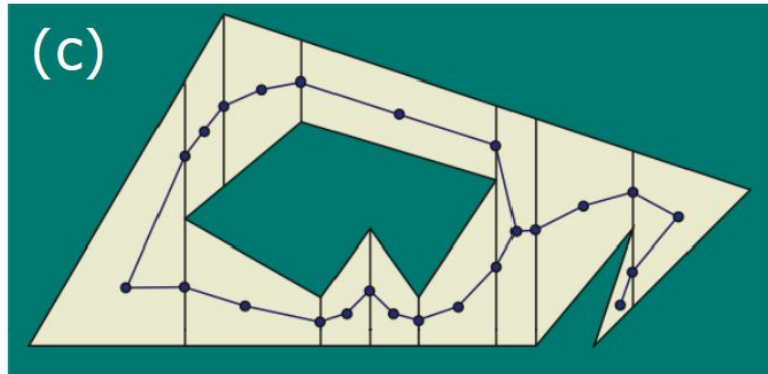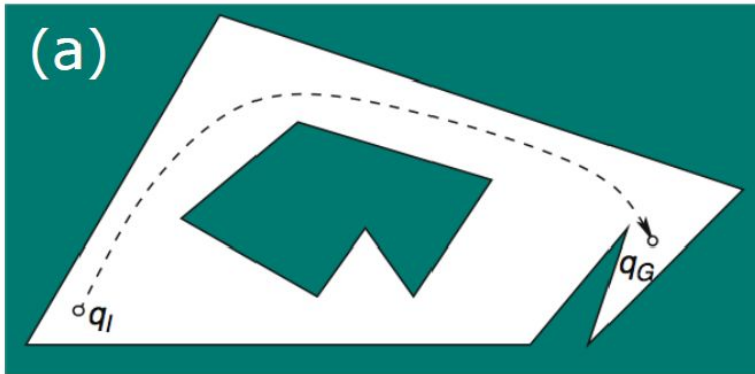
Credit: Arras

**Criticality-based (e.g., vertices) decomposition**
☐ Planar sweep ☐ O(n log n) time, O(n) space
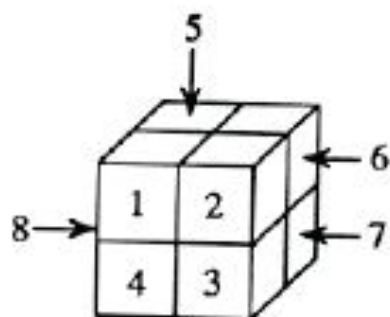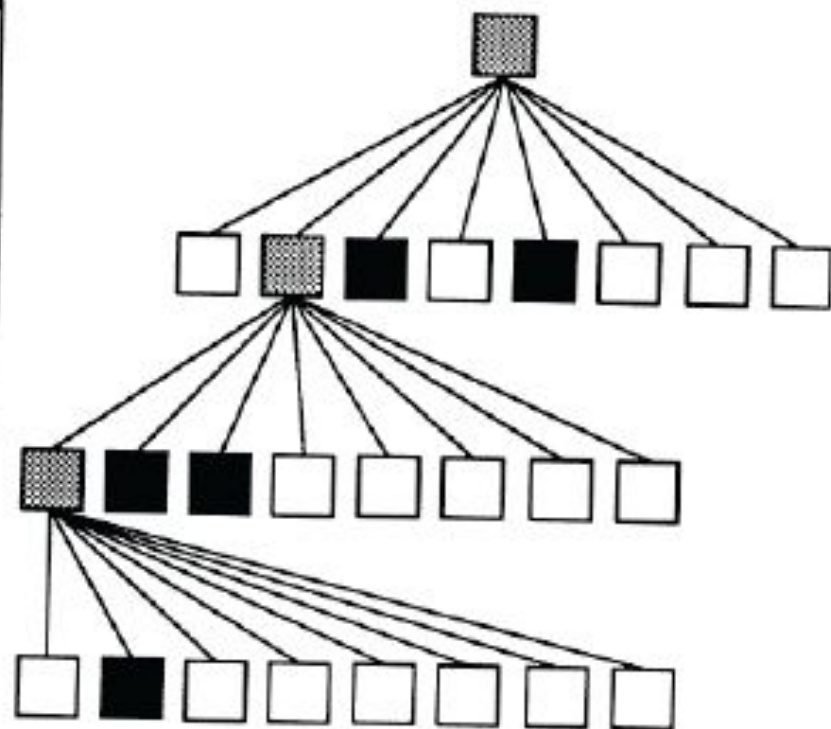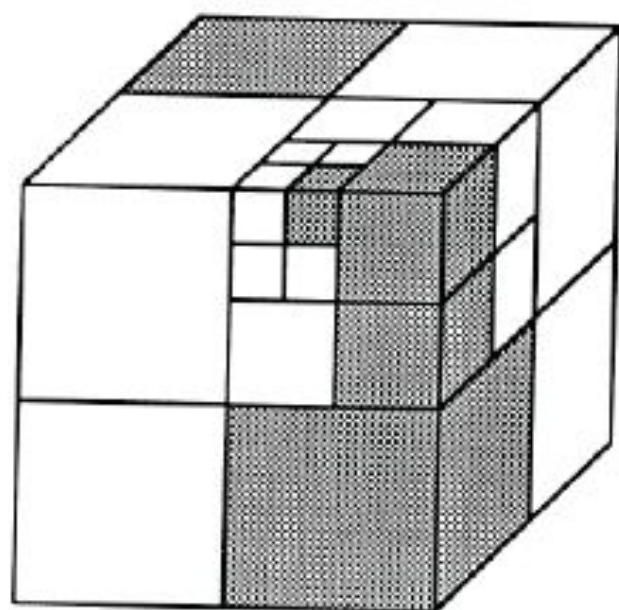
Cell-Decomposition Methods

- **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**

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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 cel**
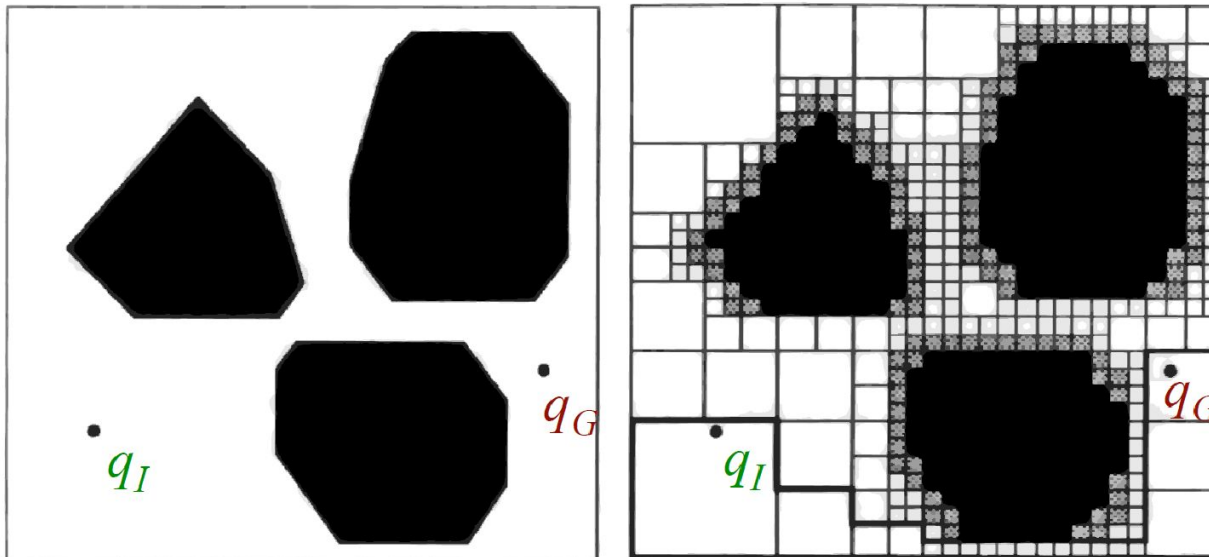
13

Octree decomposition

5

8 →

| 1 | 2 |
| 4 | 3 |

← 6

← 7

☐ EMPTY cell   ▦ MIXED cell   ■ FULL cell

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**
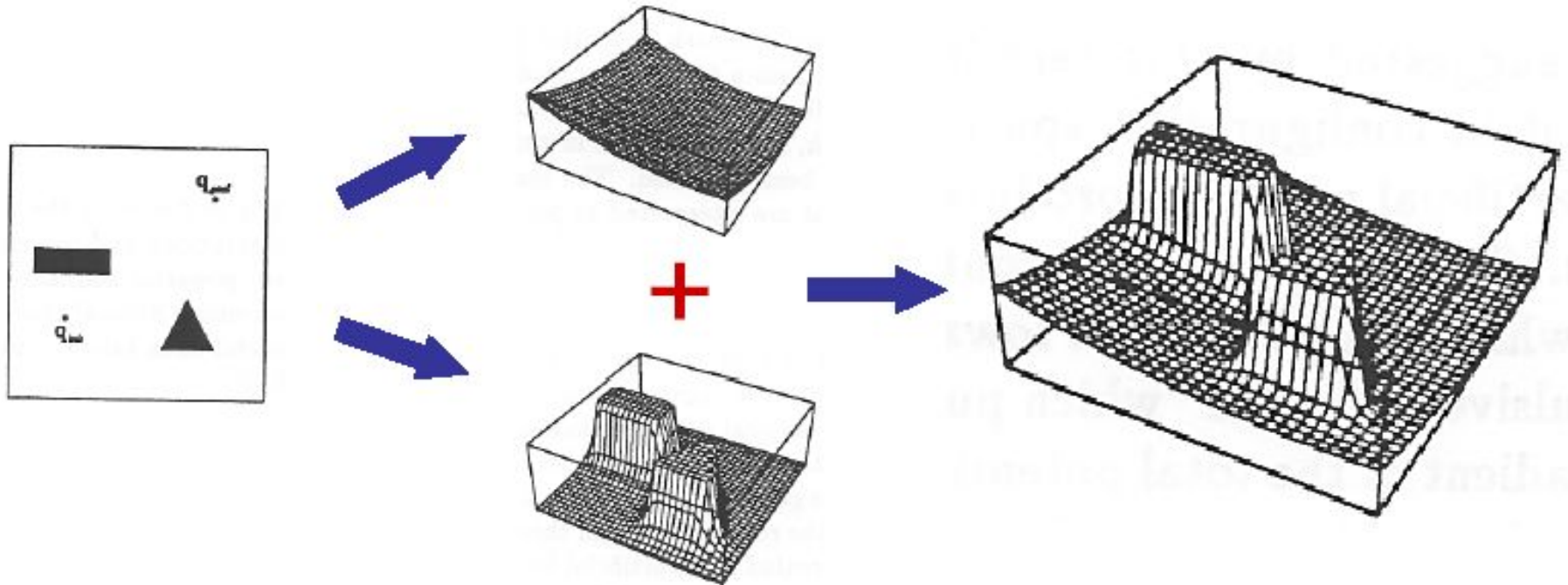 - **Compute a force proportional to the negated ...tential field**
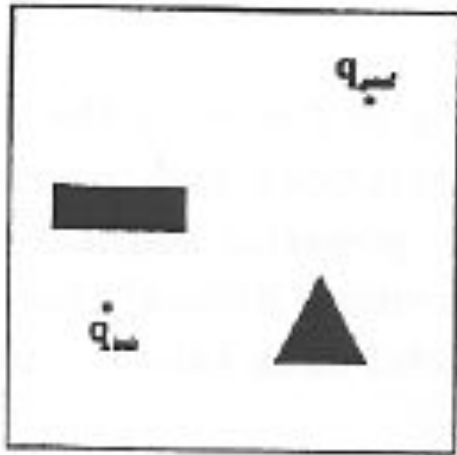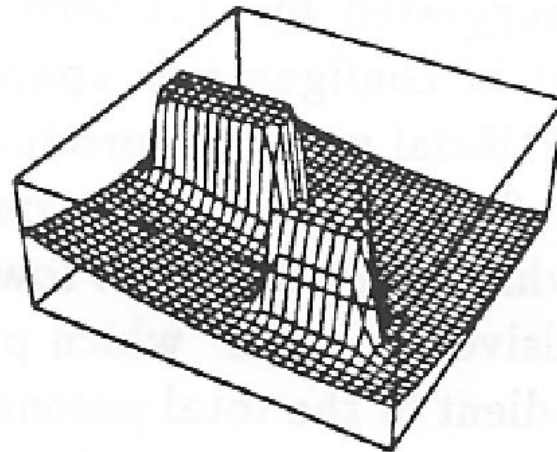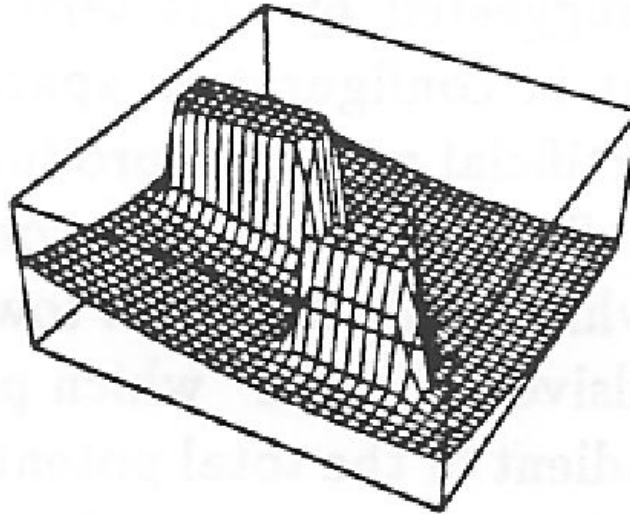
Workspace   **A potential field**

Attractive and Repulsive fields

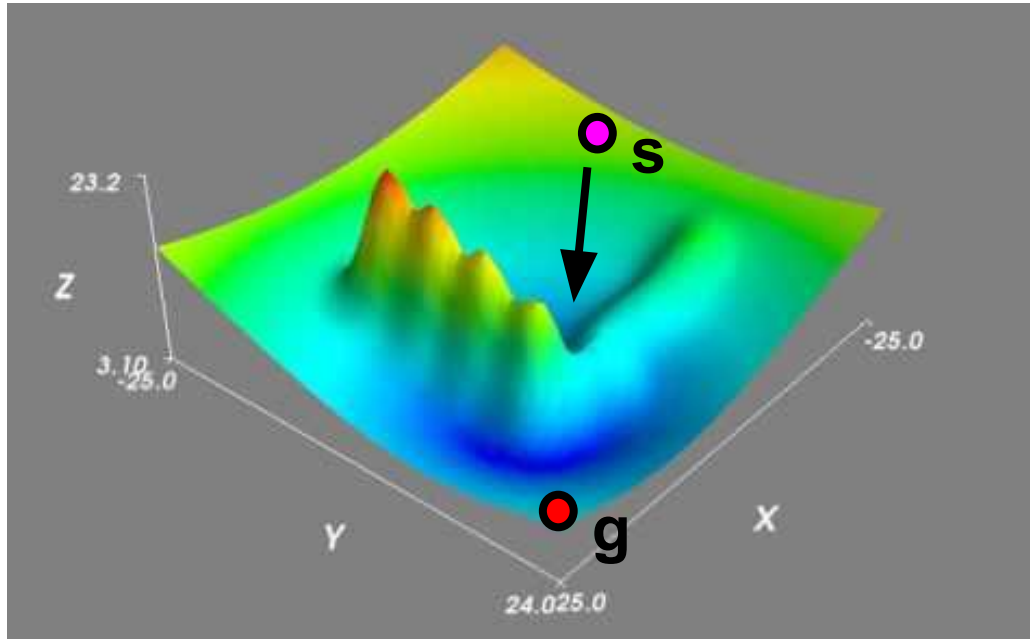**Attractive field towards the goal**

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?**

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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?**

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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**
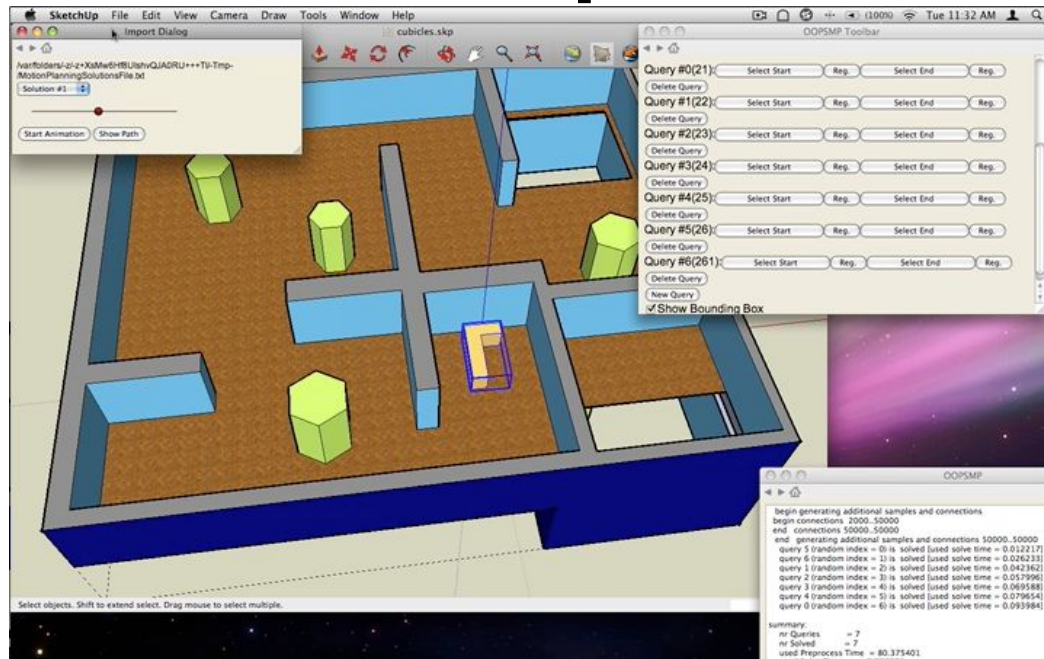
Homework

- **Deadline: 11:59pm, Sep.-24**

- **Submit at KLMS:**
  - **An image that shows a scene with a robot with a computed path**

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Conf. Deadline

- **ICRA: Oct.-15 2021**

- **RSS: Jan(?), IROS: March**

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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.

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://forms.gle/R2ZcS9pZ9me9RzmKA**

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Next Time….

- **Configuration spaces**

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