CS780:
Motion Planning and Applications

Sung-Eui Yoon
(윤성의)

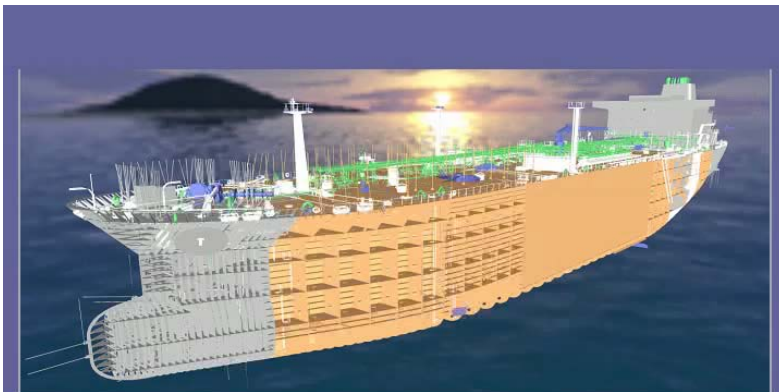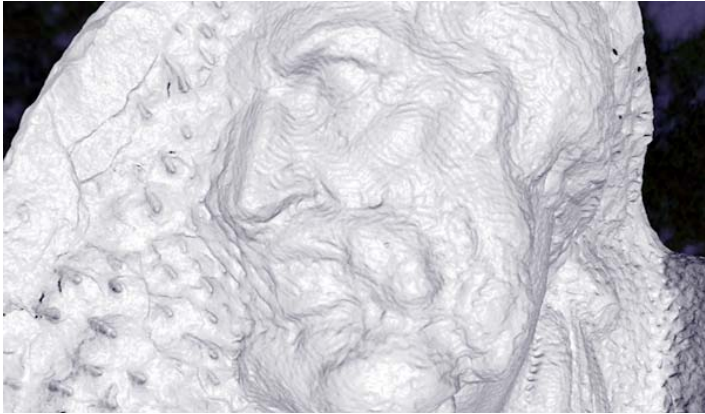**Course URL:**
http://sglab.kaist.ac.kr/~sungeui/MPA

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About the Instructor

- **Joined KAIST at 2007**

- **B.S., M.S. at Seoul National Univ.**
- **Ph.D. at Univ. of North Carolina-Chapel Hill**
- **Post. doc at Lawrence Livermore Nat'l Lab**

- **Main research focus**
  - **Handling of massive data for various computer graphics and geometric problems**

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My Recent Work

Double Eagle Tanker
82 Million triangles

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Welcome to CS780

Instructor: **Sung-eui Yoon**

Email: **sungeui@gmail.com**

Office: **3432 at CS building**

Class time: **10:30am – 11:45am on T/Th**

Class location: **4448 in the CS building**

Office hours: **3:00–4:00, T/Th (or by appt.)**

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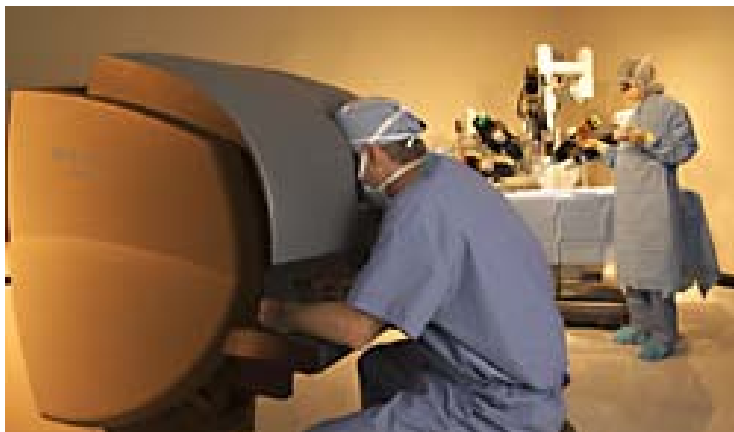 **http://sglab.kaist.ac.kr/~sungeui/MPA**

No TAs
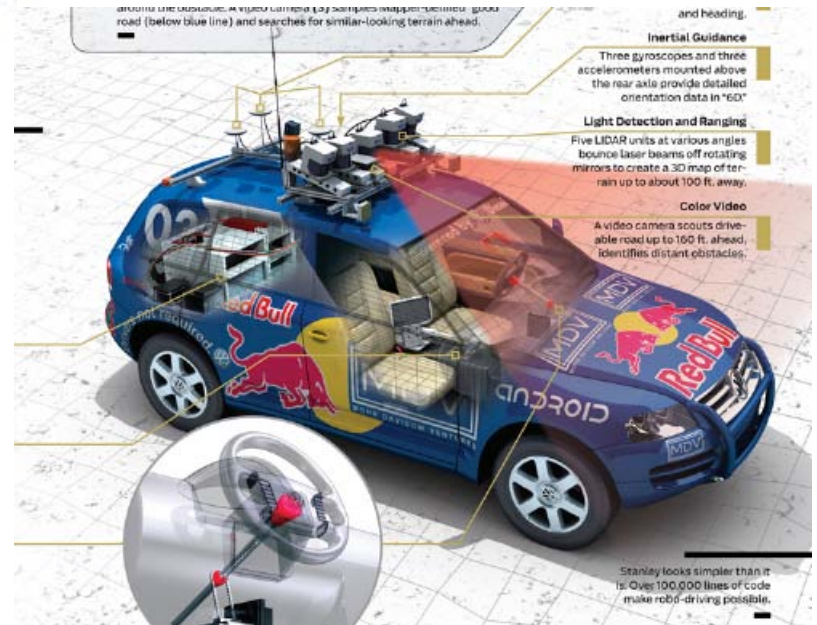
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Real World Robots

ASIMO

Sony Aibo

Da Vinci

Courtesy of Prof. Dinesh Manocha

Motion of Real Robots

Fantastic Human Robot at UAE Expo

Humanoid Robot:
http://youtube.com/watch?v=NYoY4p0_yal&mode=related&search

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Motion of Real Robots

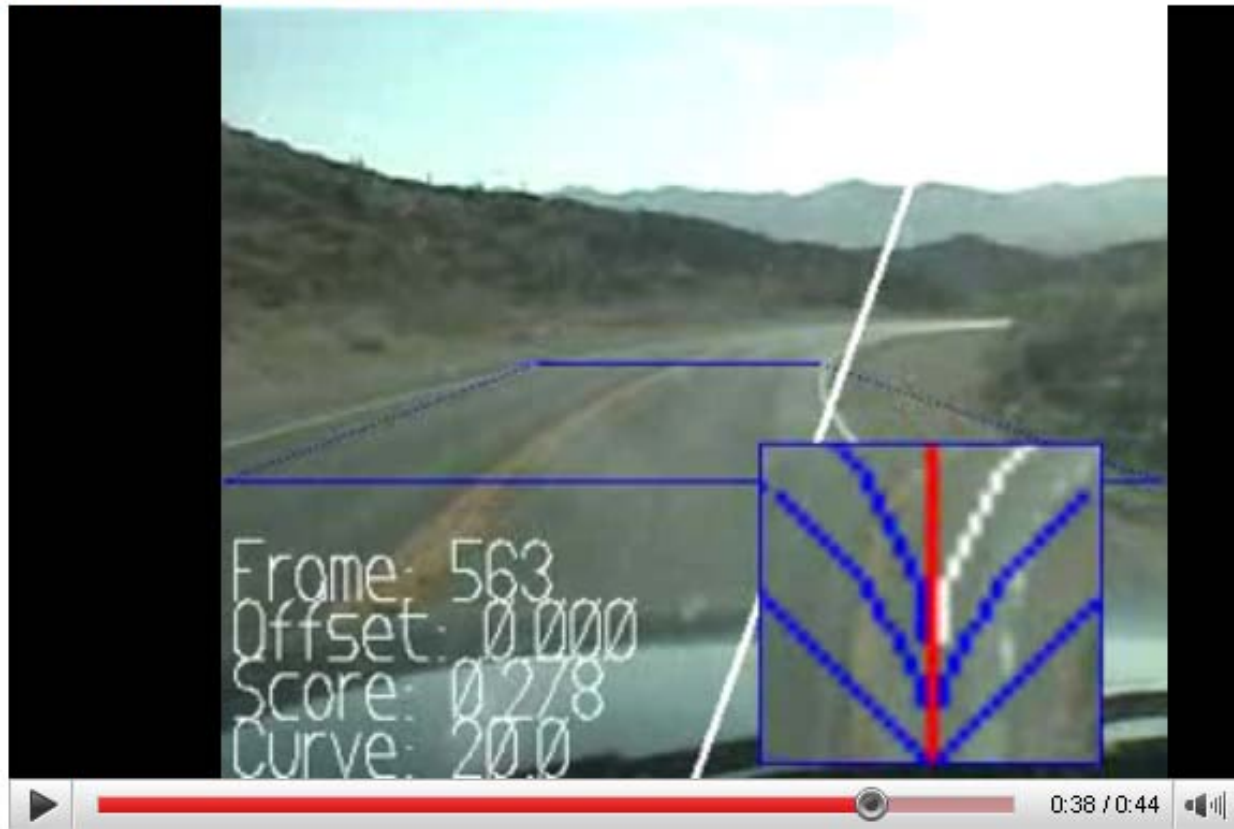Albert HUBO Introduction - korea scienceworld

Humanoid Robot:
http://www.youtube.com/watch?v=ZkYQWBXpk_0 =

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Motion of Real Robots

Autonomous robot vision 1

Autonomous robot
http://www.youtube.com/watch?v=3SQiow-X3ko

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Motion of Real Robots

Robot-Assisted Radical Prostatectomy

Medical robot:
http://www.youtube.com/watch?v=XfH8phFm2VY

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Motion of Virtual Worlds

Motion of Virtual Worlds

Crowd simulation (biped) with AI implant video 1 of 2

Computer generated simulations:
http://www.youtube.com/watch?v=5-UQmVjFdqs

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Motion of Virtual Worlds

Computer generated simulations, games, virtual prototyping:
http://www.massivesoftware.com/

Smart Robots or Agents

- **Autonomous agents** that sense, plan, and act in real and/or virtual worlds
- **Algorithms and systems for representing, capturing, planning, controlling, and rendering** motions of physical objects

- Applications:
  - Manufacturing
  - Mobile robots
  - Computational biology
  - Computer-assisted surgery
  - Digital actors

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Goal of Motion Planning

- **Compute motion strategies, e.g.:**
  - Geometric paths
  - Time-parameterized trajectories
  - Sequence of sensor-based motion commands
  - Aesthetic constraints

- **Achieve high-level goals, e.g.:**
  - Go to A without colliding with obstacles
  - Assemble product P
  - Build map of environment E
  - Find object O

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Basic Motion Planning Problem

- **Statement**:
  - Compute a collision-free path for an object (the robot) among obstacles subject to CONSTRAINTS
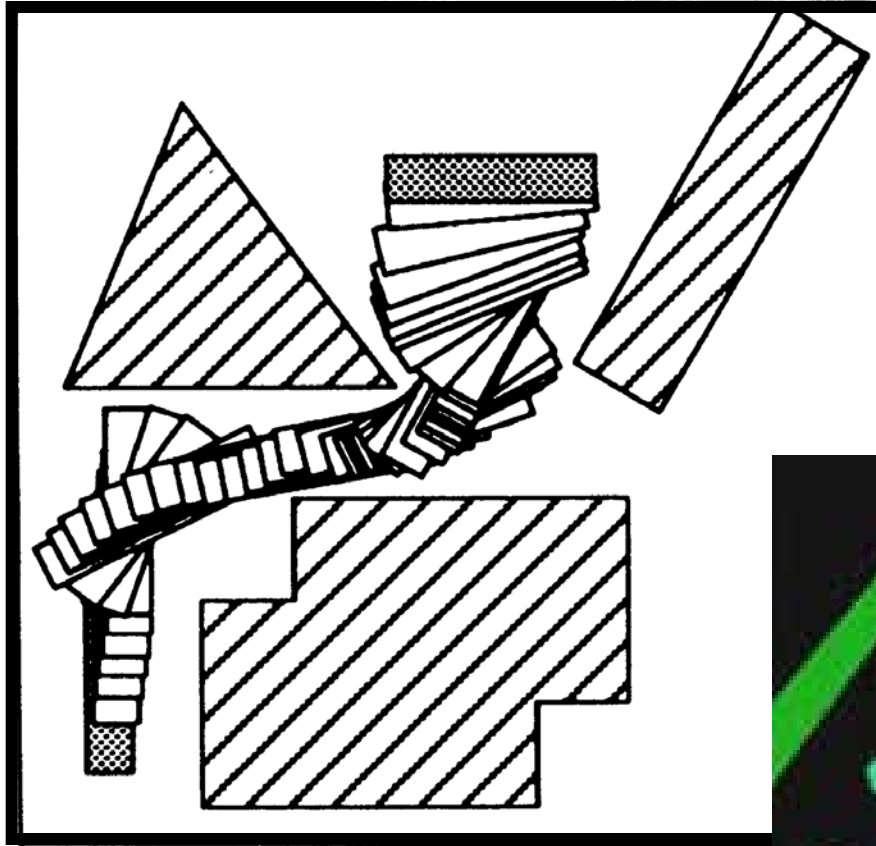
- **Inputs**:
  - Geometry of robot and obstacles
  - Kinematics of robot (degrees of freedom)
  - Initial and goal robot configurations (placements)

- **Outputs**:
  - Continuous sequence of collision-free robot configurations connecting the initial and goal configurations
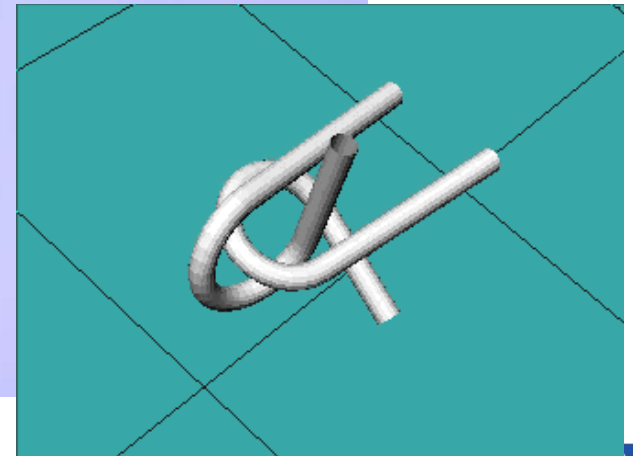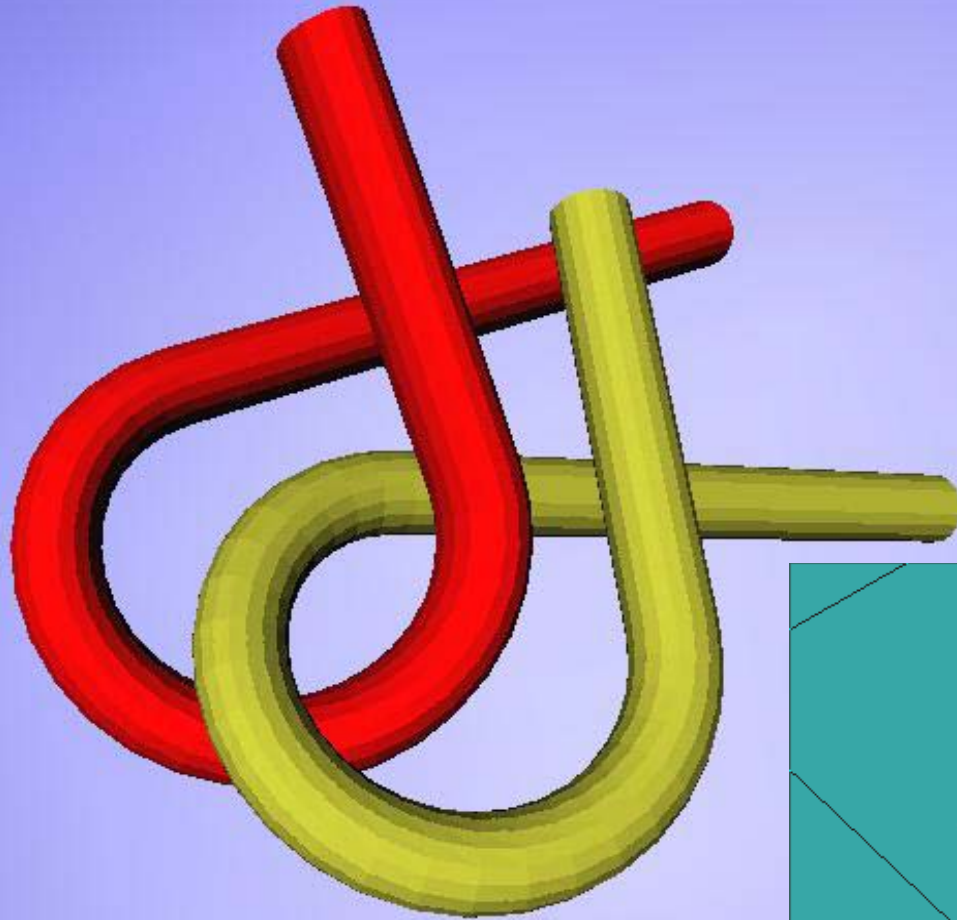
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Examples with Rigid Object

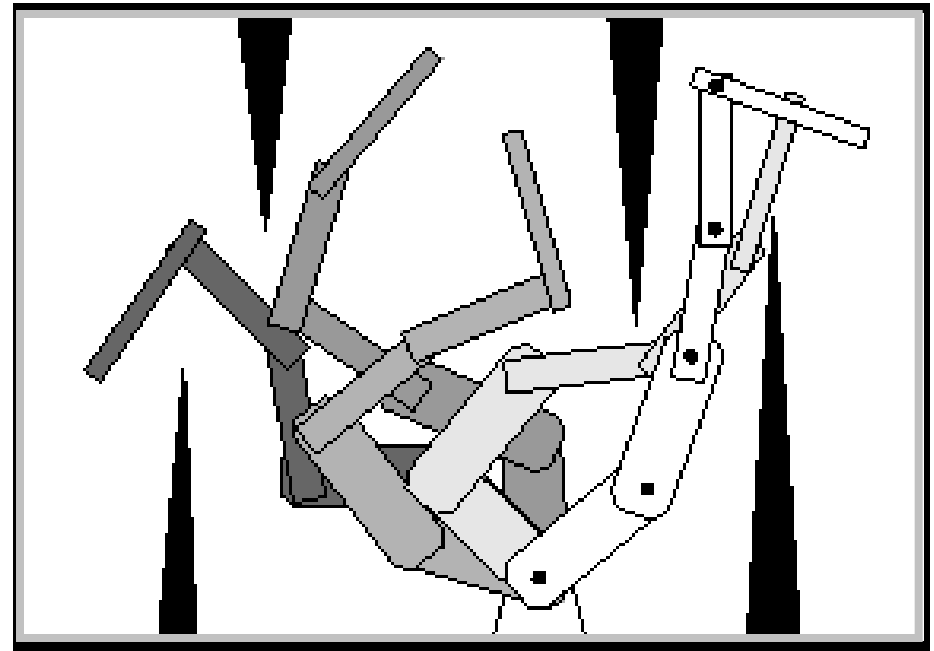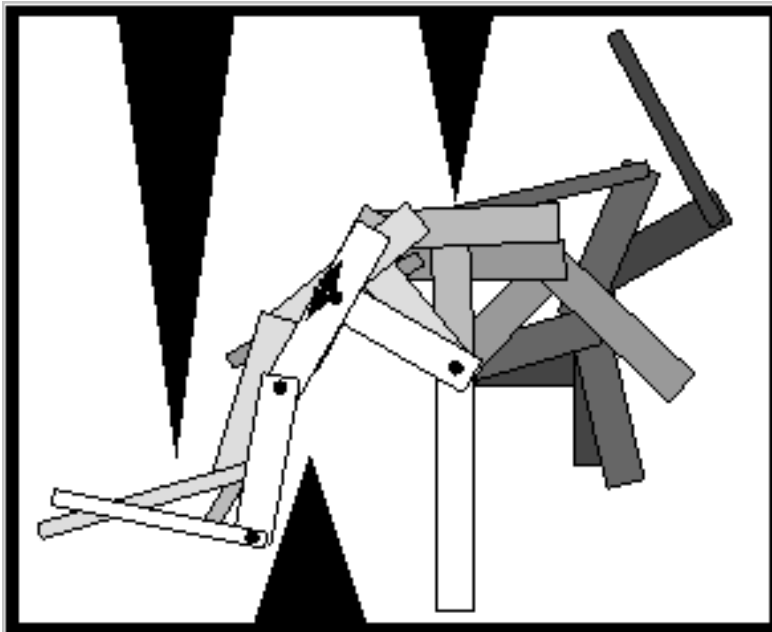→ **Ladder problem**

Piano-mover problem ←

Is It Easy?

Example with Articulated Object

Some Extensions of Basic Problem

- **Multiple robots**
- **Assembly planning**
- **Acquire information by sensing**
  - **Model building**
  - **Object finding/tracking**
  - **Inspection**
- **Nonholonomic constraints**
- **Dynamic constraints**
- **Stability constraints**

- **Optimal planning**
- **Uncertainty in model, control and sensing**
- **Exploiting task mechanics (sensorless motions, under-actualted systems)**
- **Physical models and deformable objects**
- **Integration of planning and control**
- **Integration with higher-level planning**

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Examples of Applications

- **Manufacturing:**
  - Robot programming
  - Robot placement
  - Design of part feeders
- **Design for manufacturing and servicing**
- **Design of pipe layouts and cable harnesses**
- **Autonomous mobile robots planetary exploration, surveillance, military scouting**

- **Graphic animation of "digital actors" for video games, movies, and webpages**
- **Virtual walkthrough**
- **Medical surgery planning**
- **Generation of plausible molecule motions, e.g., docking and folding motions**
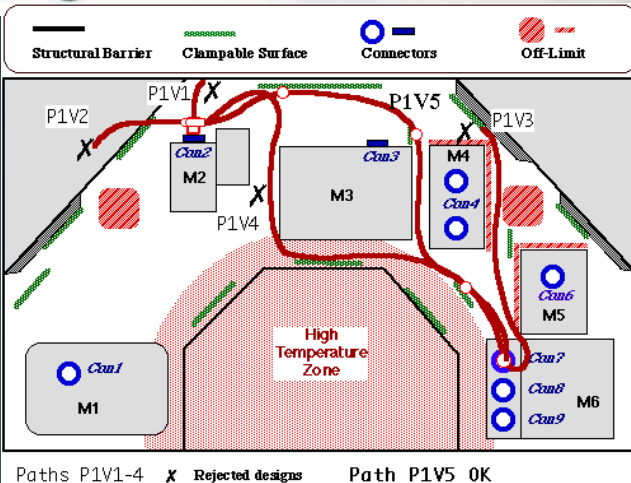- **Building code verification**

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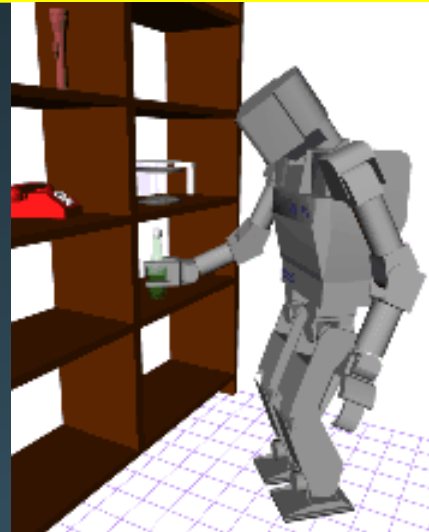# Assembly Planning and Design of Manufacturing Systems
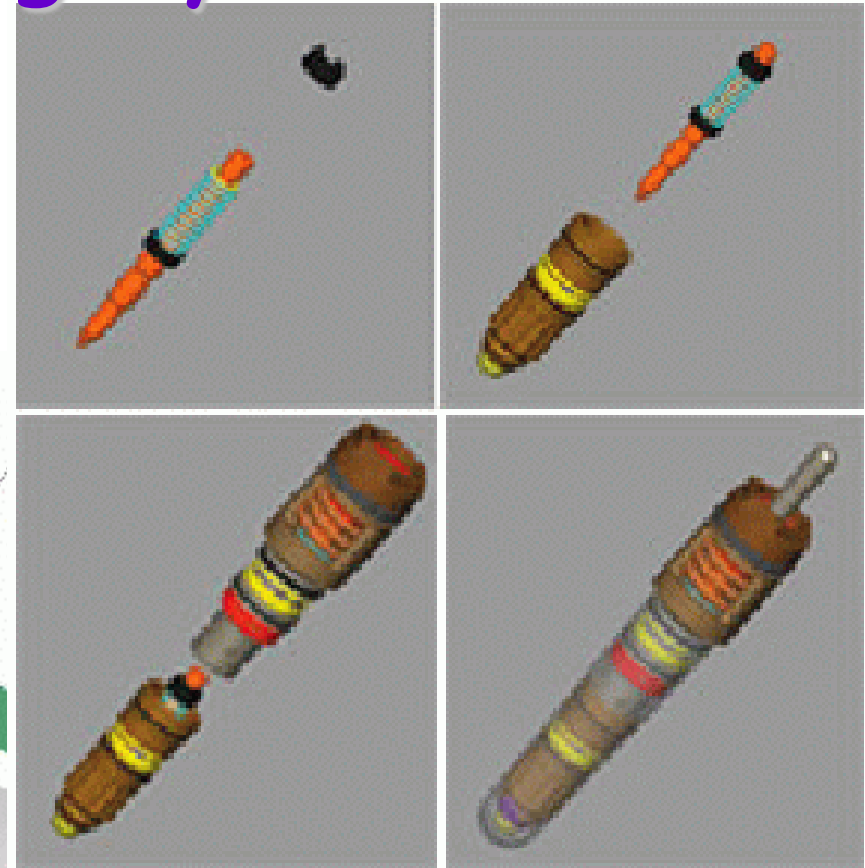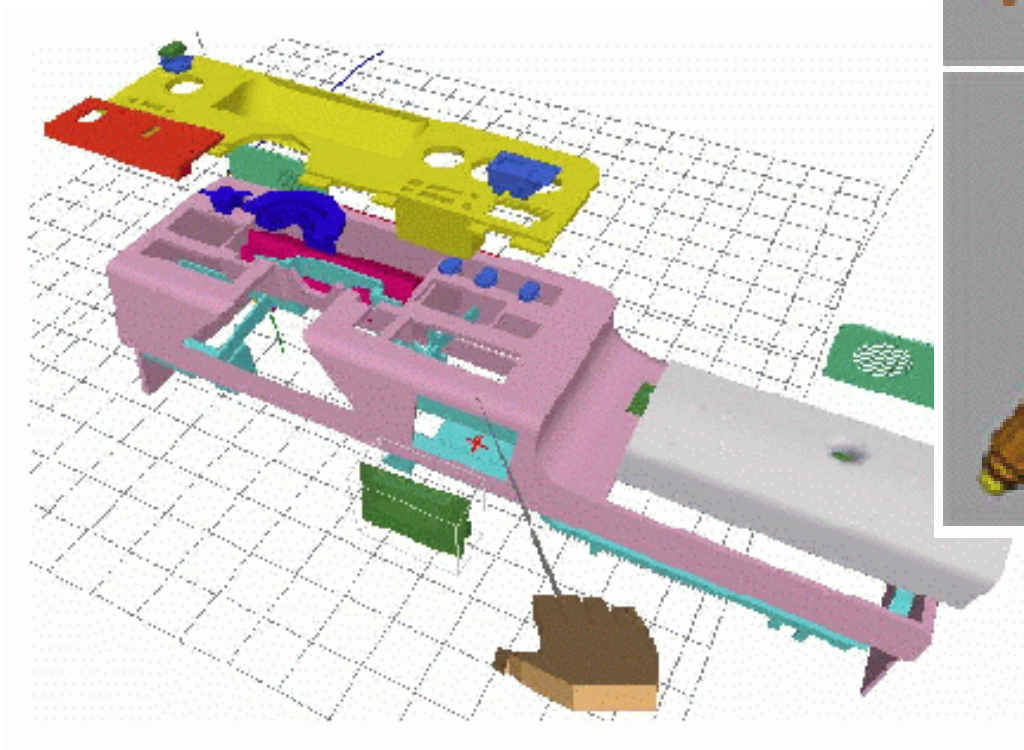
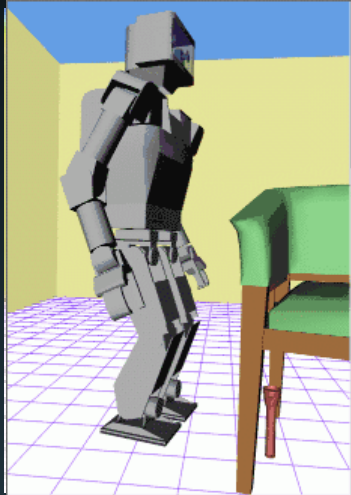# Application: Checking Building Code
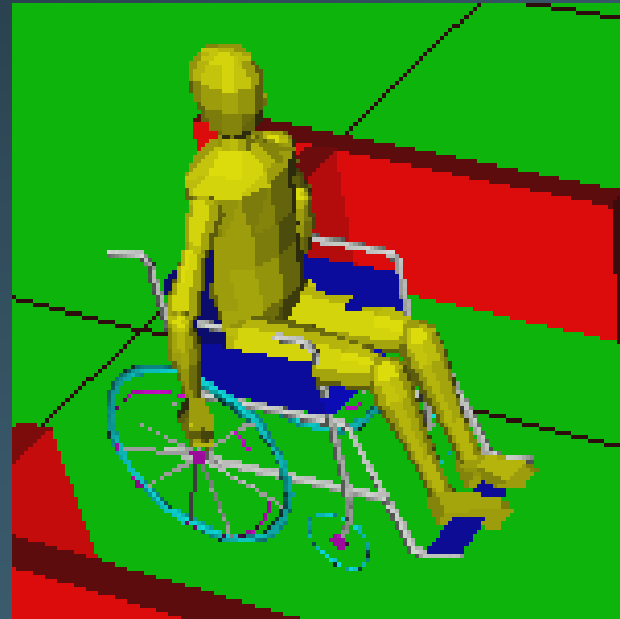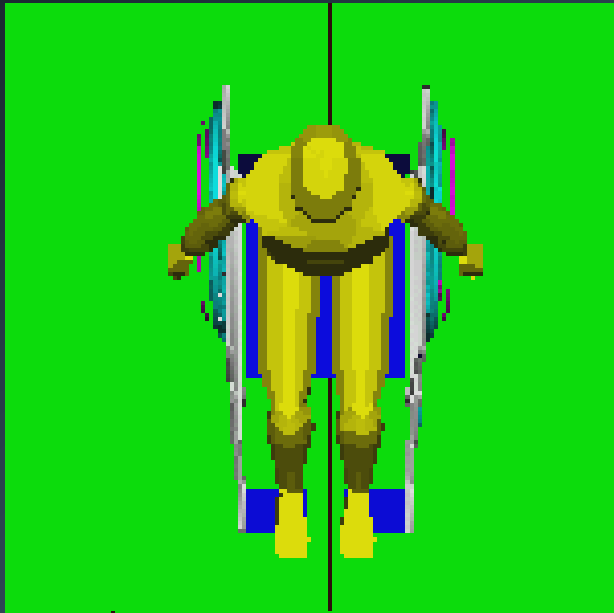
Cable Harness/ Pipe design

Humanoid Robot

[Kuffner and Inoue, 2000] (U. Tokyo)

Digital Actors

A Bug's Life (Pixar/Disney)
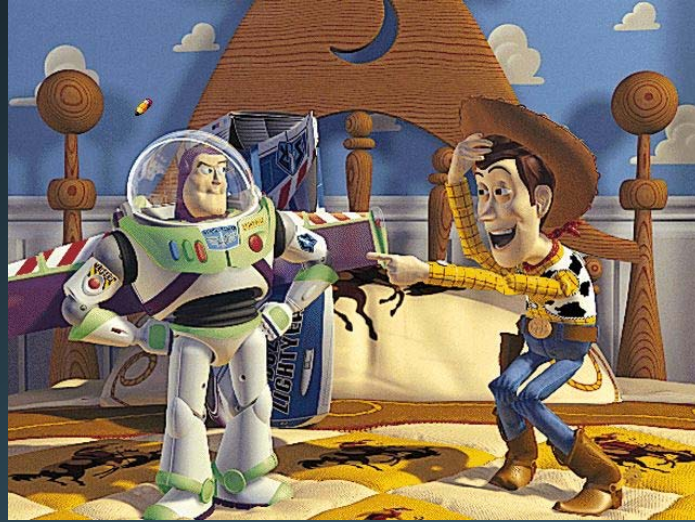
Toy Story (Pixar/Disney)

Antz (Dreamworks)

Tomb Raider 3 (Eidos Interactive)

The Legend of Zelda (Nintendo)

Final Fantasy VIII (SquareOne)

Motion Planning for Digital Actors

Manipulation

Sensory-based locomotion

Application: Computer-Assisted Surgical Planning
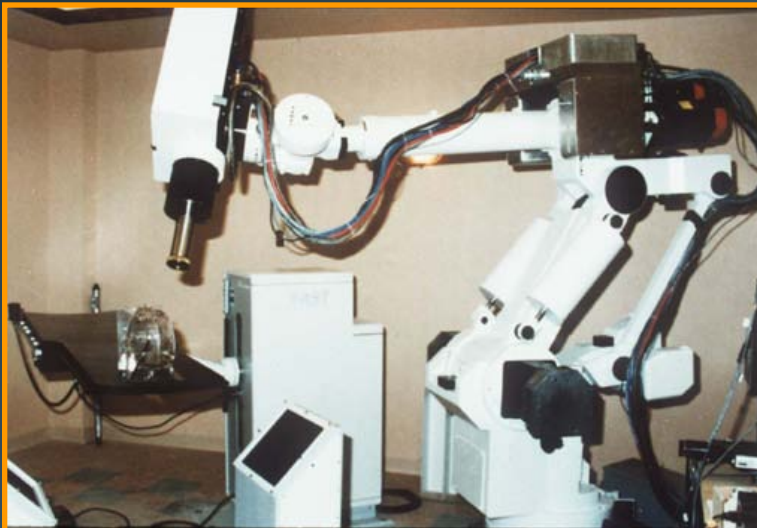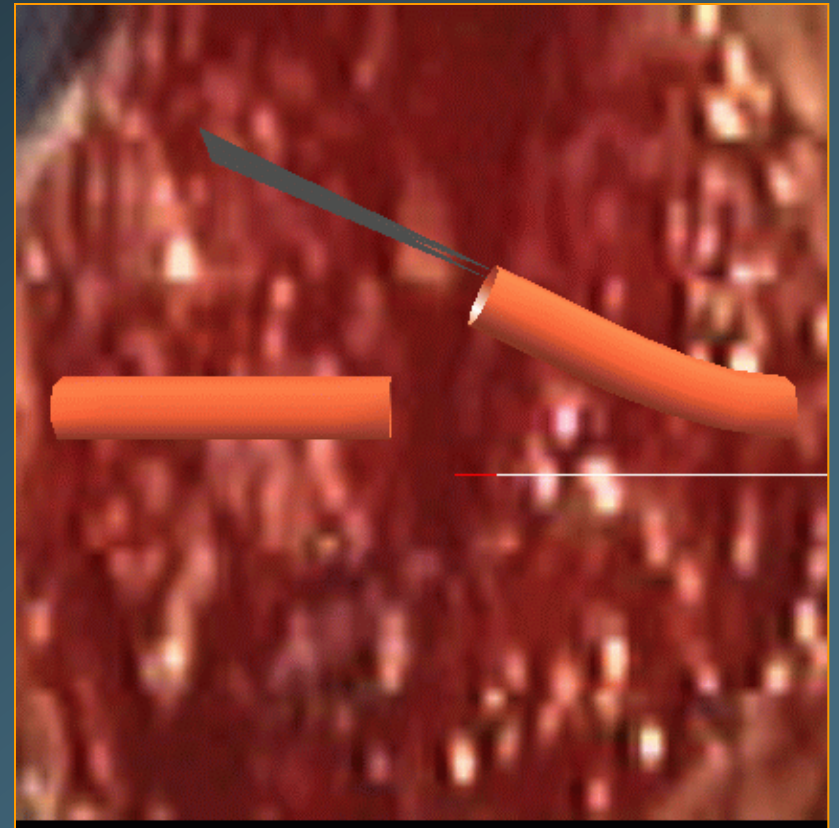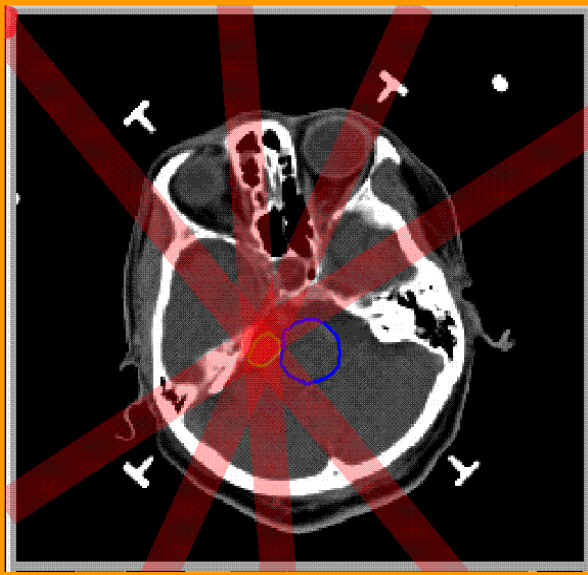
Radiosurgical Planning
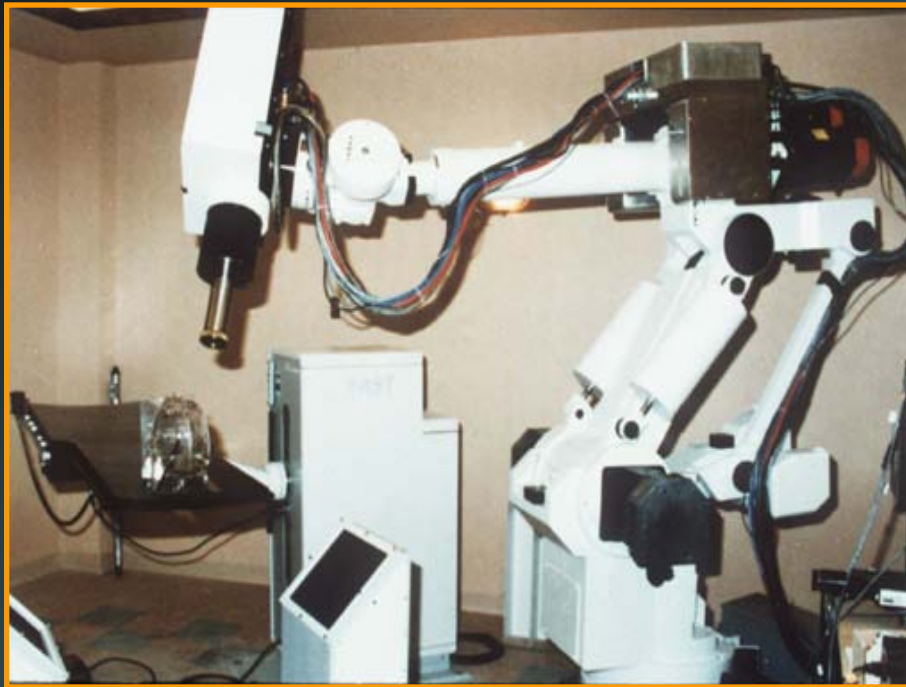
Cyberknife
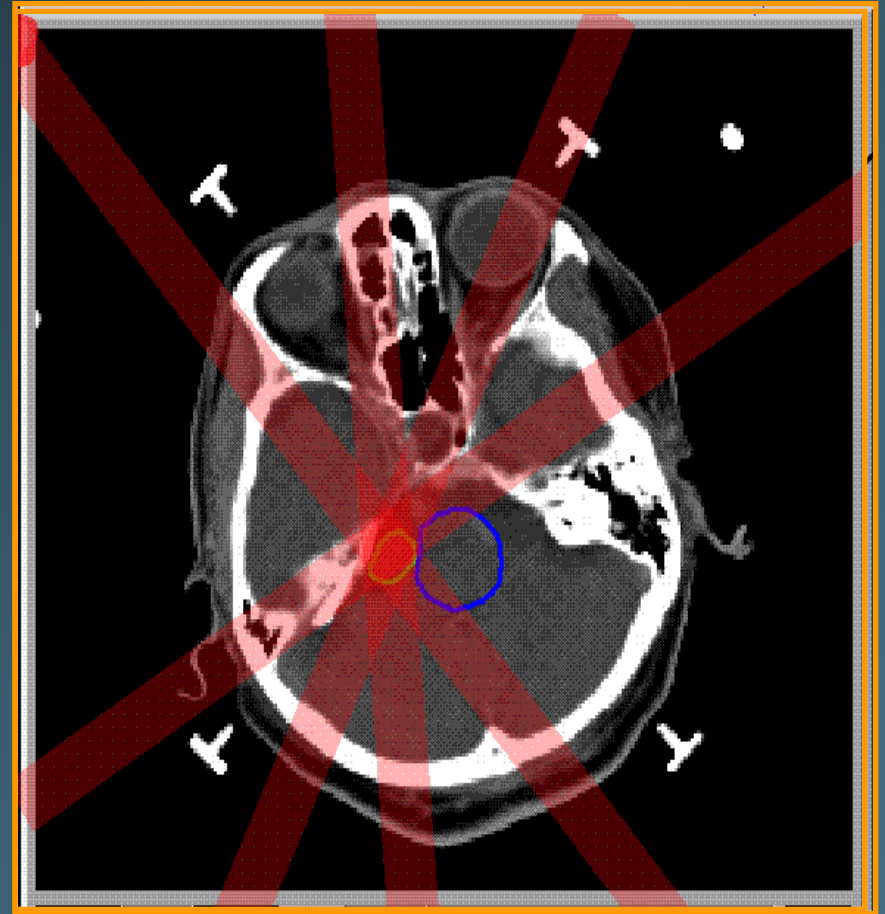
Study of the Motion of Bio-Molecules
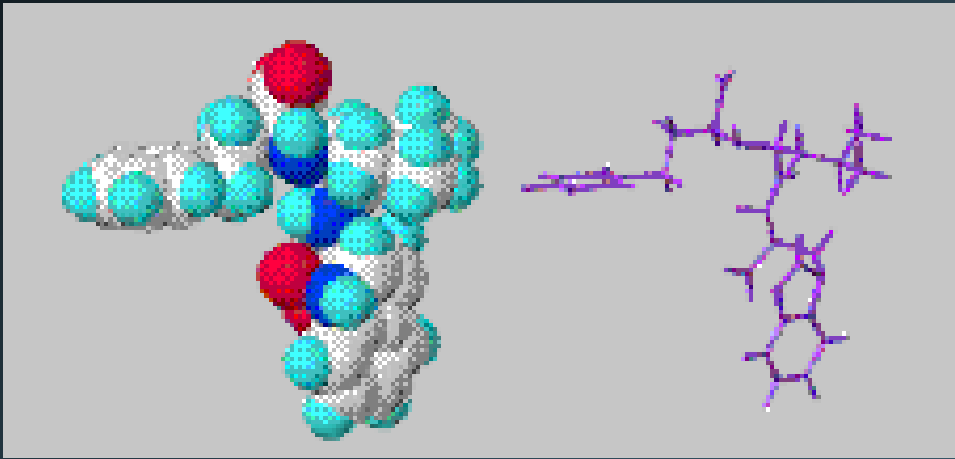
- Protein folding
- Ligand binding
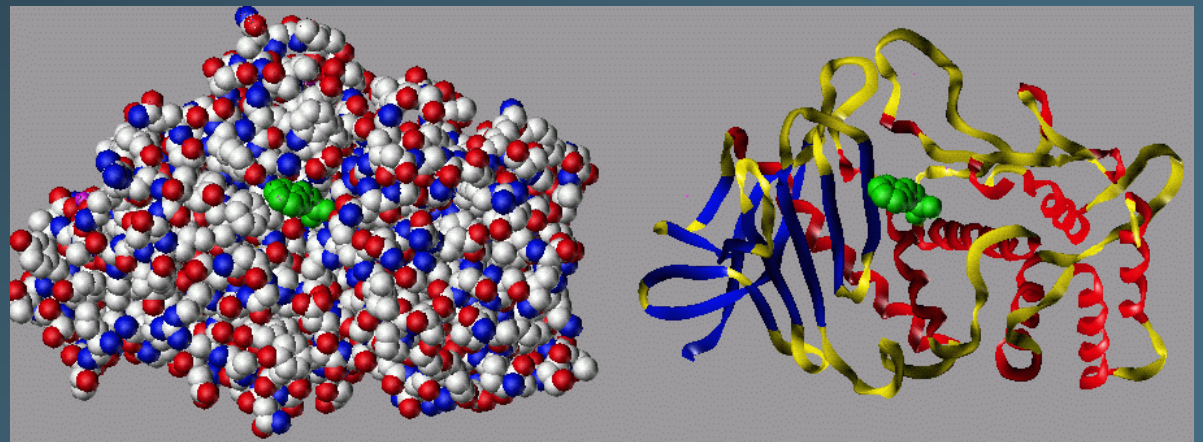
DARPA Grand Challenge

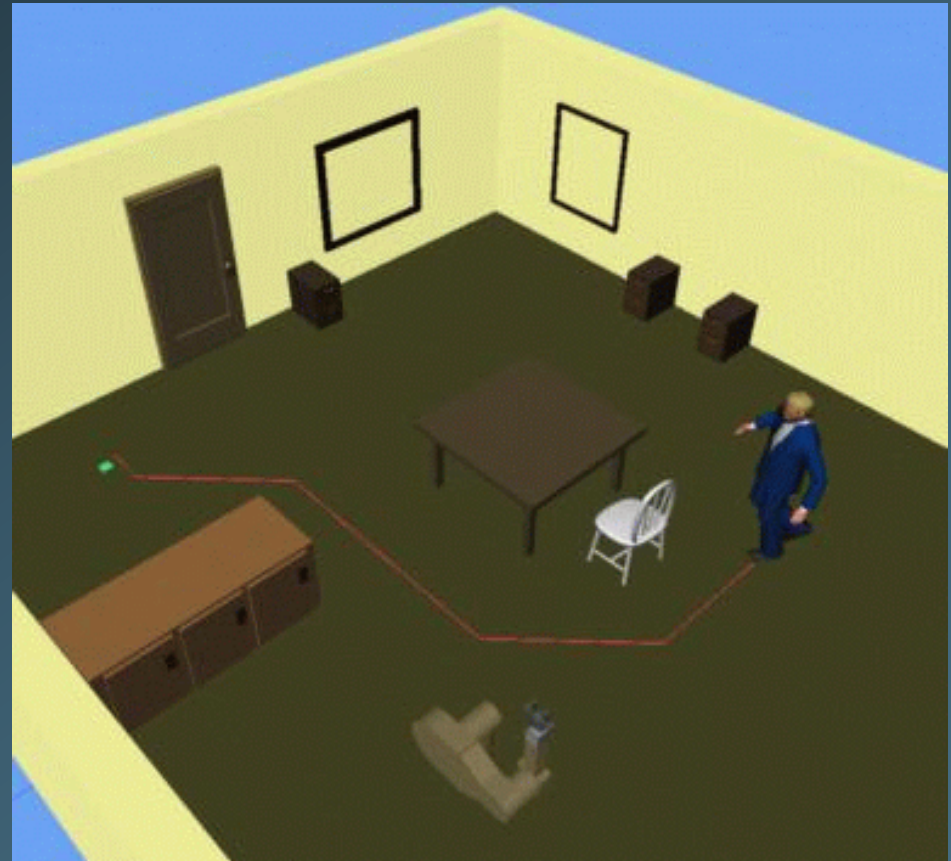**Planning for a collision-free 132 mile path
in a desert**

Prerequisites

- **Basic knowledge of probability**
  - **E.g., events, expected values, etc**
- **Your willingness to read about new concepts and applications**

- **If you are not sure, please consult the instructor at the end of the course**

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Topics

- **Underlying geometric concepts of motion planning**
  - **Configuration space**
- **Motion planning algorithms:**
  - **Complete motion planning**
  - **Randomized approaches**
- **Kinodynamic constraints**
- **Character motion in virtual environments**
- **Multi-agent and crowd simulation**

The course is about motion planning algorithms, not control of real robots!

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Course Overview

- **1/3 of lectures and 2/3 of student presentations**
    - **This is a research-oriented course**
    - **Paper reading list**

- **What you will do:**
    - **Choose papers that are interesting to you**
        - **You can bring your own research topic related to motion planning**
    - **Present talks explaining the papers**
    - **Propose idea and implement it as a final project**
    - **Quiz and mid-term**
    - **and, have fun!**

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Presentations and Final Project

- **For each paper:**
  - **Consider its main idea given its context**
  - **Look at pros and cons of each method**
  - **Think about how we can efficiently handle more realistic and complex scene**
- **Propose and implement ideas to address those problems**
  - **Prepare a final report**

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Review Service

- **I'll give you comments on your reports and presentations**

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Course Awards

- **Best speaker and best project**

- **For the best project, cost for attending the premium conf. (e.g., ICRA) will be supported**
  - We may not select the best project if the project is not enough
- **For the best presenter, a research equipment will be supported**

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Course Overview

- **Grade policy**
  - **Class presentations: 30%**
  - **Quiz, assignment, and mid-term: 30%**
  - **Final project: 40%**
  - **Instructor (50%) and students (50%) will evaluate presentations and projects**
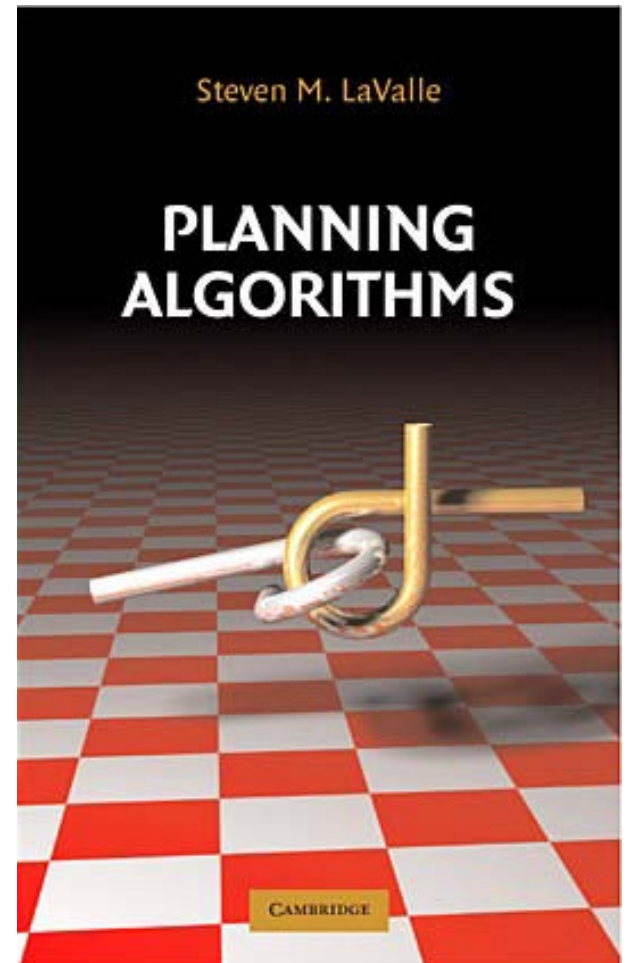- **Late policy**
  - **No score**
  - **Submit your work before the deadline!**
- **Class attendance rule**
  - **Late two times → count as one absence**
  - **Every two absences →lower your grade (e.g., A- → B+)**

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Resource

- **Textbook**
  - **Planning Algorithms, Steven M. LaValle, 2006 (http://msl.cs.uiuc.edu/planning/)**

Other Reference

- **Our paper reading list**
- **Technical papers**
  - **IEEE International Conf. on Robotics and Automation (ICRA)**
  - **IEEE/RSJ Int. Conf. o nIntelligent Robots and Systems (IROS)**
  - **Graphics-related conference (SIGGRAPH, etc)**
    - **http://kesen.huang.googlepages.com/**

- **SIGGRAPH course notes and video encore**
- **Course homepages**
- **Google or Google scholar**

Honor Code

- **Collaboration encouraged, but *assignments must be your own work***
- **Cite any other's work if you use their codes**

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Schedule

- **Please refer the course homepage:**
  - **http://sglab.kaist.ac.kr/~sungeui/MPA**

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Official Language in Class

- **English**
  - **I'll give lectures in English**
  - **I may explain again in Korean if materials are unclear to you**
  - **You are also required to use English, unless special cases**

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About You

- **Name**
- **Your (non hanmail.net) email address**

- **What is your major?**
- **Previous experience on motion planning and robotics**

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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 beginning of the next class**
  - **1**
  - **2 for typical questions**
  - **3 for questions with thoughts**
  - **4 for questions that surprised me**

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Homework

- **Read Chapter 1 of our textbook**

- **Optional:**
  - **Motion planning: A journey of robots, molecules, digital Actors, and other artifacts. J.C. Latombe. Int. J. Robotics Research, 18(11):1119-1128, 1999.**

Next Time…

- Configuration spaces
- Motion planning framework
- Classic motion planning approaches

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