
CS686: Motion Planning and Applications

Sung-Eui Yoon
(윤성익)

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

KAIST



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**

My Recent Work



Welcome to CS780

Instructor: Sung-eui Yoon
Email: sungeui@gmail.com
Office: 3432 at CS building

Class time: 4:00pm – 5:15pm on T/Th
Class location: 3444 in the CS building
Office hours: 3:00–4:00 MWF (or by appt.)

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

TA: Duksu Kim (XXX)

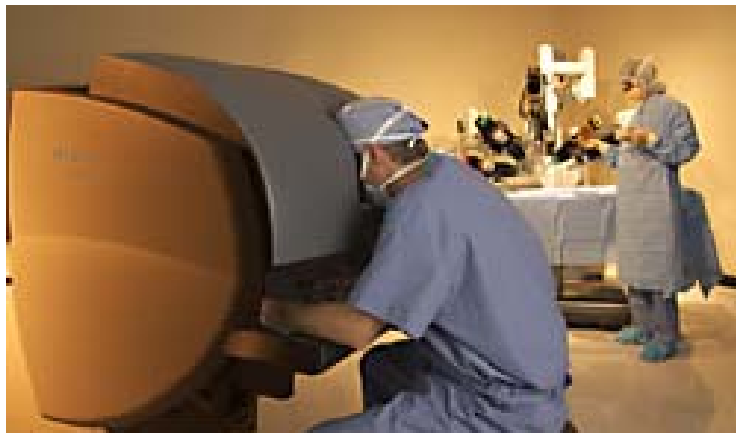
Real World Robots



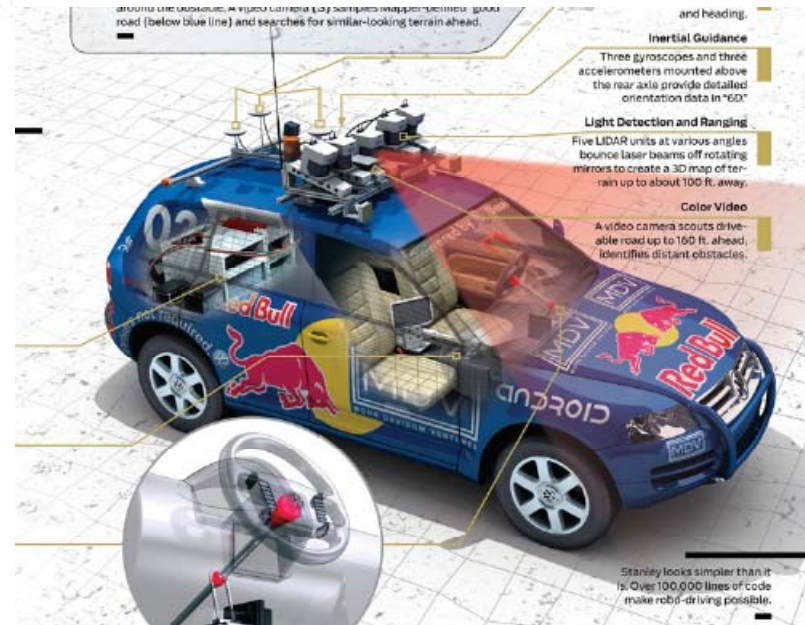
ASIMO



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

Motion of Real Robots

Albert HUBO Introduction - korea scienceworld

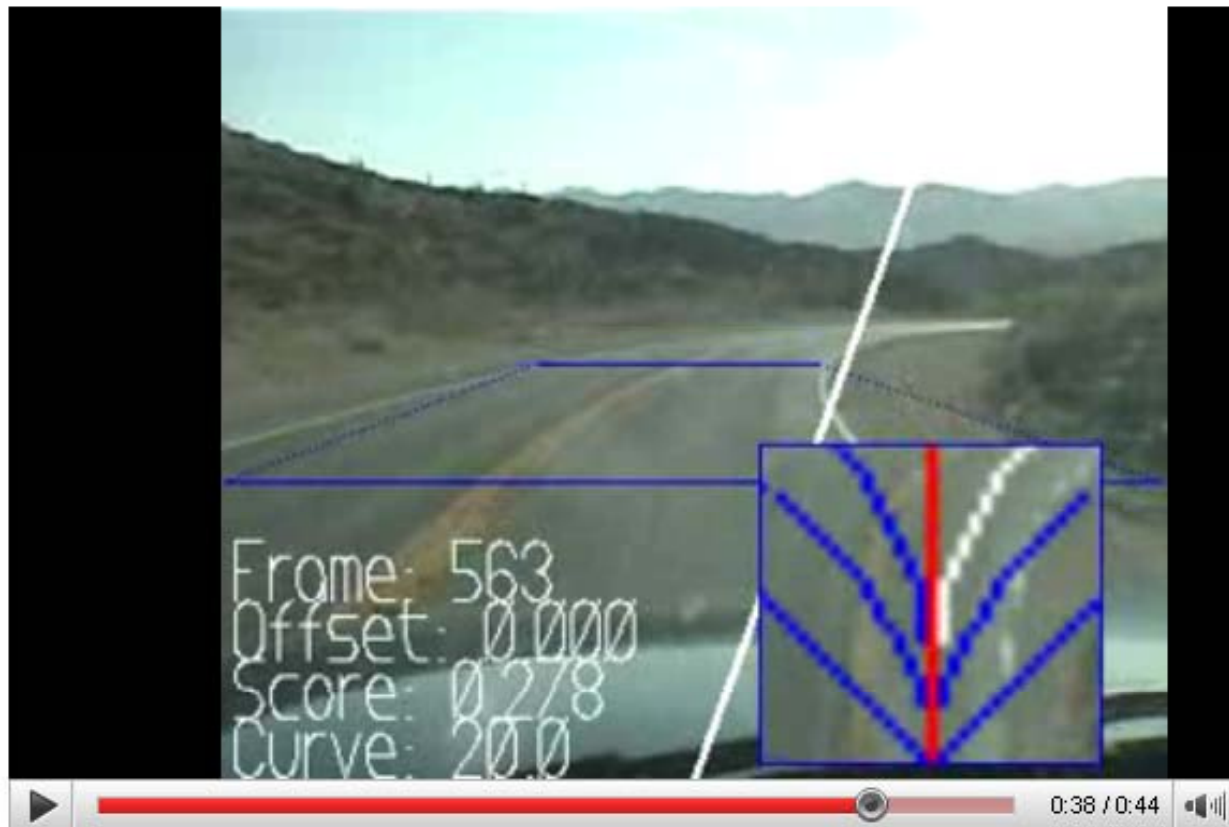


Humanoid Robot:

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

Motion of Real Robots

Autonomous robot vision 1



Autonomous robot

<http://www.youtube.com/watch?v=3SQiow-X3ko>

Motion of Real Robots

Robot-Assisted Radical Prostatectomy



Medical robot:

<http://www.youtube.com/watch?v=XfH8phFm2VY>

Open Platform Humanoid Project: DARwIn-OP



<http://www.youtube.com/watch?v=0FFBZ6M0nKw>

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>

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

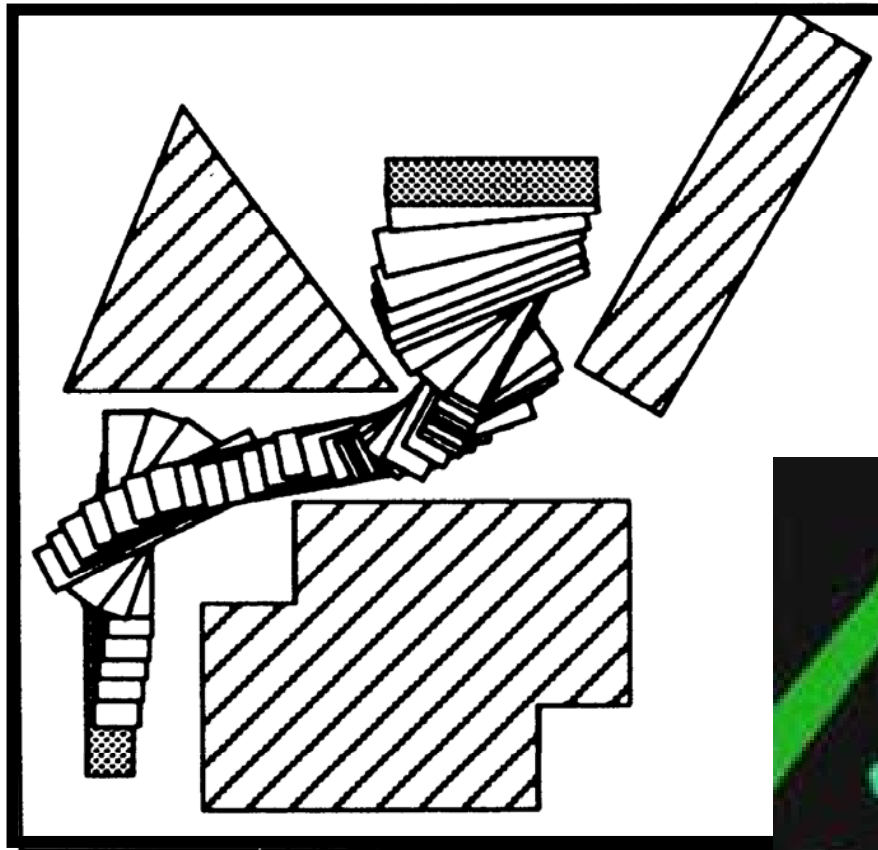
Goal of Motion Planning

- 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

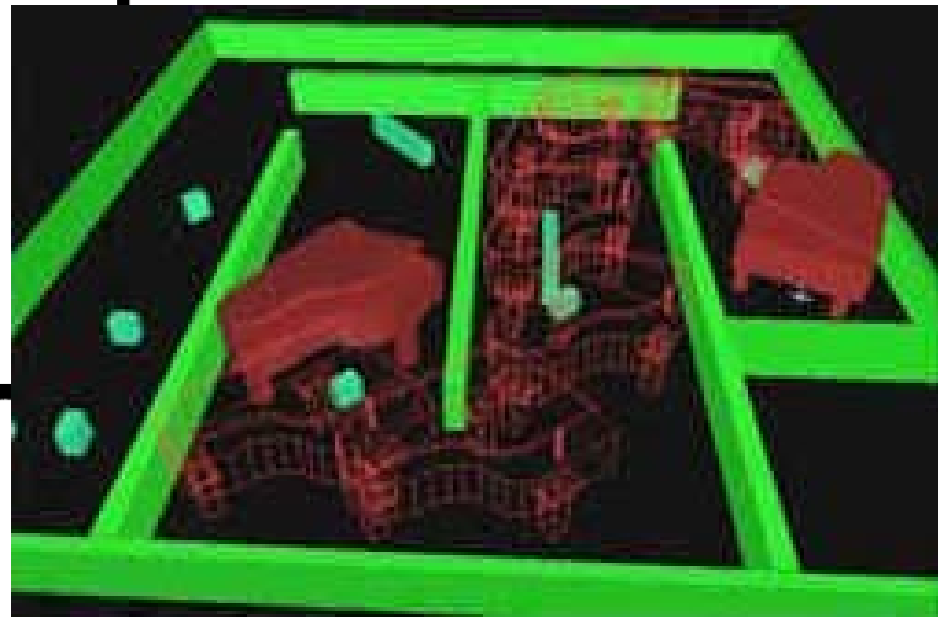
Basic Motion Planning Problem

- **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

Examples with Rigid Object

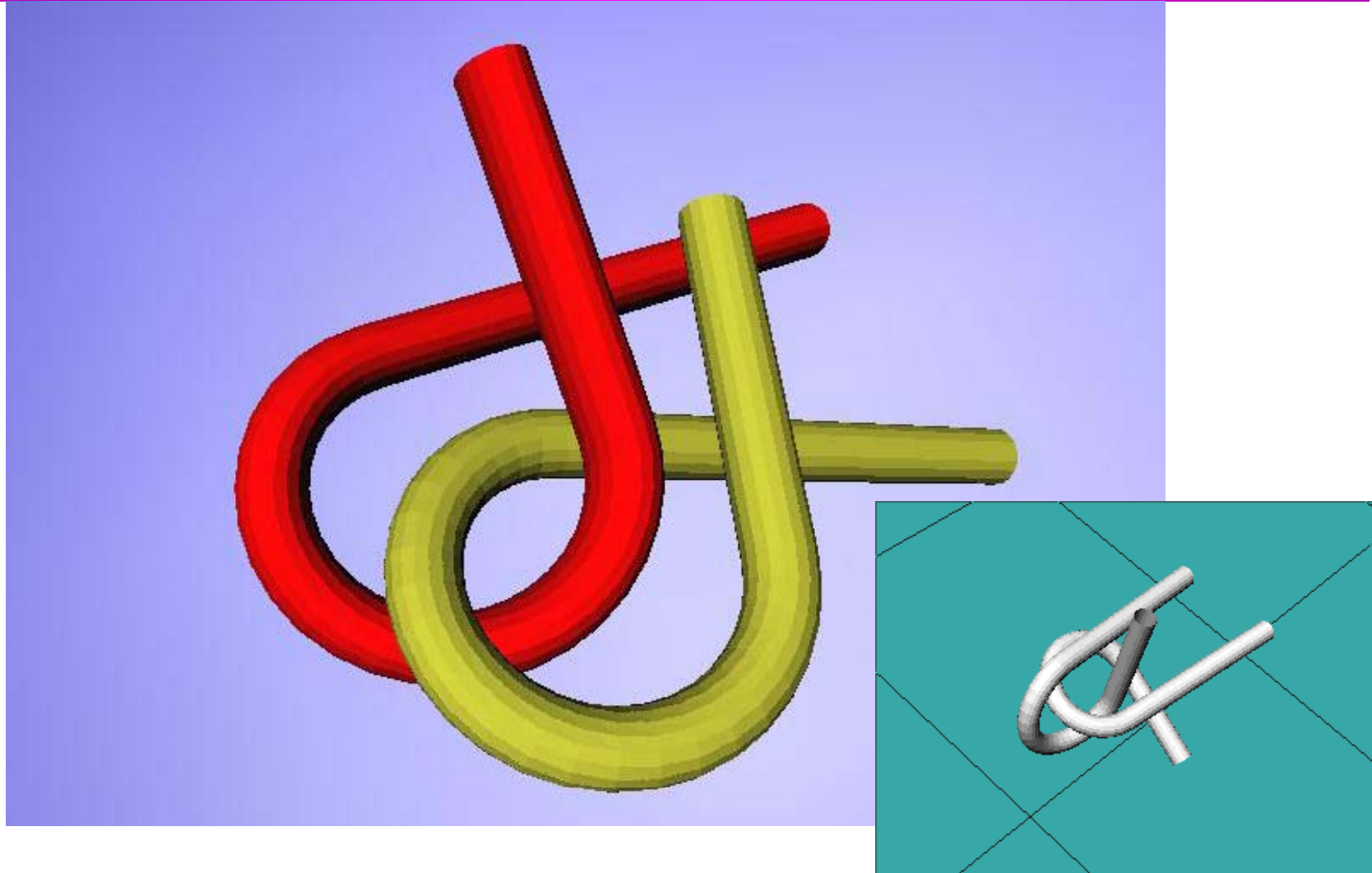


→ Ladder problem

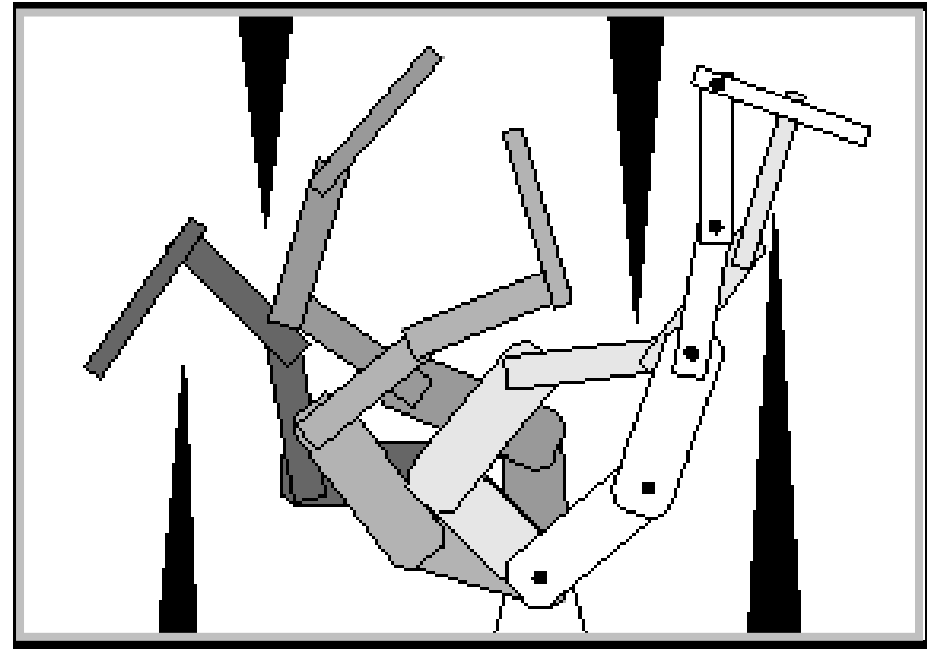
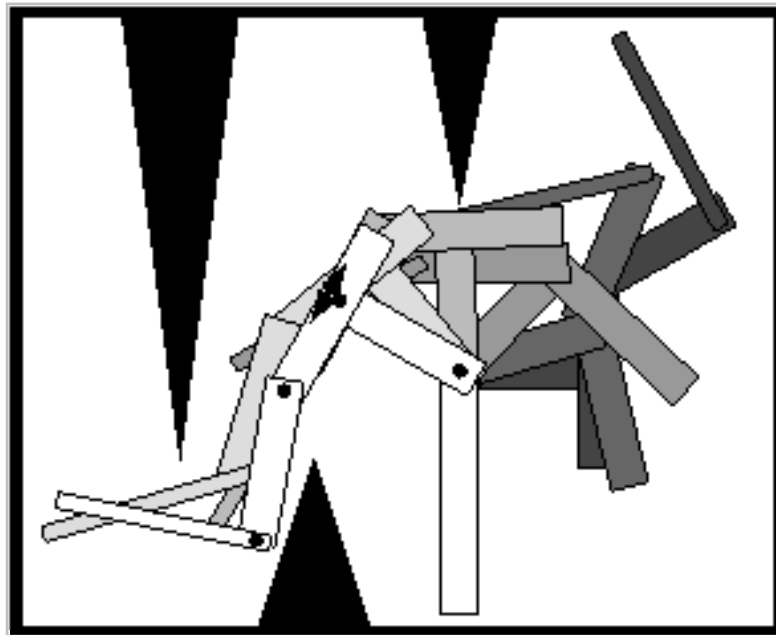


Piano-mover problem ←

Is It Easy?



Example with Articulated Object



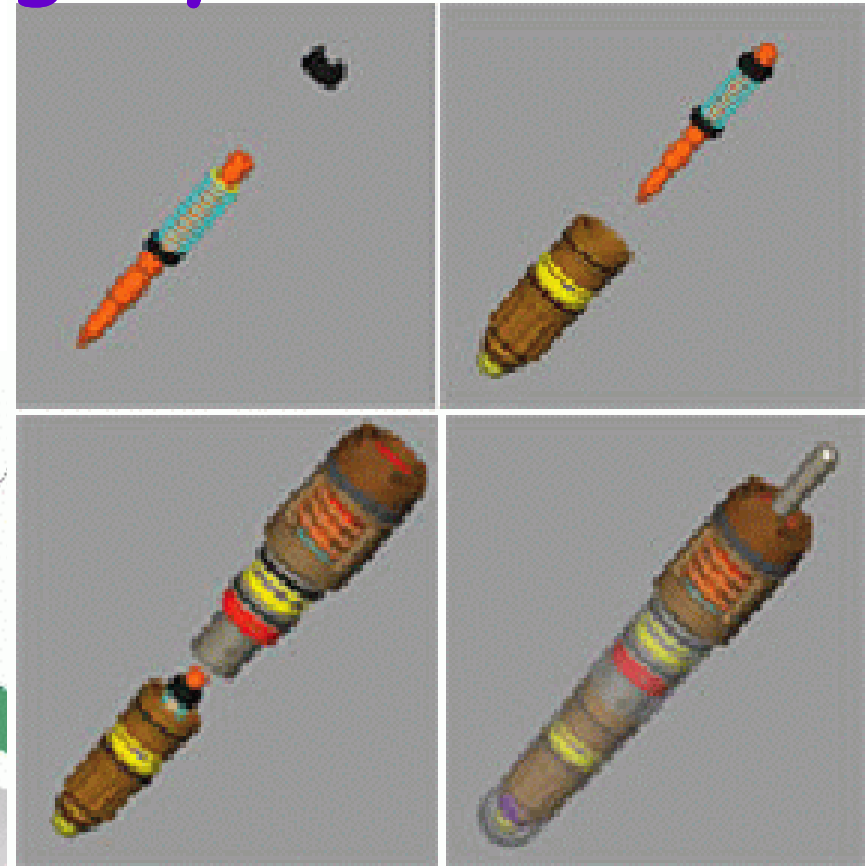
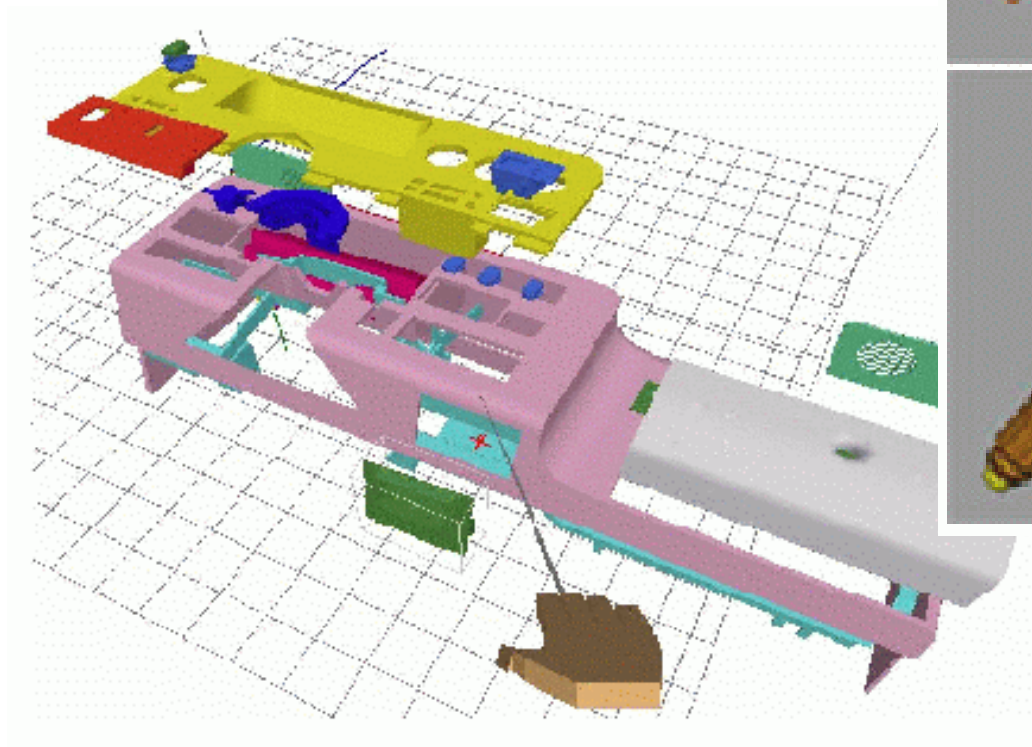
Some Extensions of Basic Problem

- 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-actuated systems)
- Physical models and deformable objects
- Integration of planning and control
- Integration with higher-level planning

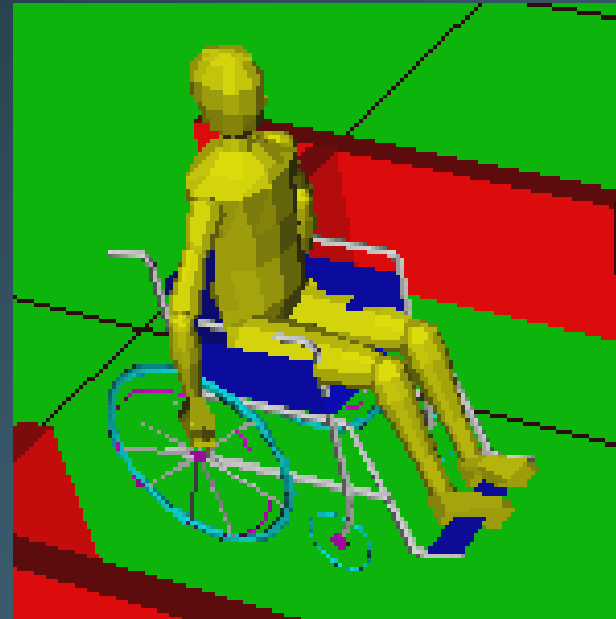
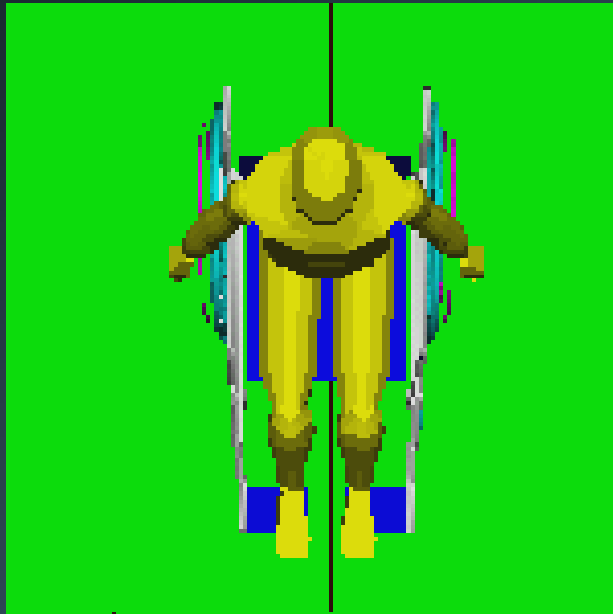
Examples of Applications

- **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**

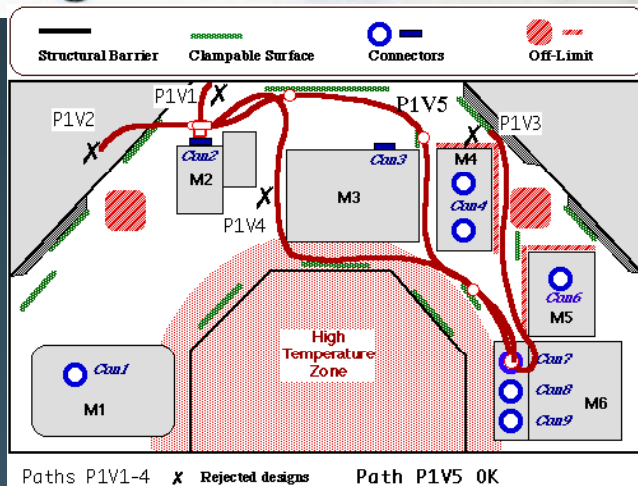
Assembly Planning and Design of Manufacturing Systems



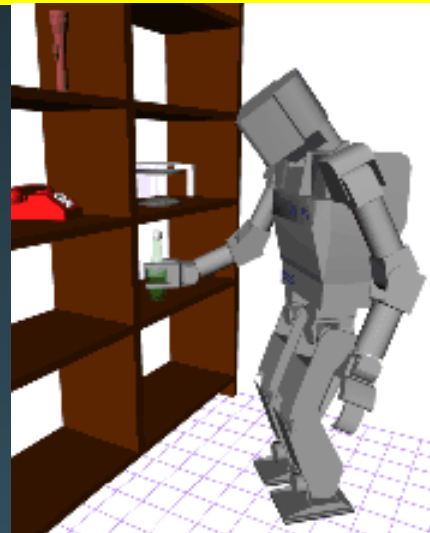
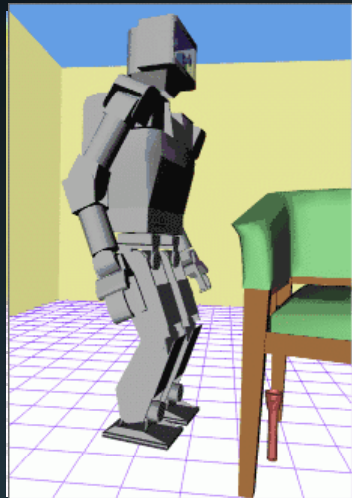
Application: Checking Building Code



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)



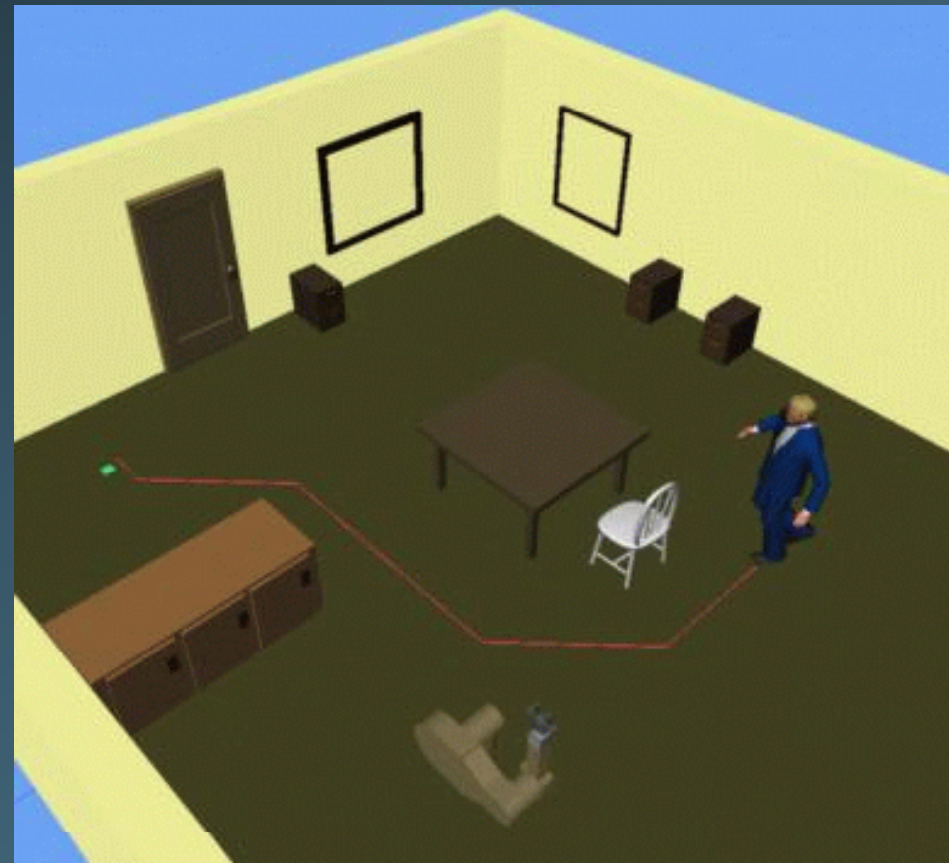
Final Fantasy VIII (SquareOne)

Motion Planning for Digital Actors

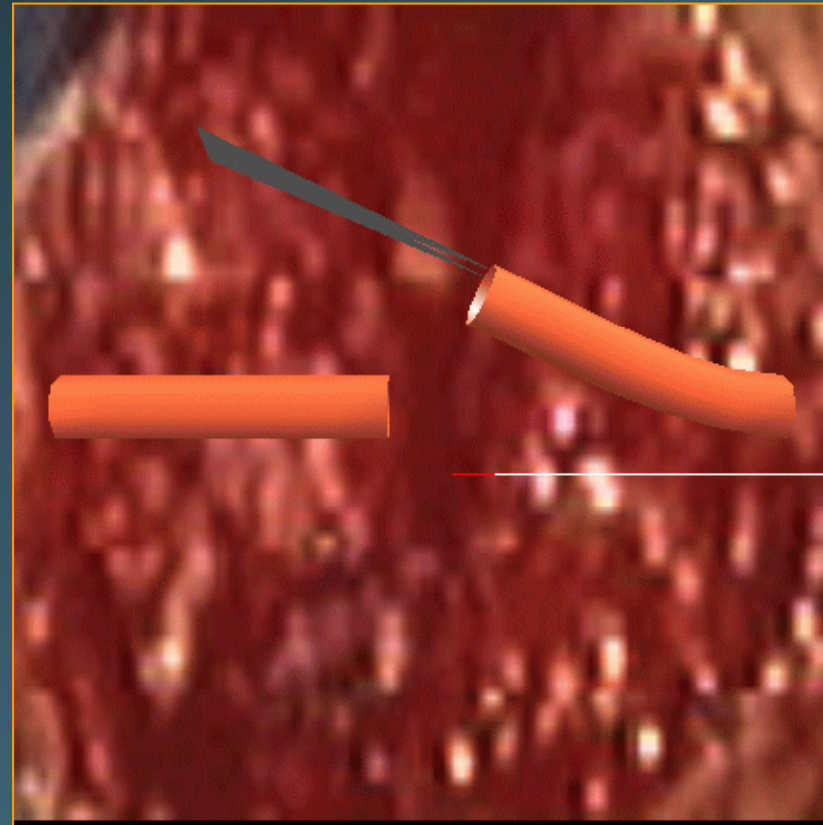
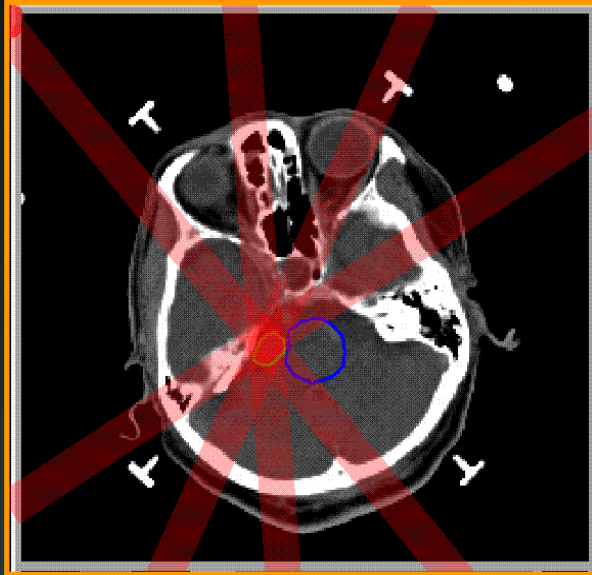
Manipulation



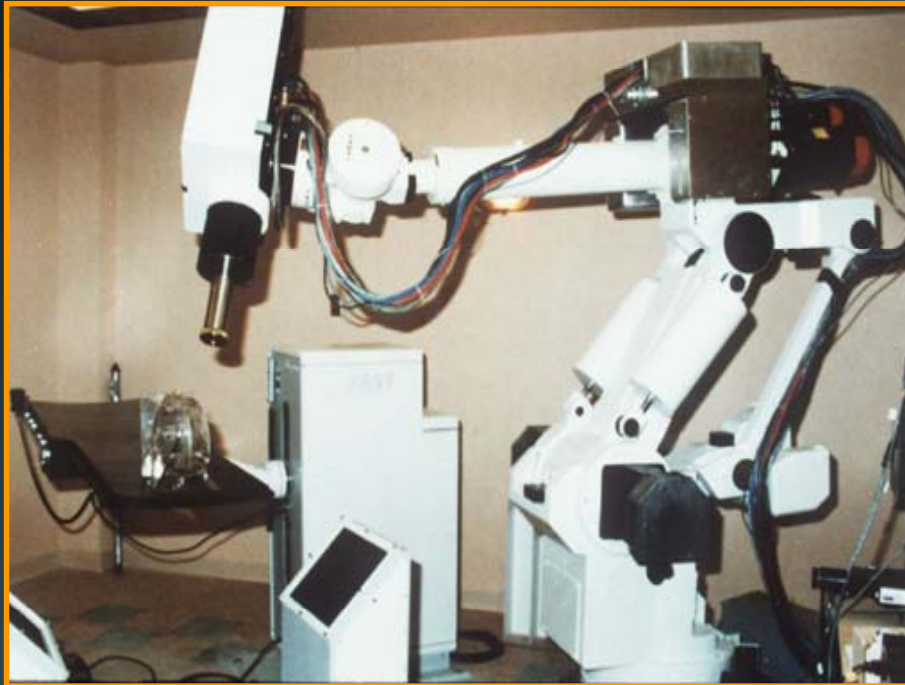
Sensory-based locomotion



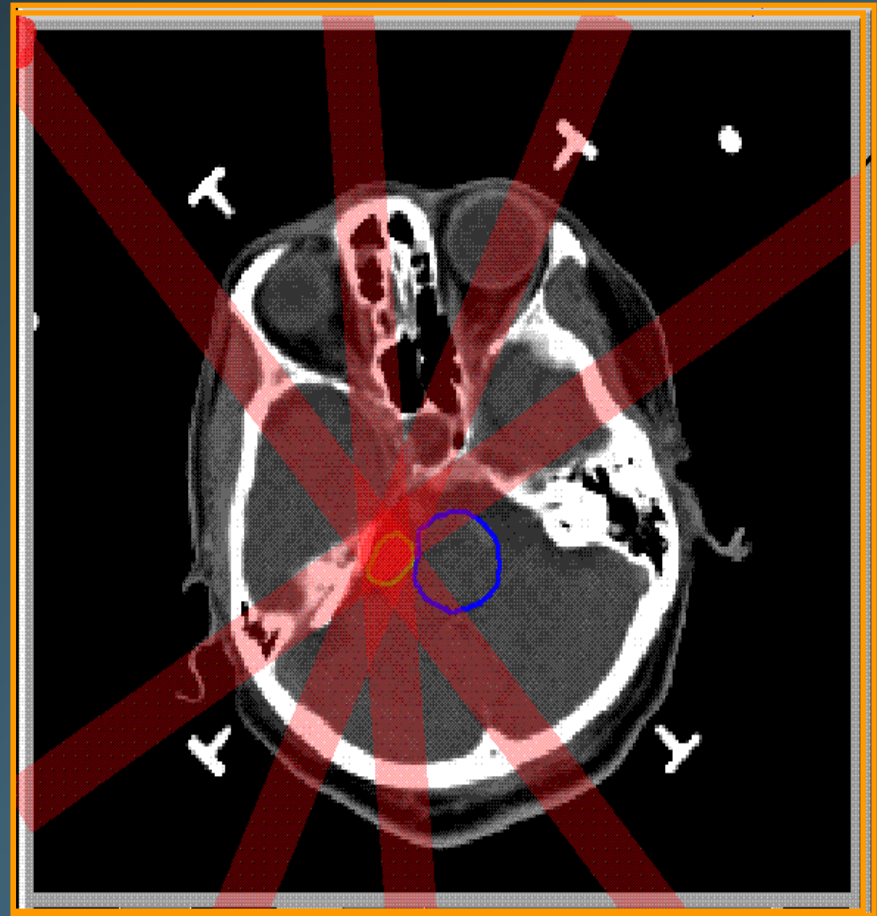
Application: Computer-Assisted Surgical Planning



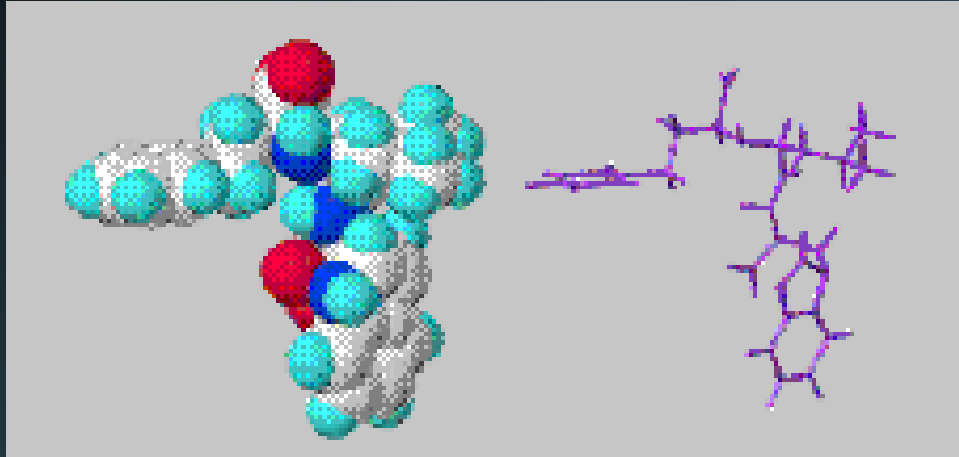
radiosurgical Planning



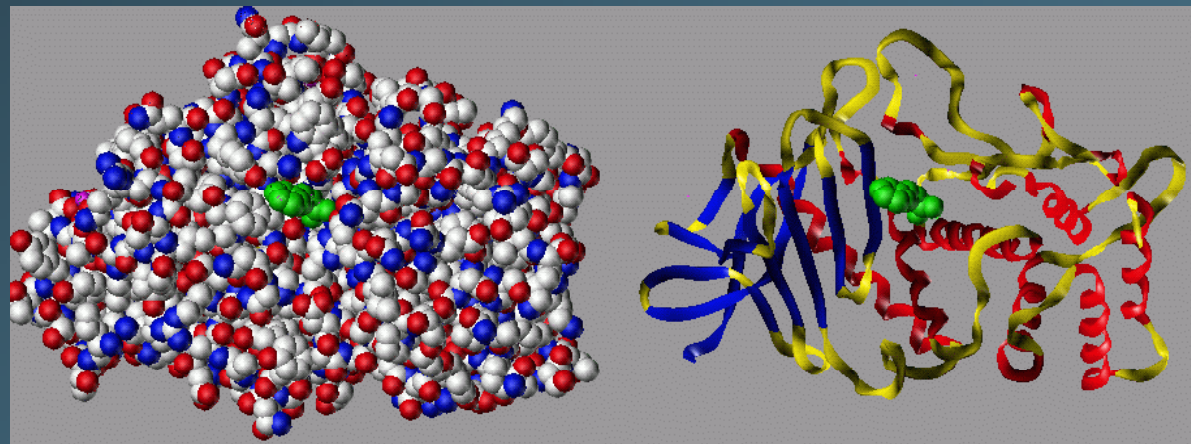
Cyberknife



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

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!

Course Overview

- **1/2 of lectures and 1/2 of student presentations**
 - This is a research-oriented course
 - Paper reading list
- **What you will do:**
 - Choose papers that are interesting to you
 - Present those papers
 - Propose ideas that can improve the state-of-the-art techniques; implementation is not required, but is recommended
 - Quiz and mid-term
 - **and, have fun!**

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 ideas to address those problems**
 - Show convincing reasons why your ideas can improve those problems
 - Implementation is optional

Course Awards

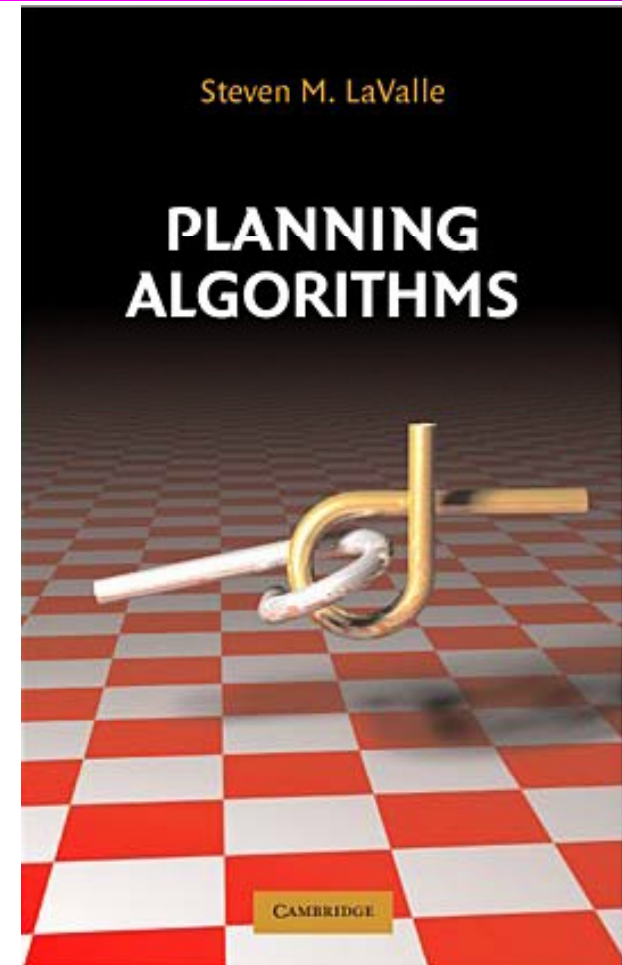
- **Best speaker and best project**
- **For the best presenter, a small research related device will be supported**
- **For the best project, a high grade will be given**

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+)

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. on Intelligent 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

Our Research Focus

- **Design general motion planning algorithms that:**
 - **Easily adapt to various motion planning problems**
 - **Show high performance**
 - **Provide high scalability for complex and high-dimensional problems**

Ranking of Robotics-Related Conf. (among last 10 years)

- Based on last 10 years records among 2.3K conf.
- Name (rank): publications, citations
- ICCV (10): 1K, 23K
- CVPR (18): 3.5K, 42K
- IROS (59): 0.5K, 6.5K
- ICRA (75): 7K, 30K
- I3D (91): 0.2K, 3K
- RSS (missed): 0.1K, 1.2K (recent conf.)
- ISRR (missed): 0.1K, 1.2K

Ranking of Robotics-Related Journals

- Based on last 10 years records among 0.9K journals
- Name (rank): publications, citations
- TOG (1): 1.2K, 38K
- PAMI (5): 1.9K, 40K
- IJCV (7): 0.9K, 19K
- IJRR (65): 0.8K, 7K (IF '09: 1.993)
- TVCG(72): 1.2K, 8.6K
- CGF (83): 1.4K, 9.2K
- Trob (87): 1.1K, 7.6K (IF '09: 2.035)
- Autonomous Robot (missed): 2K, 13K (whole years) (IF '09: 1.2)

Honor Code

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

Schedule

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

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

About You

- Name
- Your (non hanmail.net) email address
- What is your major?
- Previous experience on motion planning and robotics

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**
 - **0 for no questions**
 - **2 for typical questions**
 - **3 for questions with thoughts**
 - **4 for questions that surprised me**

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