CS686: Robot Motion Planning and Applications

Sung-Eui Yoon
(윤성의)

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

About the Instructor

- **Main research theme**
  - **Work on large-scale problems related to motion planning, computer graphics, recognition, etc.**
  - **Paper and video: http://sglab.kaist.ac.kr/papers.htm**
  - **YouTube videos: http://www.youtube.com/user/sglabkaist**

Welcome to CS686

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

Class time: 1:00pm – 2:15pm on TTh
Class location: 3444 in the CS building
Office hours: Right after class
Course webpage:
http://sglab.kaist.ac.kr/~sungeui/MPA

TA

김수민(SooMin Kim):
PhD student

soo.kim813 at gmail.com

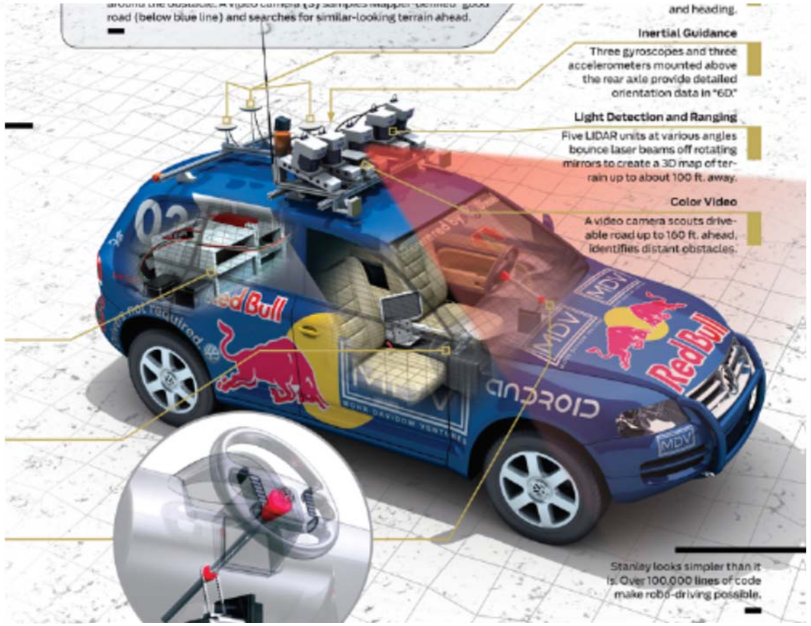
E3-1, 3440

Real World Robots

ASIMO

Sony Aibo

Da Vinci



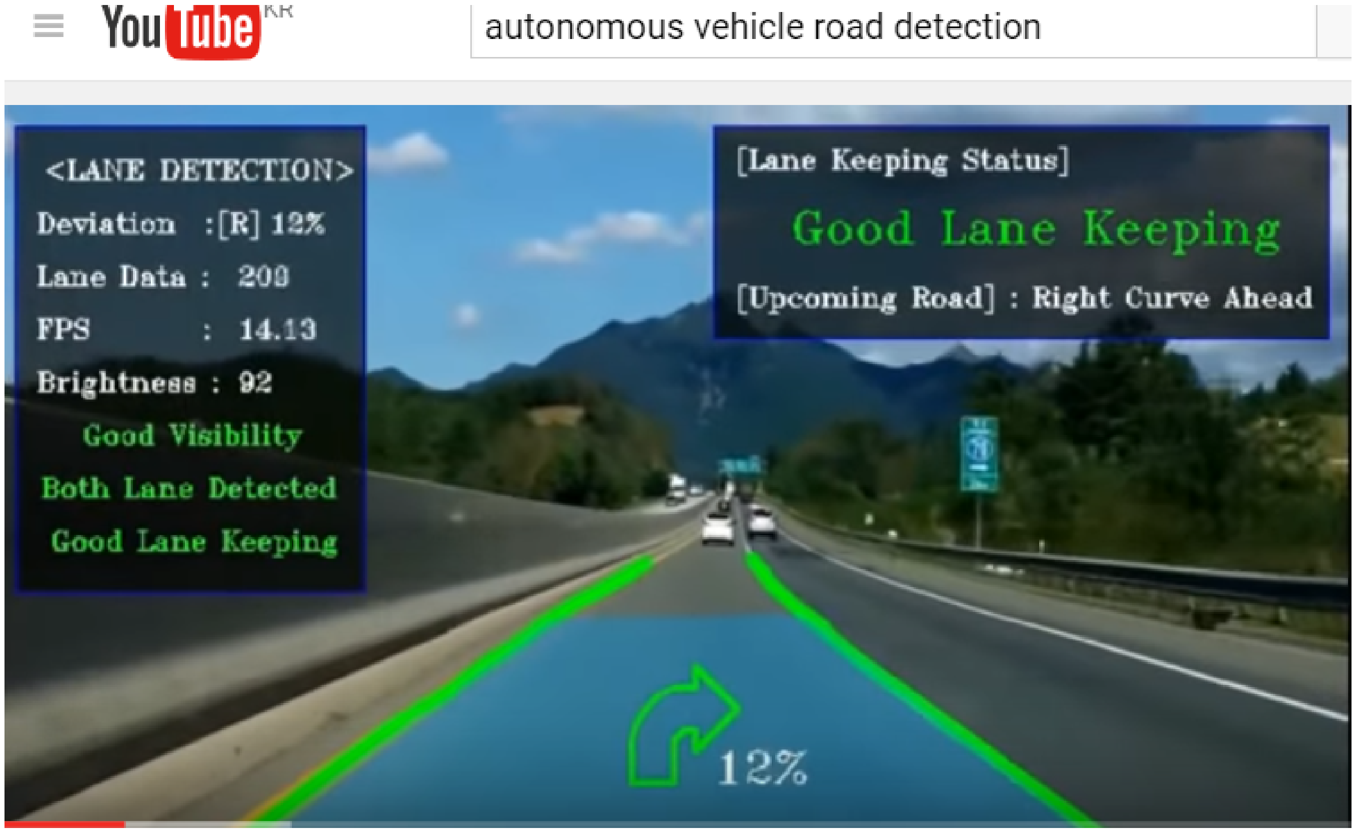
Courtesy of Prof. Dinesh Manocha

Motion of Real Robots

- **DRC final winner at 2016**

Humanoid Robot:
https://www.youtube.com/watch?v=BGOUSvaQcBs

Motion of Real Robots



Autonomous vehicle:
https://www.youtube.com/watch?v=zQTQNJ4QUvo

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Motion of Real Robots

Robot-Assisted Radical Prostatectomy

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

Open Platform Humanoid Project: DARwIn-OP

Just USD 8K!

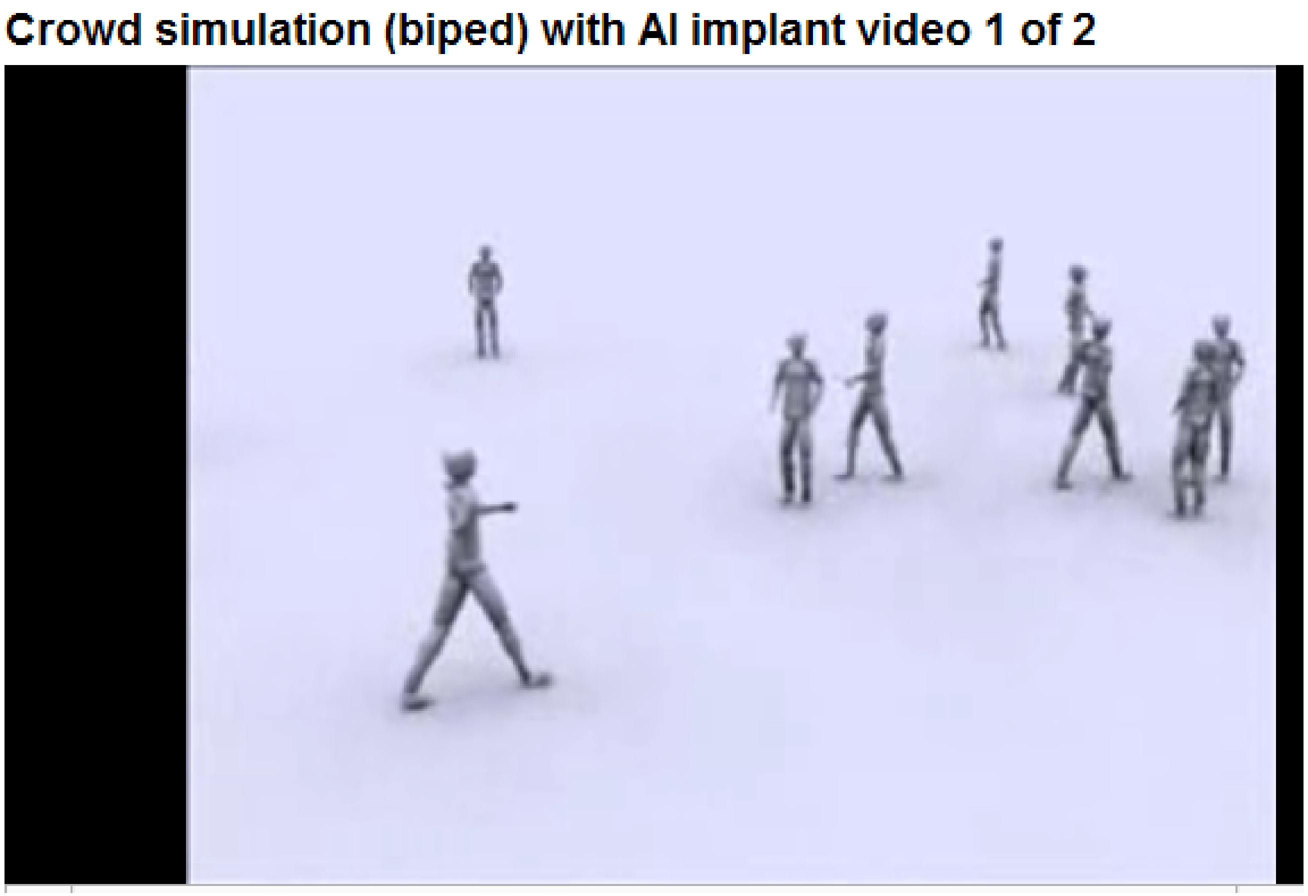
http://www.youtube.com/watch?v=0FFBZ6M0nKw

TurtleBot

http://www.youtube.com/watch?feature=player_detailpage&v=MOEjL8JDvd0

Motion of Virtual Worlds

Motion of Virtual Worlds



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**

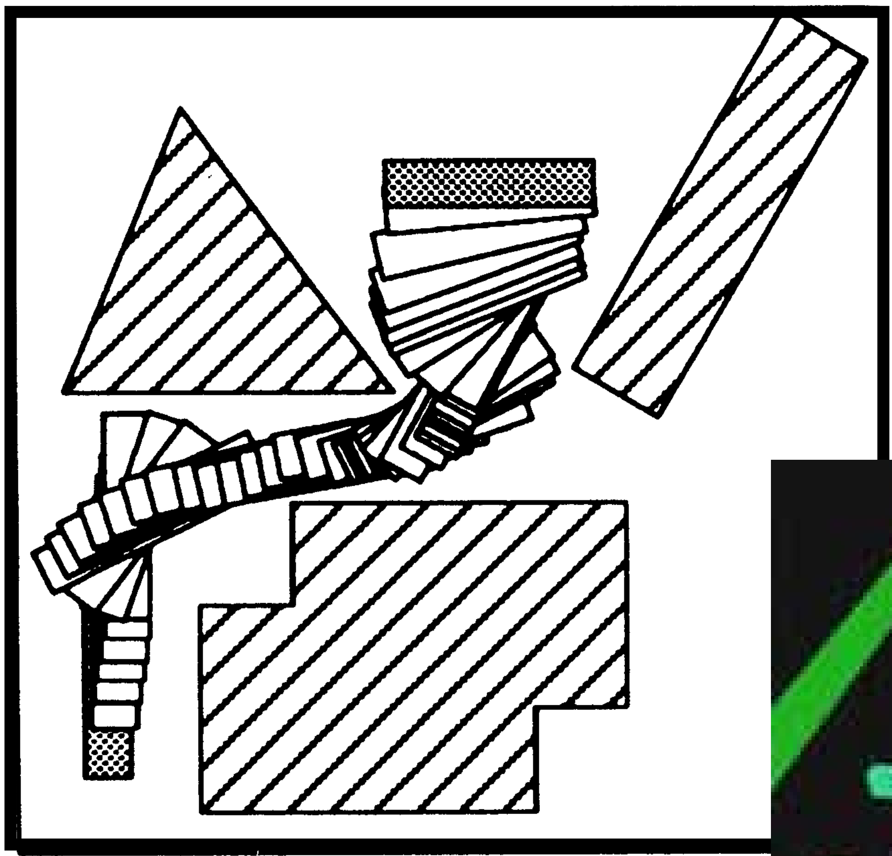
- Applications:
  - Manufacturing
  - Mobile robots
  - Computational biology
  - Computer-assisted surgery
  - Digital actors

Goal of Motion Planning

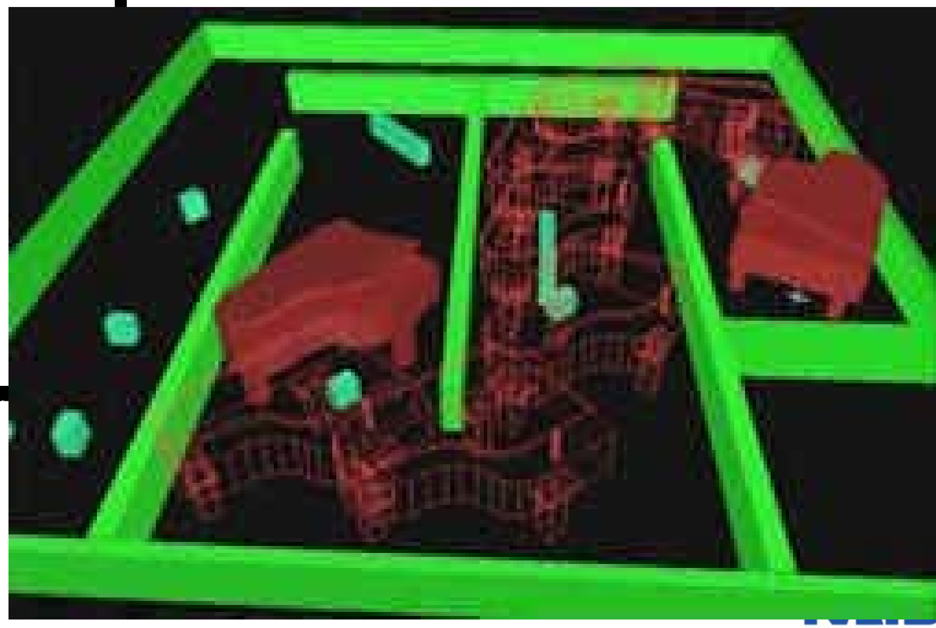
- Compute **motion strategies**, e.g.:
  - Geometric paths
  - Time-parameterized trajectories
  - Sequence of sensor-based motion commands
  - Aesthetic constraints

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

Examples with Rigid Object

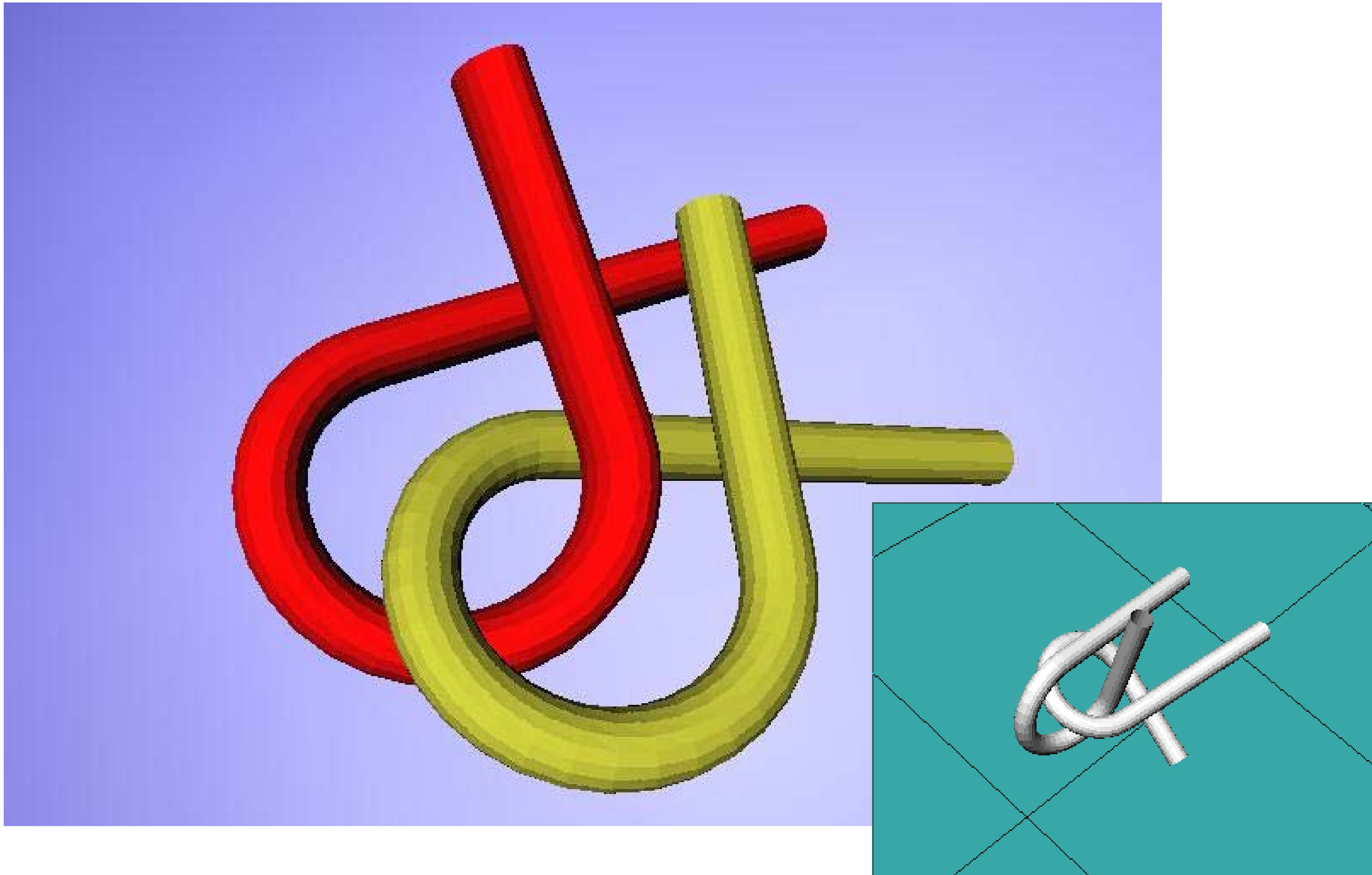


→ Ladder problem

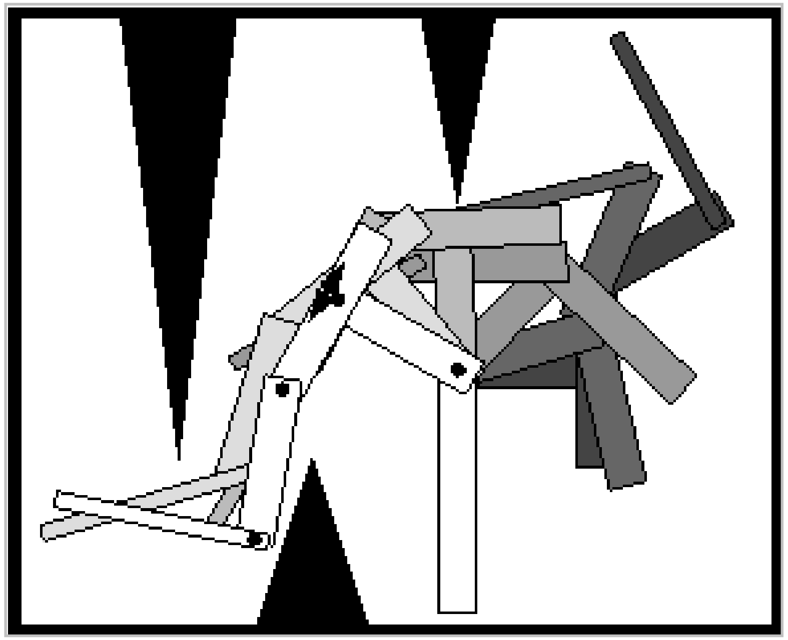


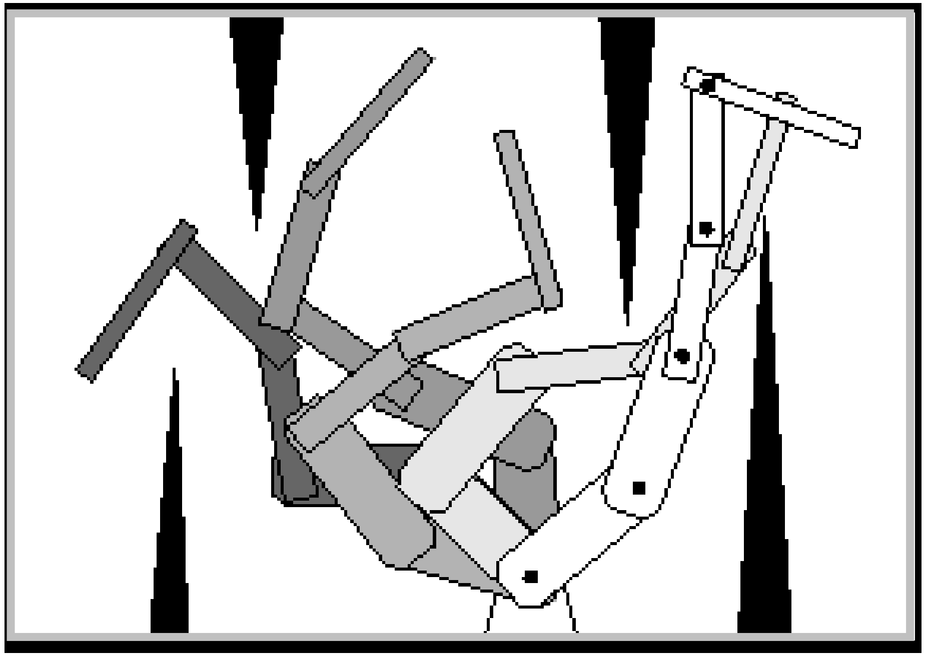
Piano-mover problem ←

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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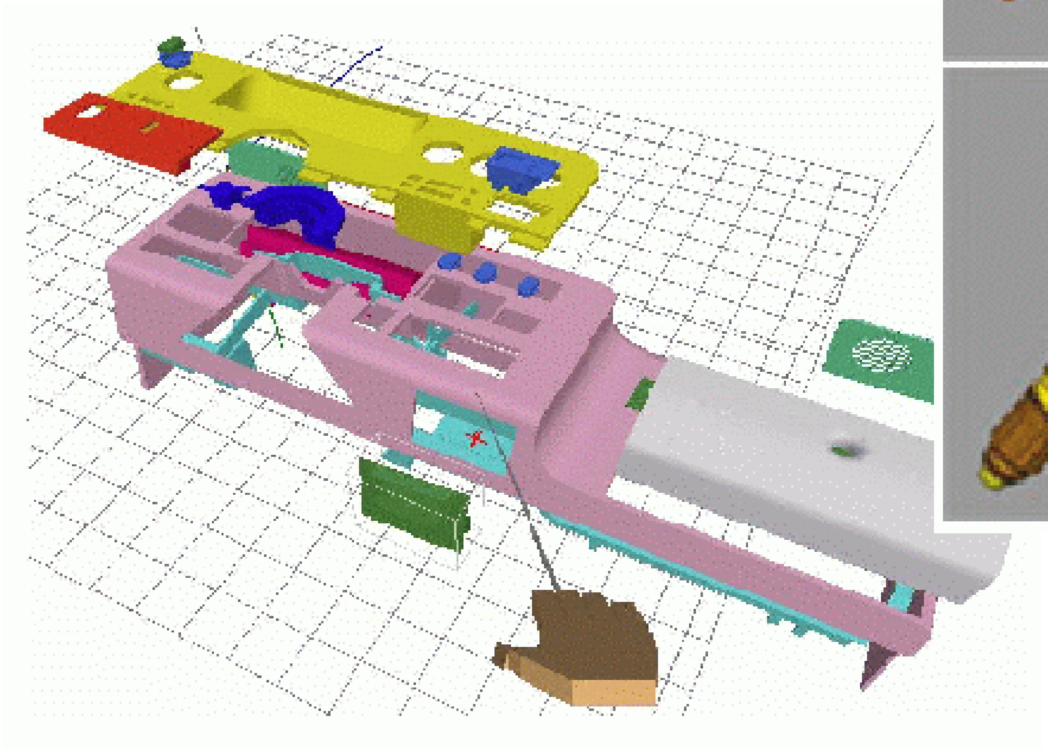
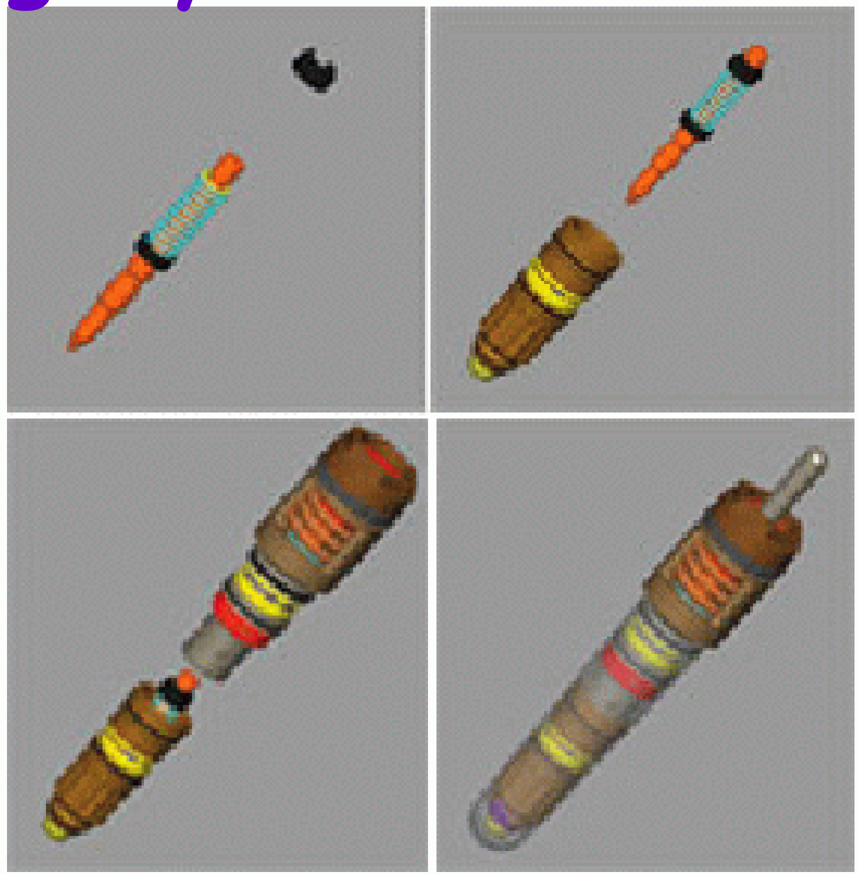
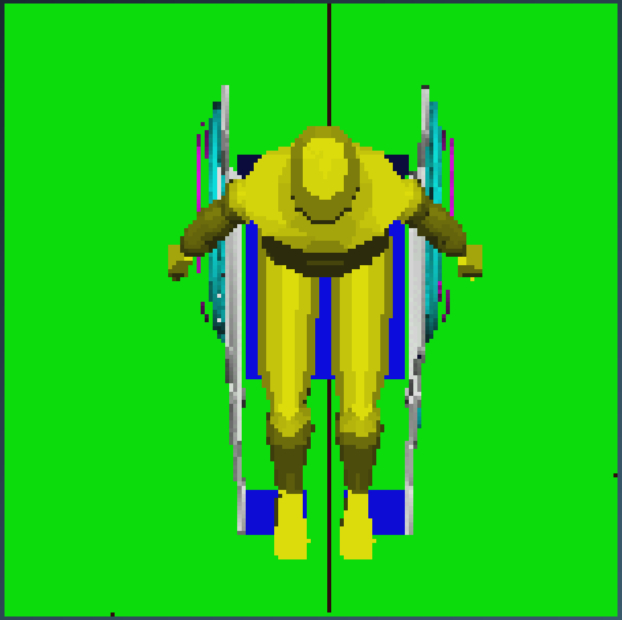
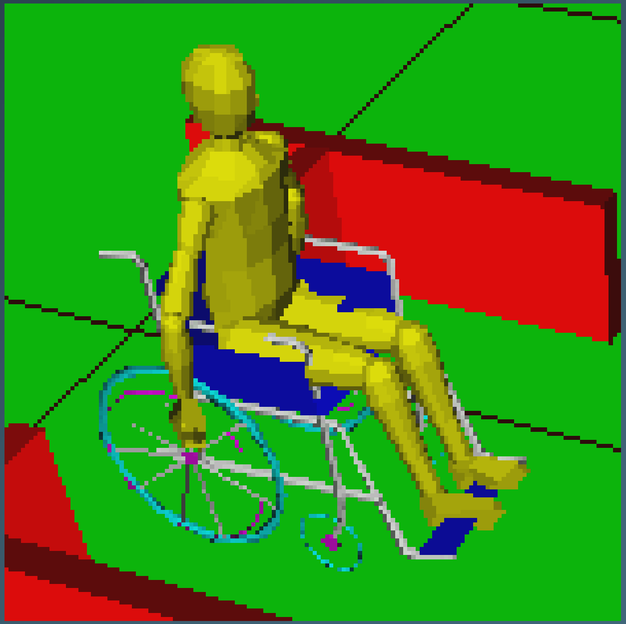
Assembly Planning and Design of Manufacturing Systems



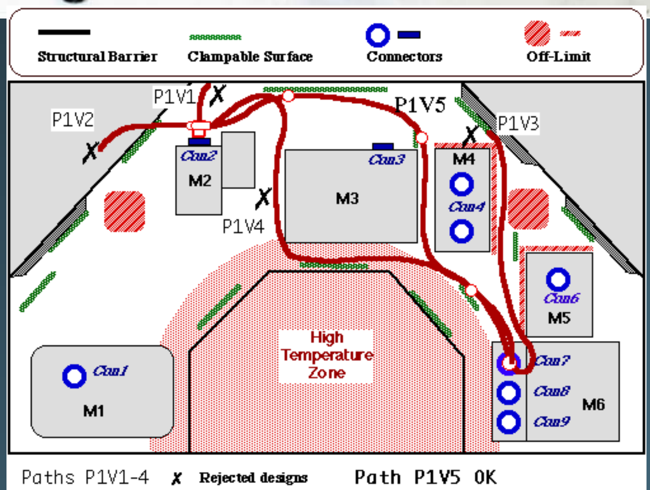


Application: Checking Building Code

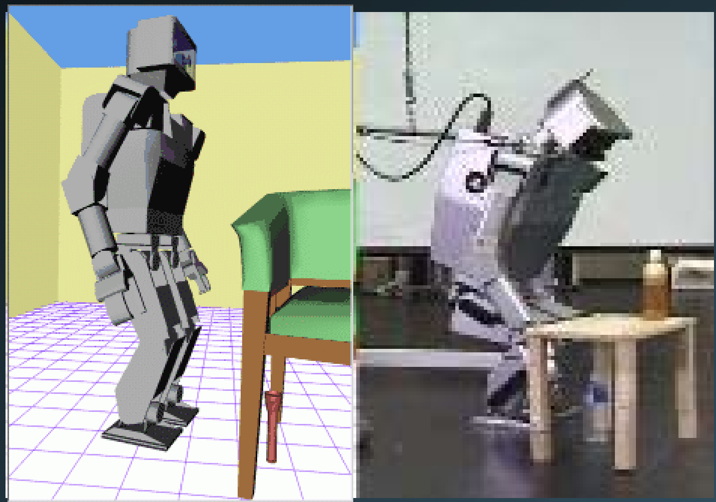


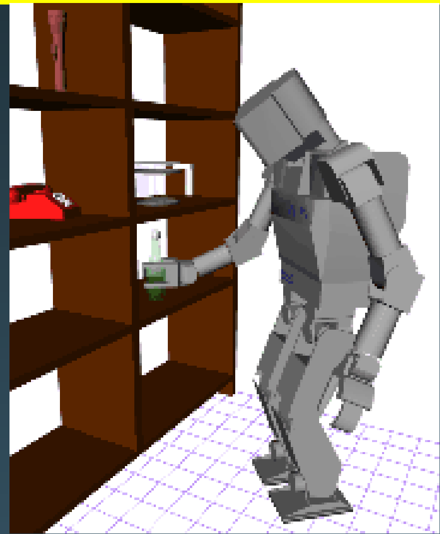


Cable Harness/ Pipe design



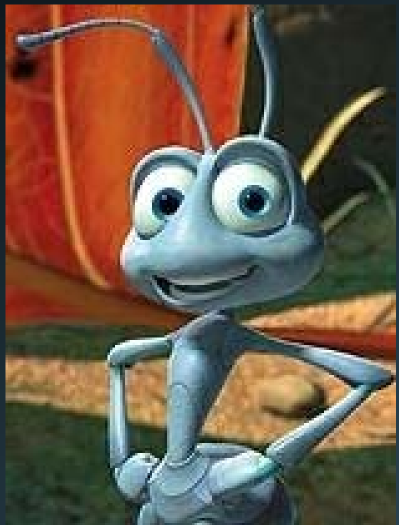
Humanoid Robot

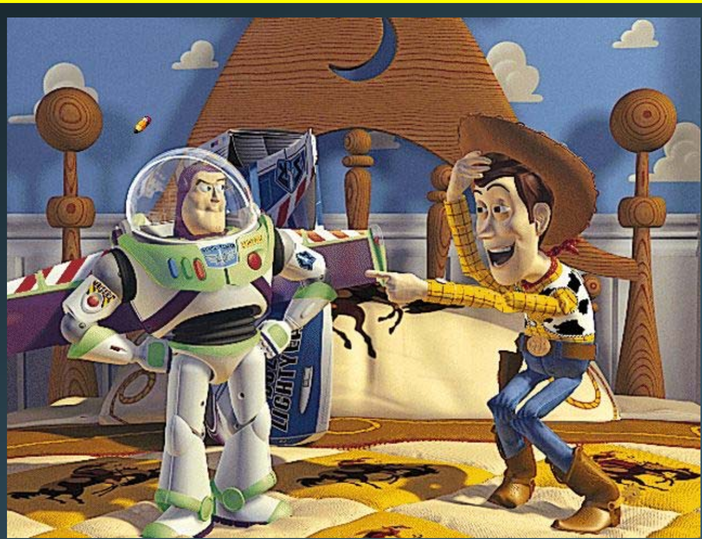




[Kuffner and Inoue, 2000] (U. Tokyo)

Digital Actors


A Bug's Life (Pixar/Disney)


Toy Story (Pixar/Disney)


Antz (Dreamworks)


Tomb Raider 3 (Eidos Interactive)

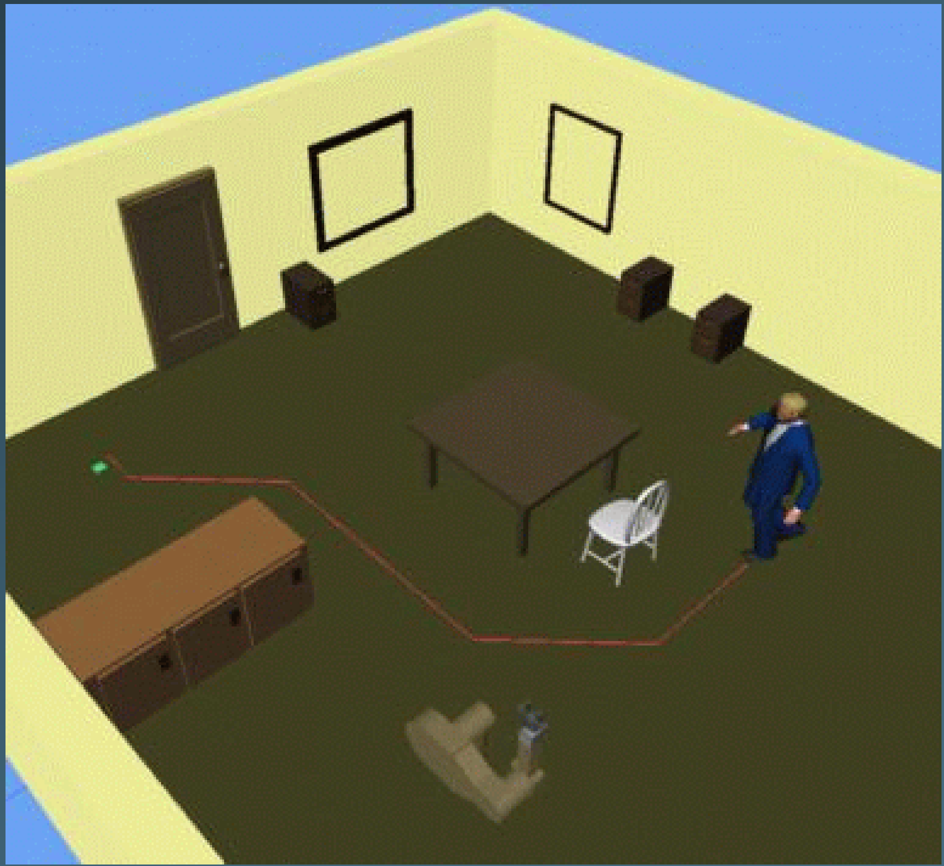
The Legend of Zelda (Nintendo)


Final Fantasy VIII (SquareOne)

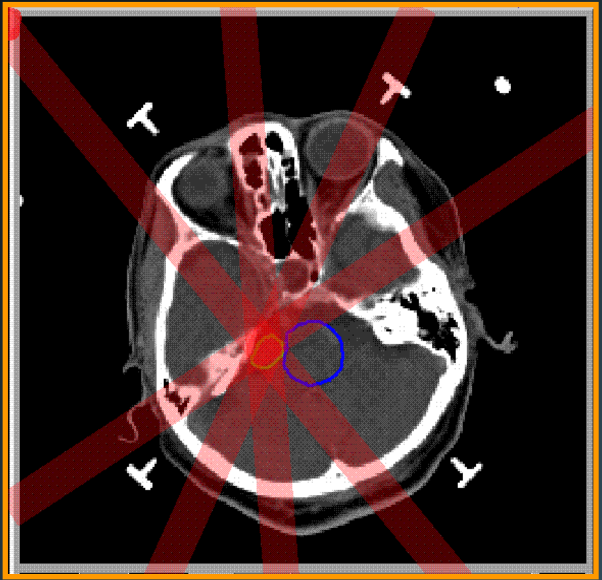
Motion Planning for Digital Actors

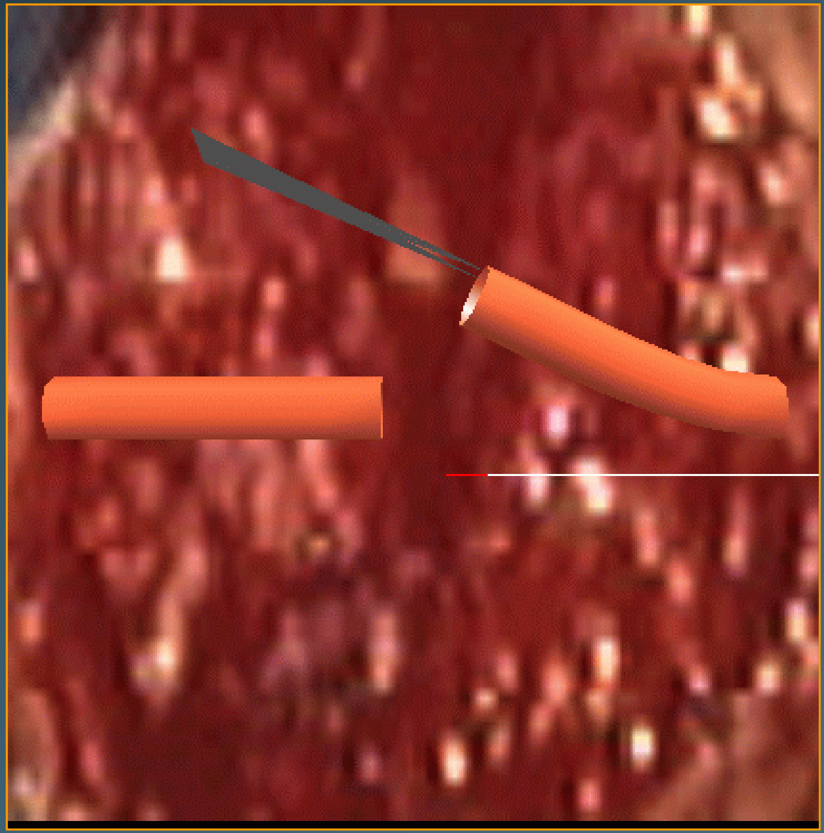
Manipulation

Sensory-based locomotion

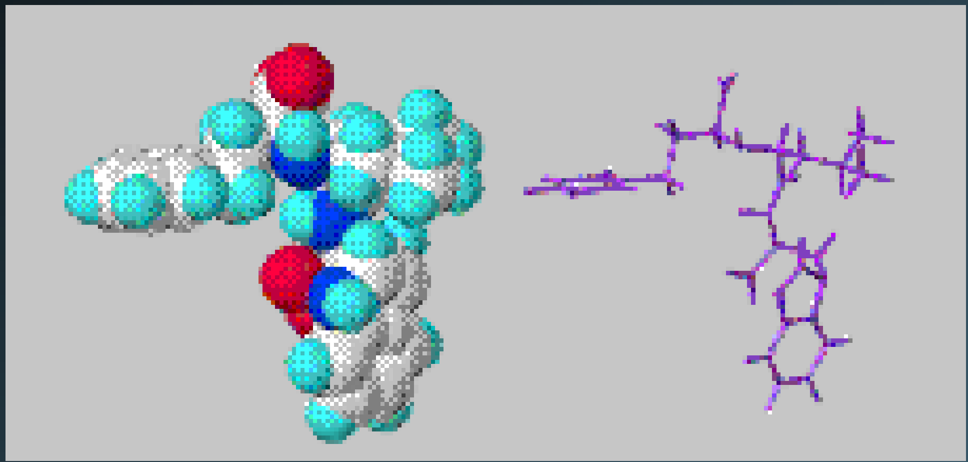


Application: Computer-Assisted Surgical Planning

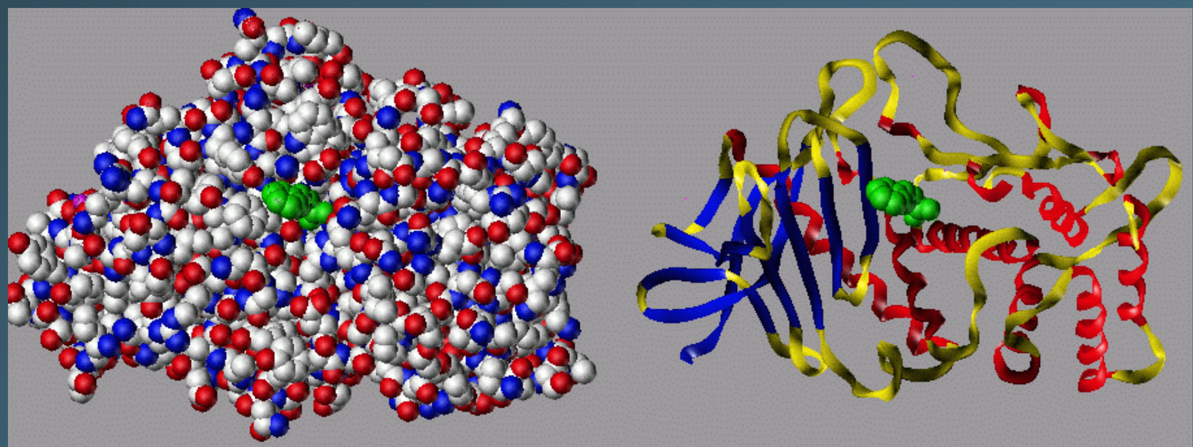




Study of the Motion of Bio-Molecules



- Protein folding
- Ligand binding



DARPA Grand Challenge

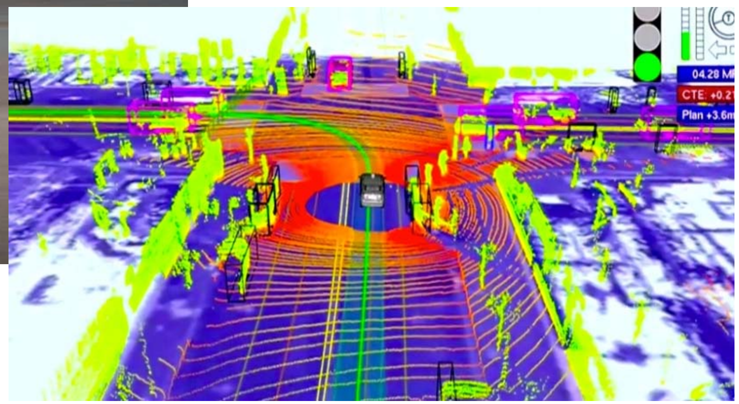
Planning for a collision-free 132 mile path in a desert

DARPA Robotics Challenges, 2016

- **Focus on disaster or emergency-response scenarios**

From wiki

Google Self-Driving Vehicles



Prerequisites

- **Programing skills**
- **Basic understanding of probability and geometric concepts**
  - **E.g., events, expected values, etc.**
- **Some prior exposure to robotics problems/applications/HWs**
- **If you did not take any prior course on robotics, this course is inappropriate for you**
  - **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**

- **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!**

Course Awards

- Best speaker and best project

- For the best presenter/project, a small research related device will be supported

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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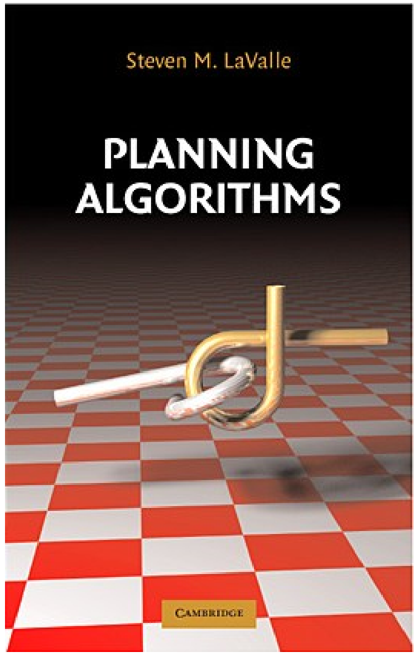
Resource

- Textbook
  - Planning Algorithms, Steven M. LaValle, 2006 (http://msl.cs.uiuc.edu/planning/)
- Technical papers
  - IEEE International Conf. on Robotics and Automation (ICRA)
  - IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS)
  - Robotics Science and Systems (RSS)
  - Bi-annual
    - Work. on Algorithmic Foundations of Robotics (WAFR)
    - Int. Symp. on Robotics Research (ISRR)



Other Reference

- Graphics-related conference (SIGGRAPH, etc)
    - http://kesen.huang.googlepages.com/
- Google or Google scholar
- UDACITY course:
    - Artificial Intelligence for Robotics

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 and Classroom Etiquette

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

- **Classroom etiquette**
  - **Help you and your peer to focus on the class**
  - **Turn off cell phones**
  - **Arrive to the class on time**
  - **Avoid private conversations**
  - **Be attentive in class**

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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**

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.

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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**
  - **1 for typical questions**
  - **2 for questions with thoughts or that surprised me**

- **Write a question at least 4 times during Sep./Oct.**
  - **Online submission is available at the course webpage**

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My Responses to Those Questions

- Identify common questions and address them at the Q&A file
- Some of questions will be discussed in the class

- If you want to know the answer of your question, ask me or TA on person
  - Feel free to ask questions in the class
- We are focusing on having good questions!
  - All of us are already well trained for answering questions

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**

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Next Time…

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

About You

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

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