CS686: Robot Motion Planning and Applications

Sung-Eui Yoon
(윤성의)

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

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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**

Some Achievement

- Tutorials/Workshop in international conf.
  - Workshop on sound source localization at ICRA
  - Tutorial on collision detection at SIGGRAPH

- Best paper award
  - Best paper in robotic planning, Int. Conf. on Advanced Robotics (ICAR), 2017
  - Test-Of-Time 2006 Award at High Performance Graphics, 2015
  - Distinguished paper award at Pacific Graphics 2009

Welcome to CS686

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

Class time: 4:00pm – 5:15pm on TTh
Class location: 3445 in the CS building
Office hours: Right after class
Course webpage:
http://sglab.kaist.ac.kr/~sungeui/MPA

TA

안인규(InKyu Ahn):
PhD student working sound source localization

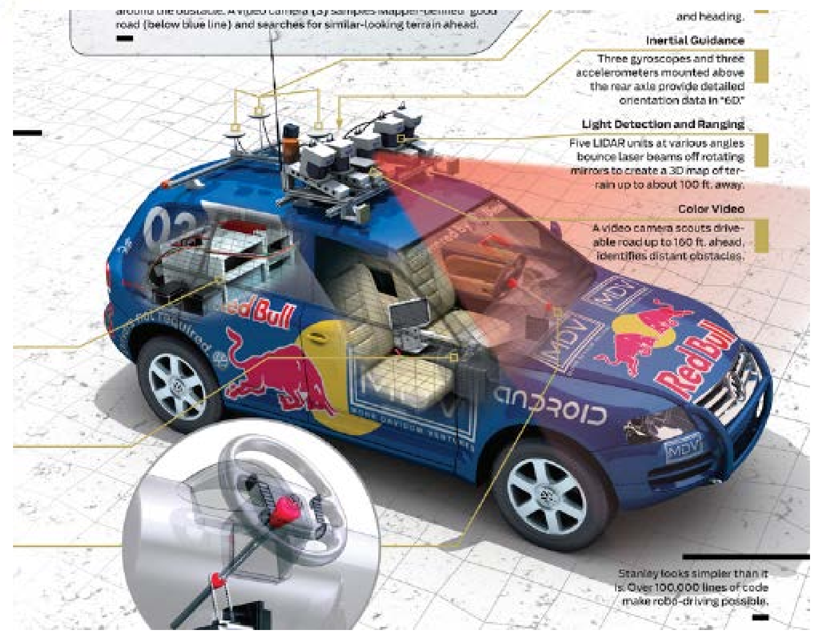
dksdlsrb89@gmail.com
(use KLMS board first)

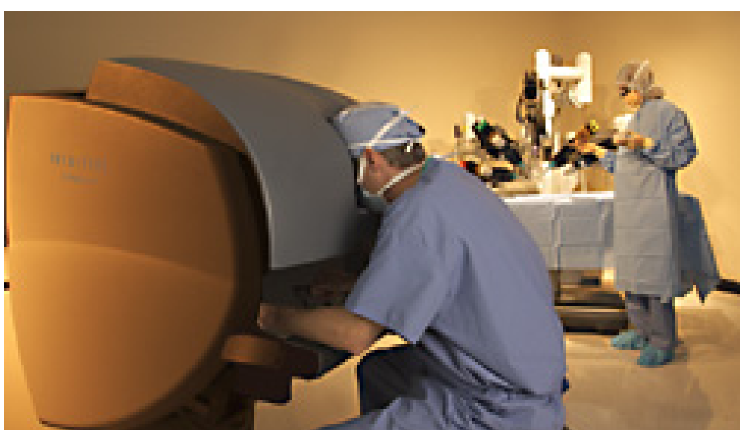
E3-1, 3440

Real World Robots

ASIMO

Sony Aibo





Da Vinci

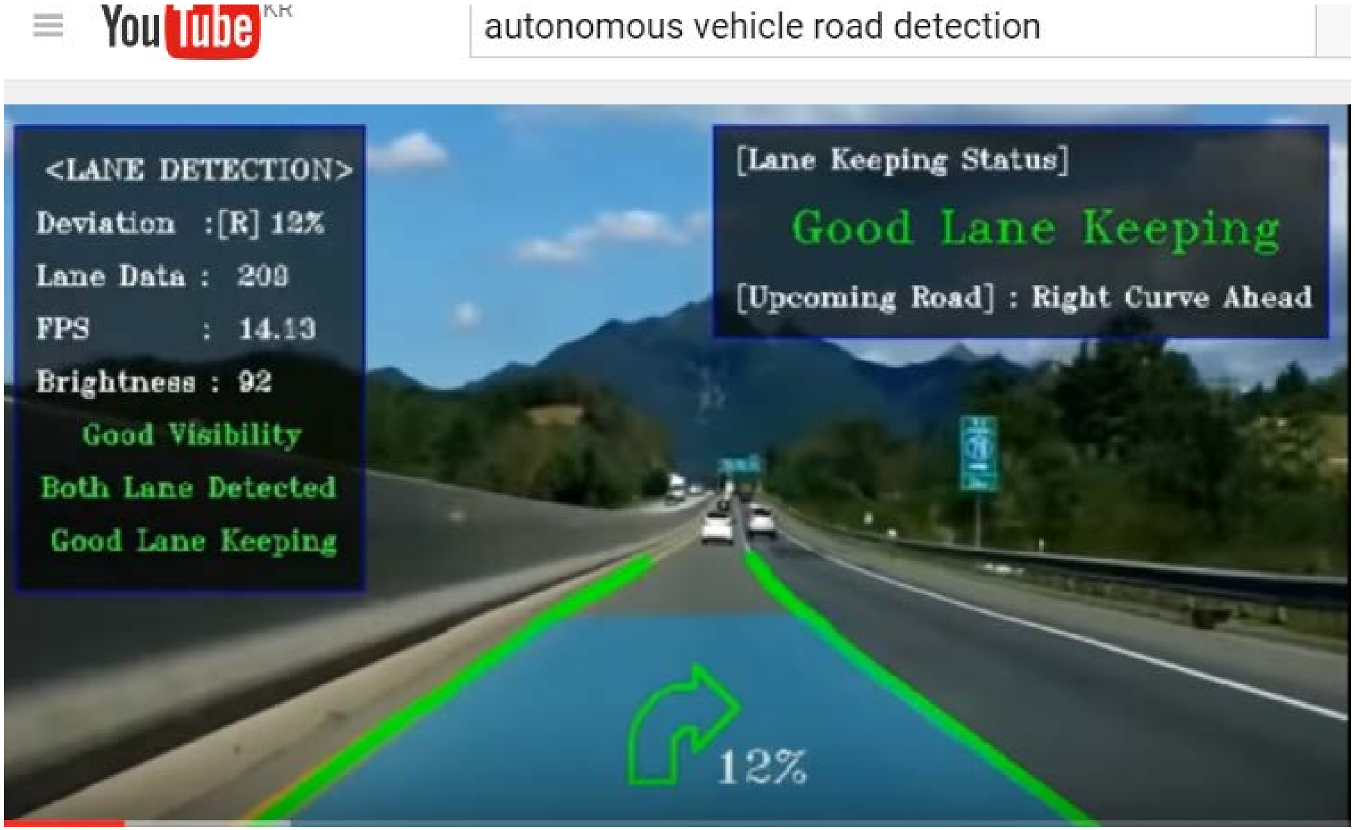
Courtesy of Prof. Dinesh Manocha

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

Motion of Real Robots

Robot-Assisted Radical Prostatectomy

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

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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

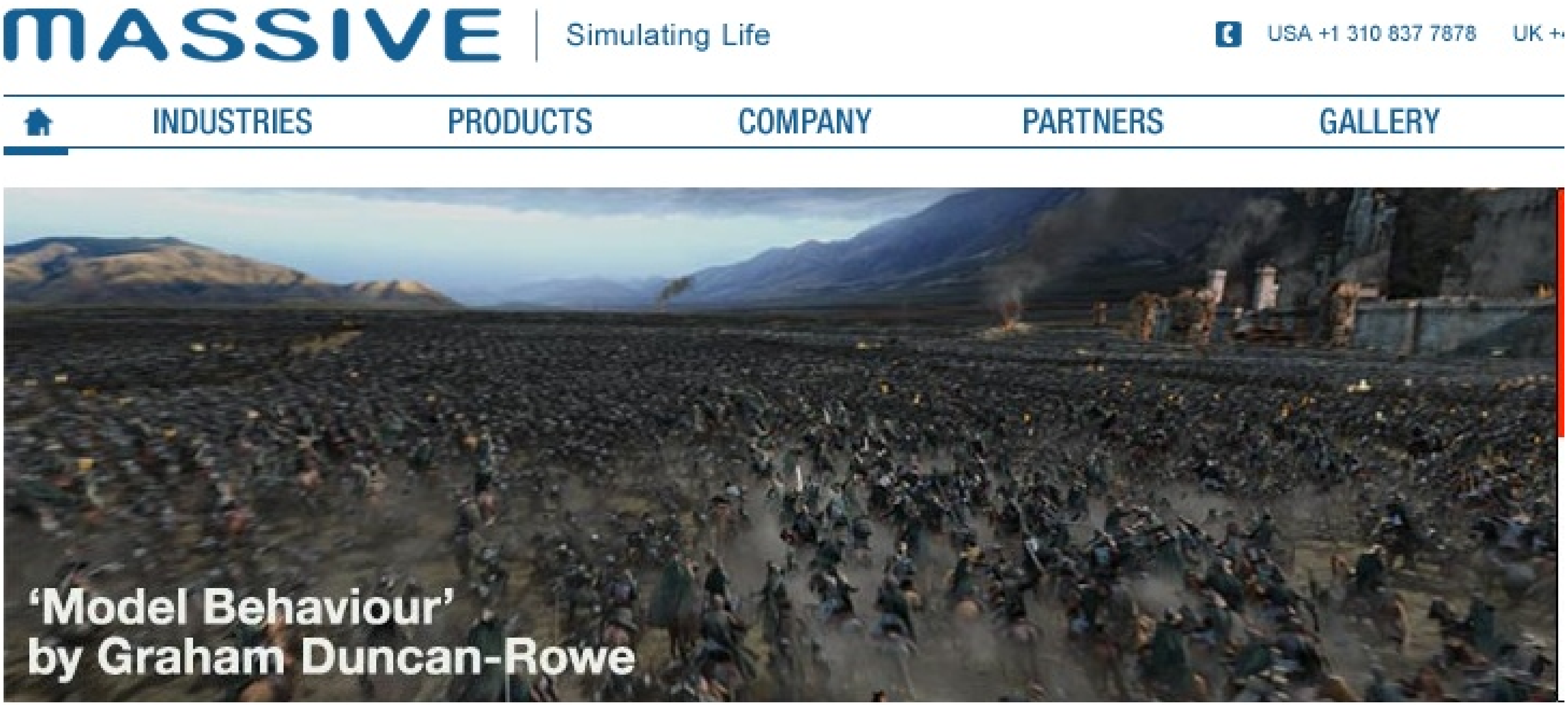
Motion of Virtual Worlds

Motion of Virtual Worlds

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

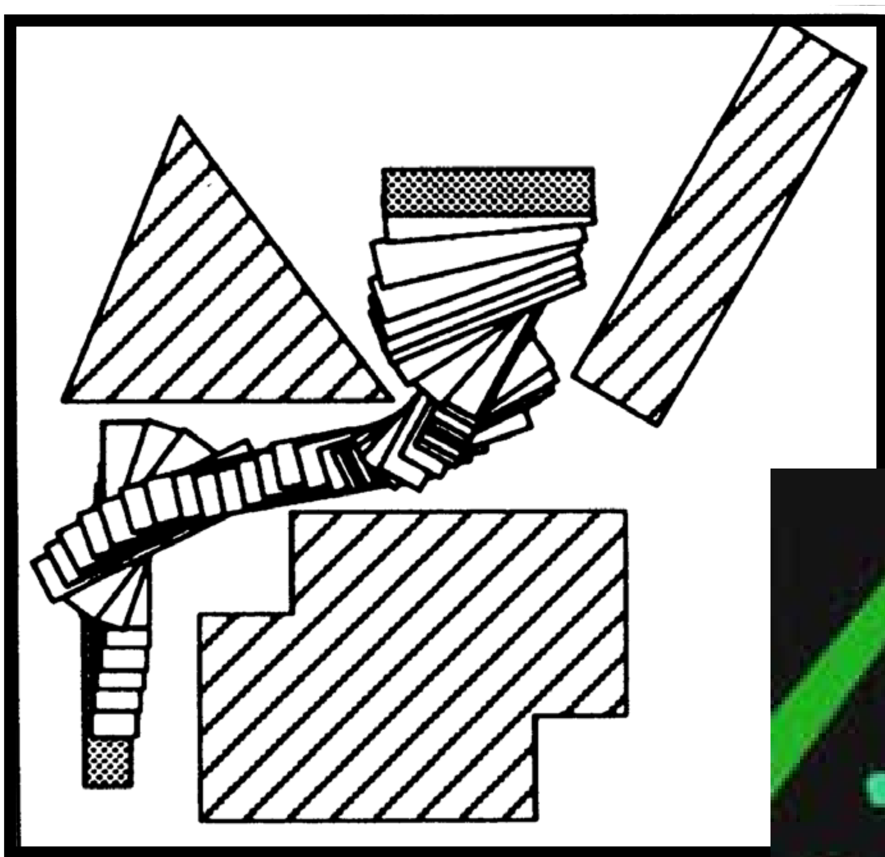
- Applications:
  - Manufacturing
  - Mobile robots
  - Computational biology
  - Computer-assisted surgery
  - Digital actors

Goal of Motion Planning

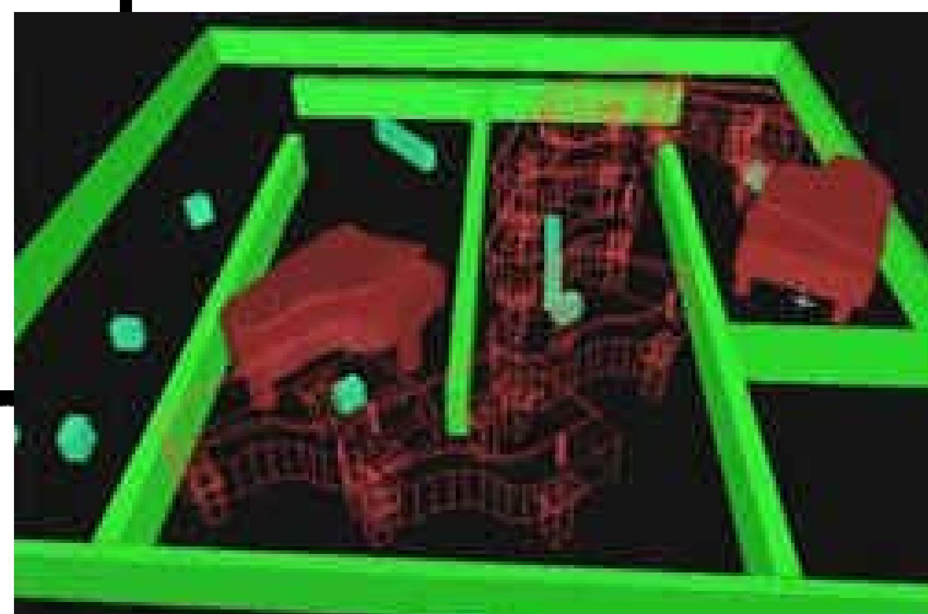
- Compute **motion strategies**, e.g.:
  - Geometric paths
  - Time-parameterized trajectories
  - Sequence of sensor-based motion commands
  - Aesthetic constraints

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

Examples with Rigid Object

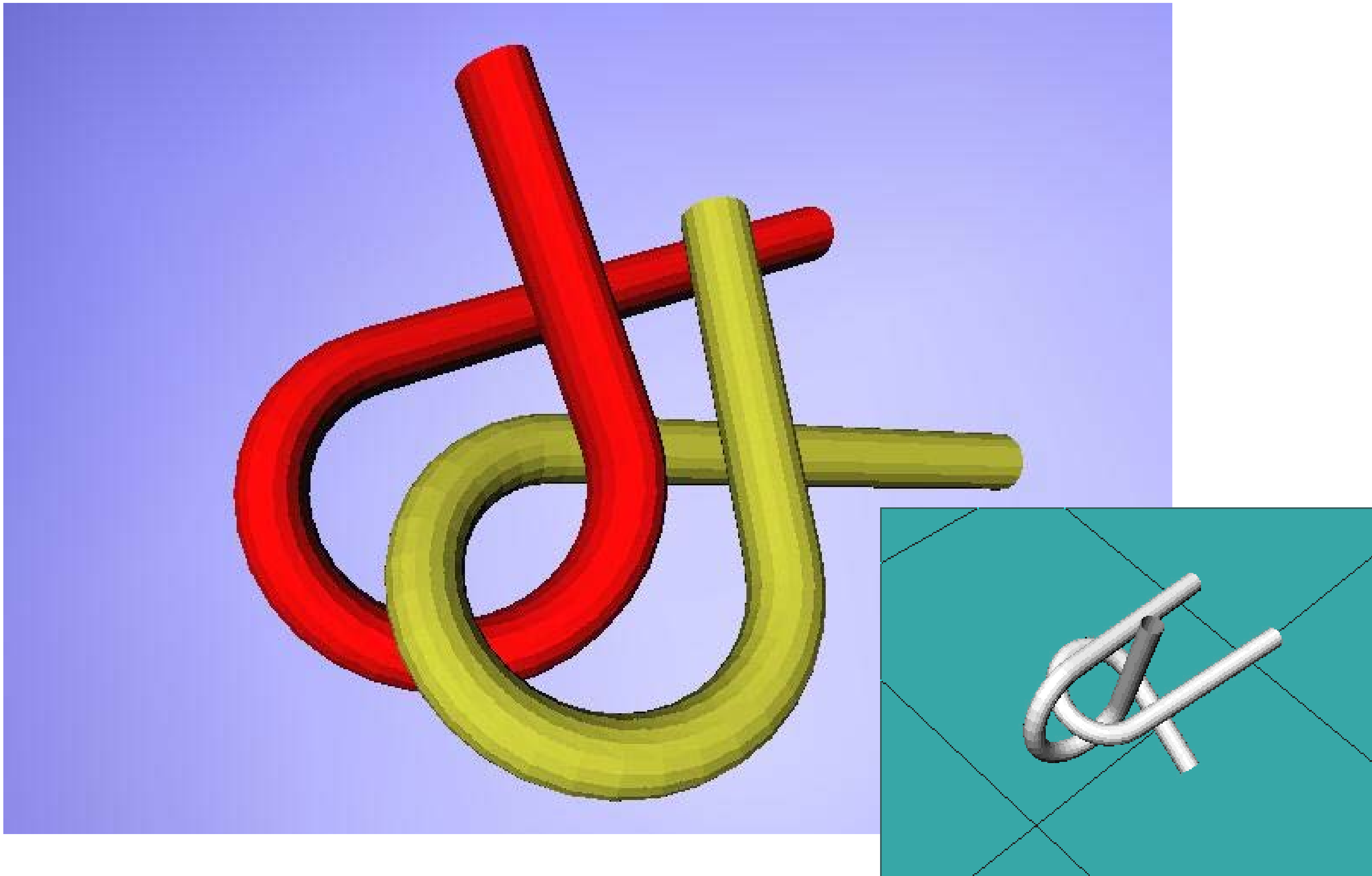


→ Ladder problem

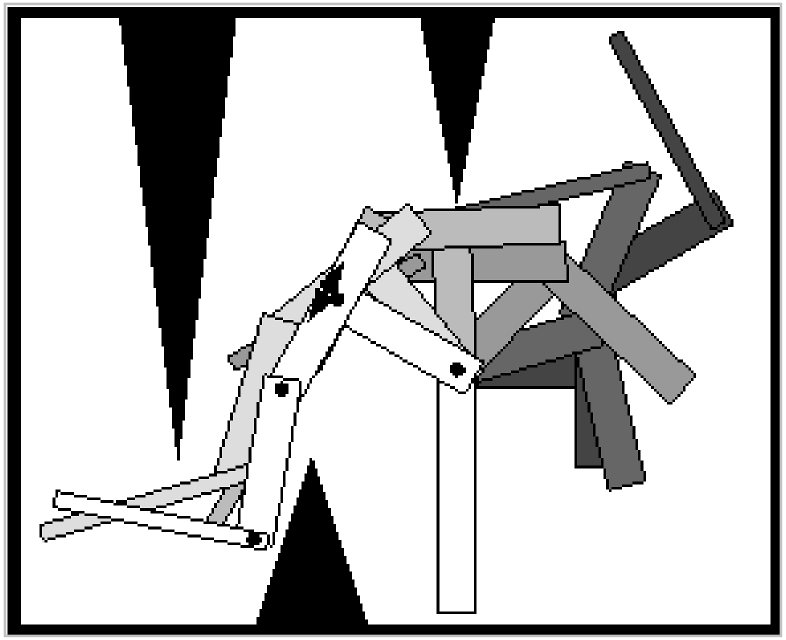


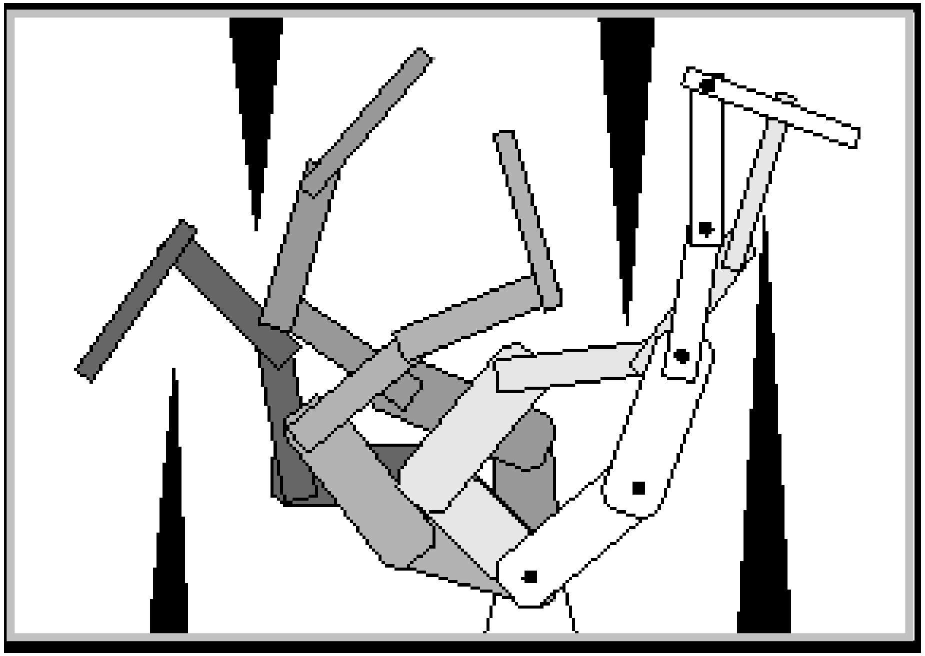
Piano-mover problem ←

Is It Easy?



Example with Articulated Object





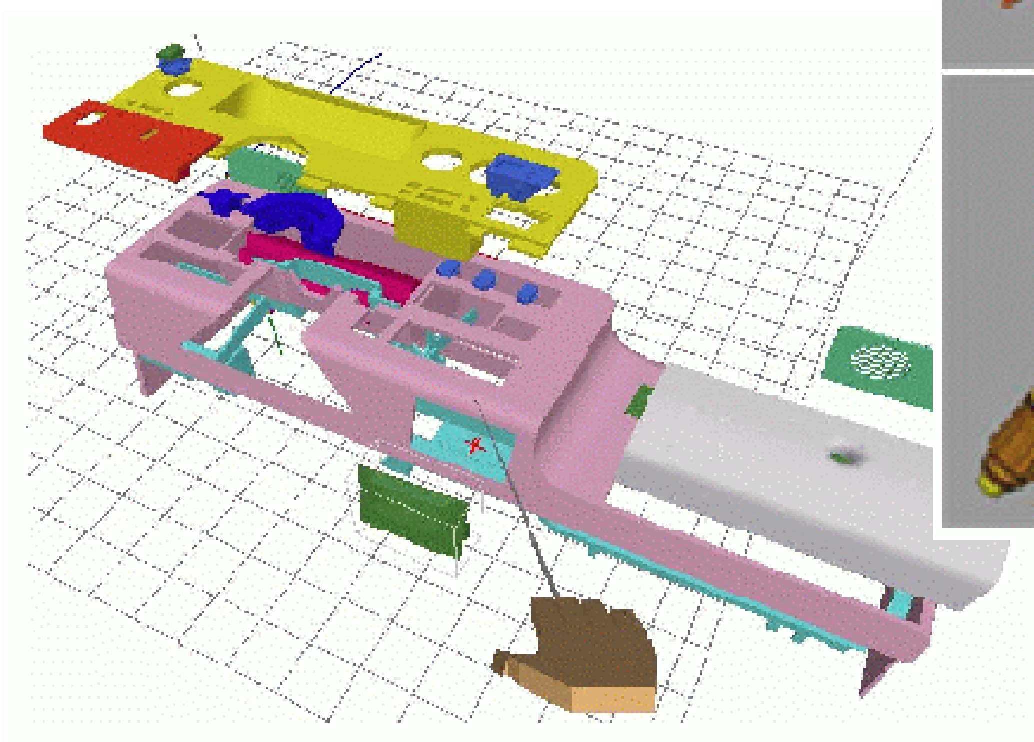
Some Extensions of Basic Problem

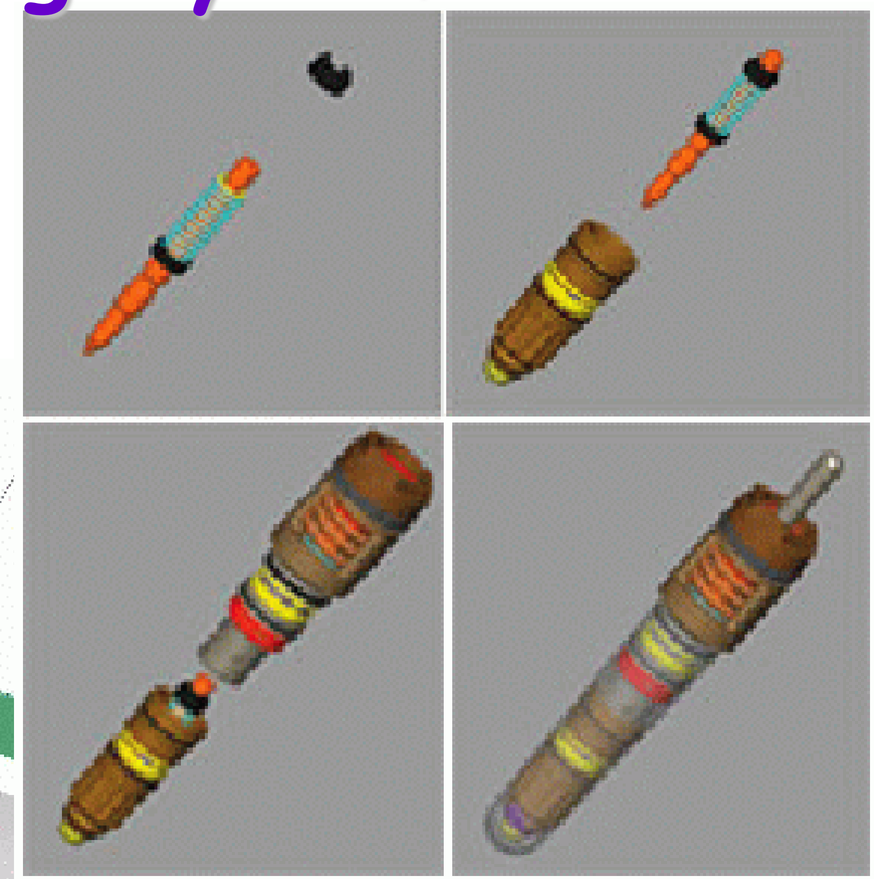
- Multiple robots
- Assembly planning
- Acquire information by sensing
  - Model building
  - Object finding / tracking
  - Inspection
- Nonholonomic constraints
- Dynamic constraints
- Stability constraints
- Optimal planning
- Uncertainty in model, control and sensing
- Exploiting task mechanics (sensorless motions, under-actualted systems)
- Physical models and deformable objects
- Integration of planning and control
- Integration with higher-level planning

Examples of Applications

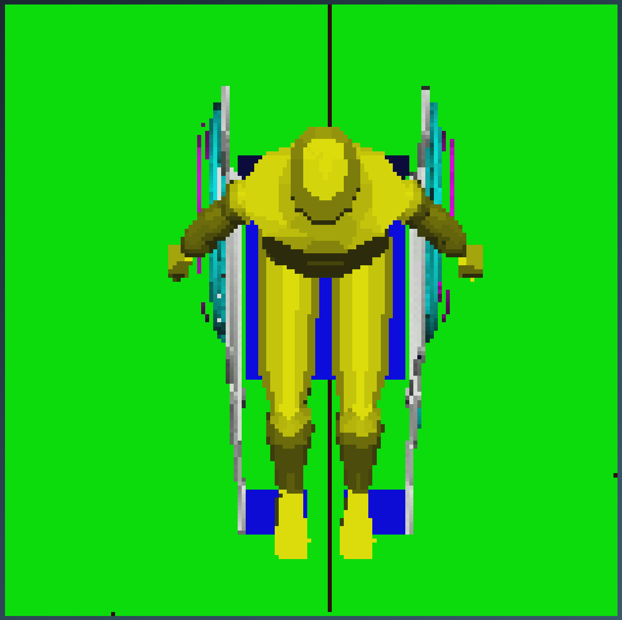
- Manufacturing:
  - Robot programming
  - Robot placement
  - Design of part feeders
- Design for manufacturing and servicing
- Design of pipe layouts and cable harnesses
- Autonomous mobile robots planetary exploration, surveillance, military scouting
- Graphic animation of “digital actors” for video games, movies, and webpages
- Virtual walkthrough
- Medical surgery planning
- Generation of plausible molecule motions, e.g., docking and folding motions
- Building code verification

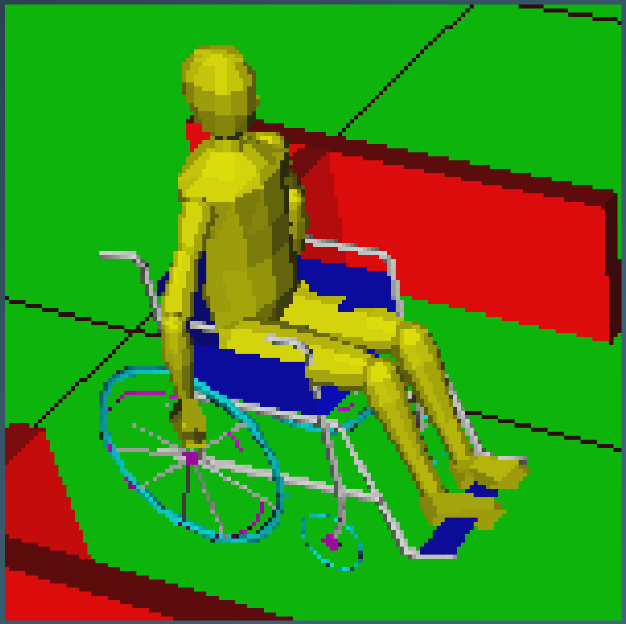
Assembly Planning and Design of Manufacturing Systems



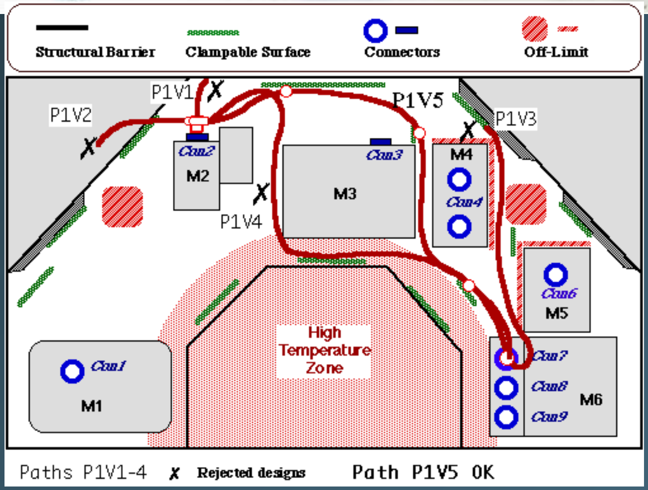


Application: Checking Building Code

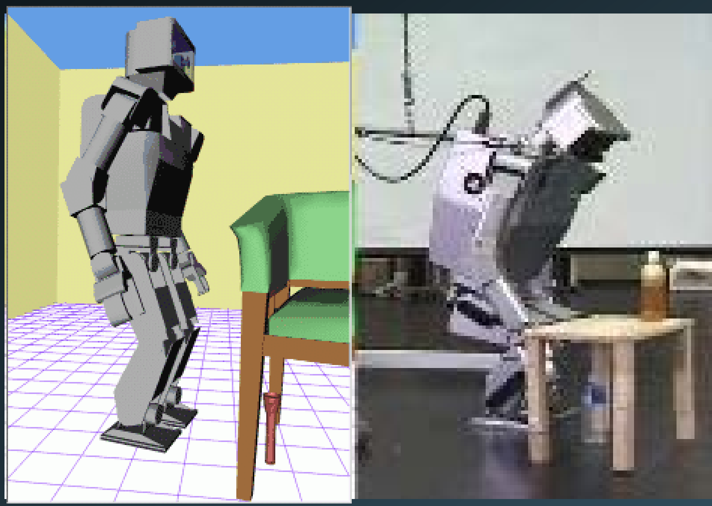


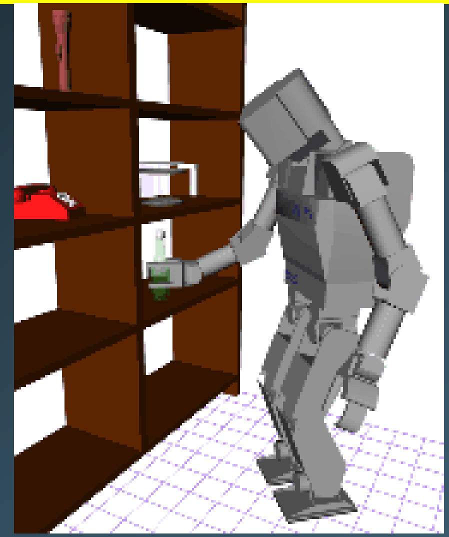


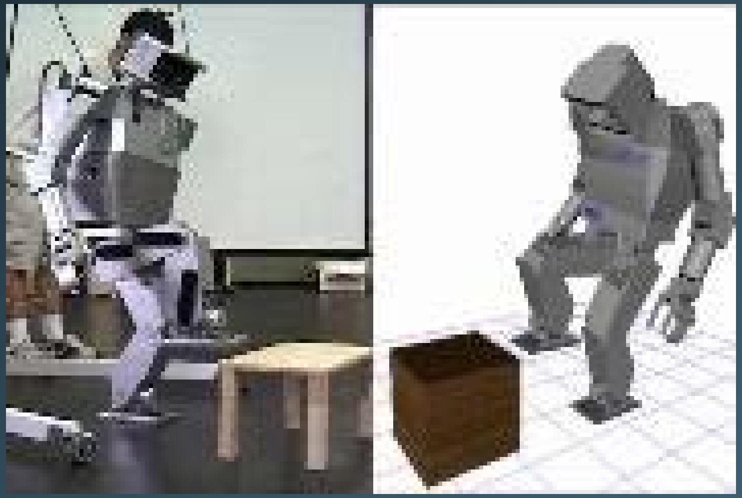
Cable Harness/ Pipe design



Humanoid Robot



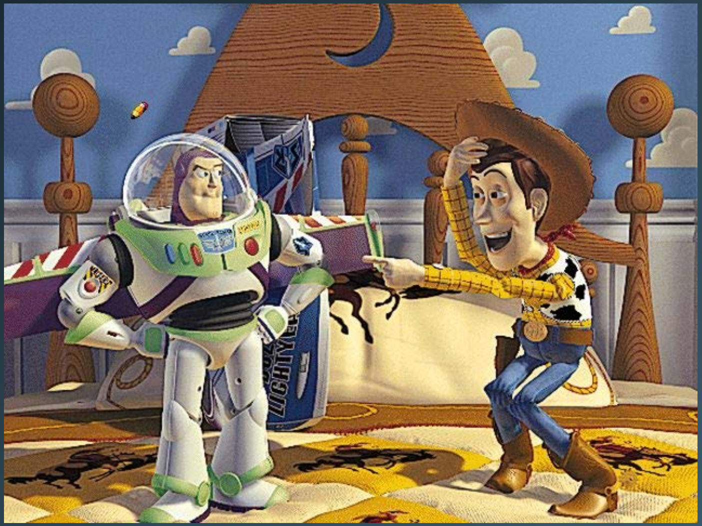




[Kuffner and Inoue, 2000] (U. Tokyo)

Digital Actors


A Bug's Life (Pixar/Disney)


Toy Story (Pixar/Disney)


Antz (Dreamworks)


Tomb Raider 3 (Eidos Interactive)

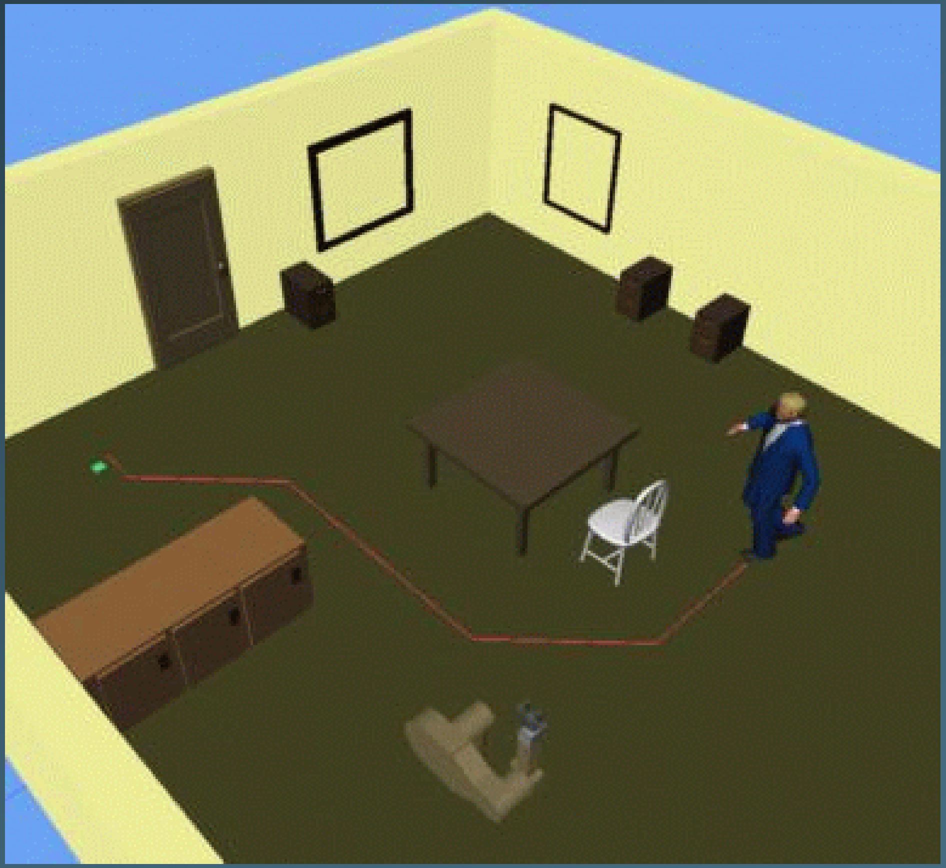
The Legend of Zelda (Nintendo)


Final Fantasy VIII (SquareOne)

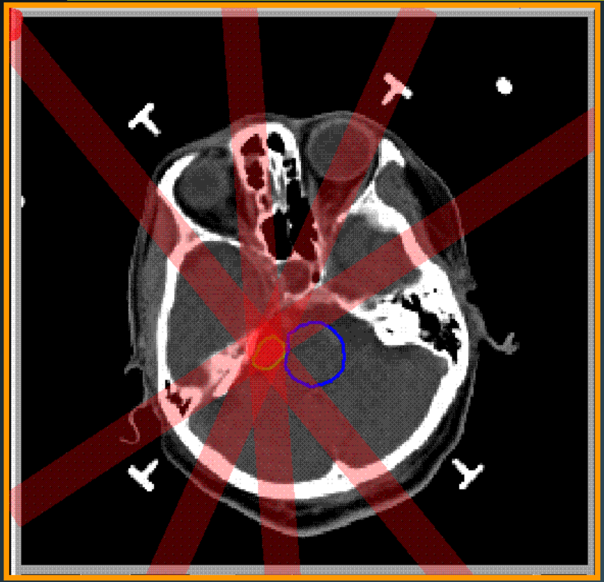
Motion Planning for Digital Actors

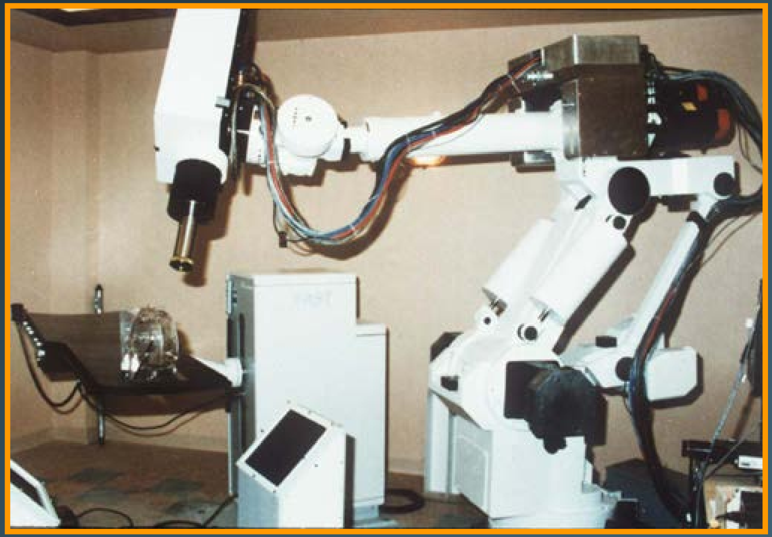
Manipulation

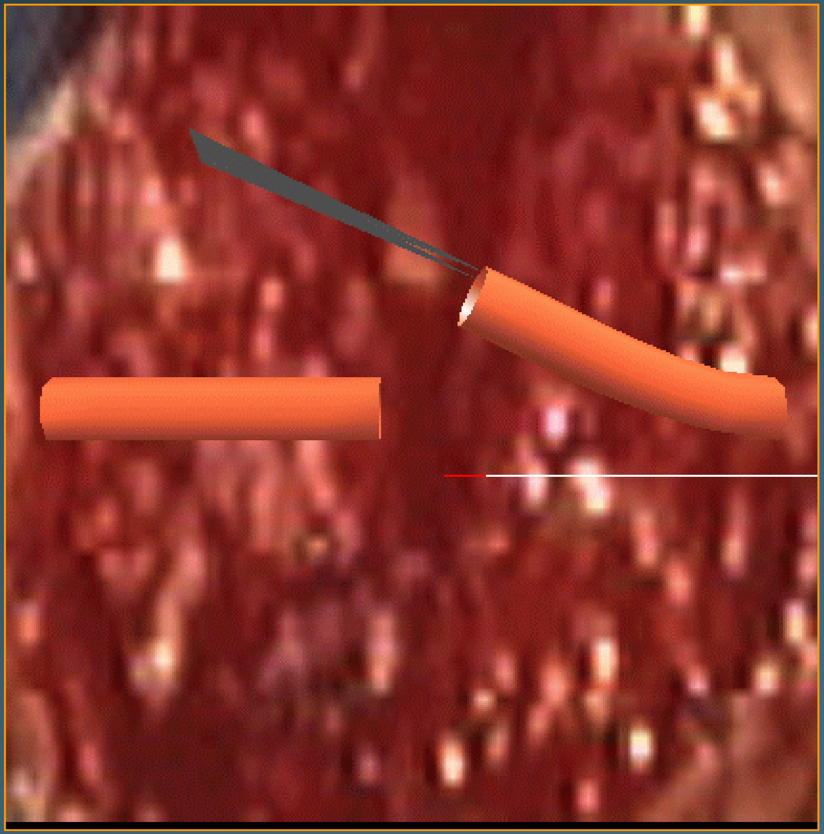
Sensory-based locomotion



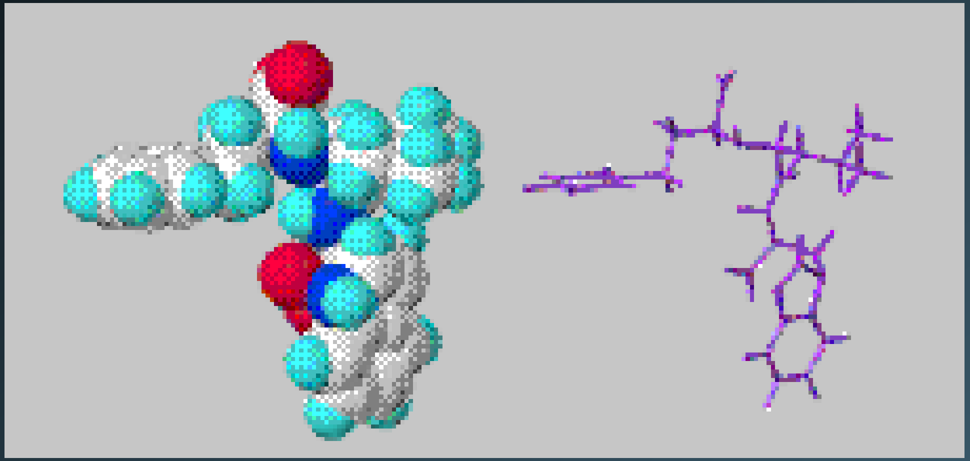
Application: Computer-Assisted Surgical Planning



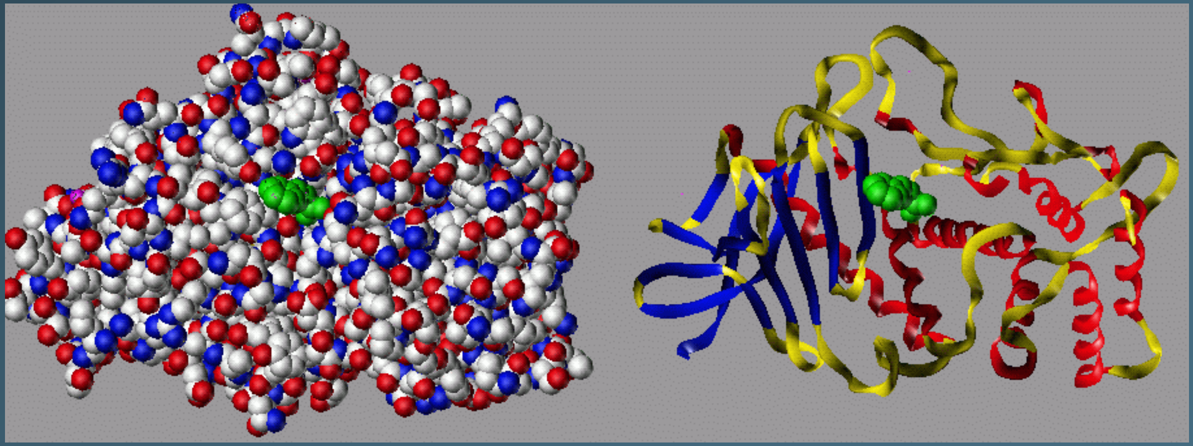




Study of the Motion of Bio-Molecules



- 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

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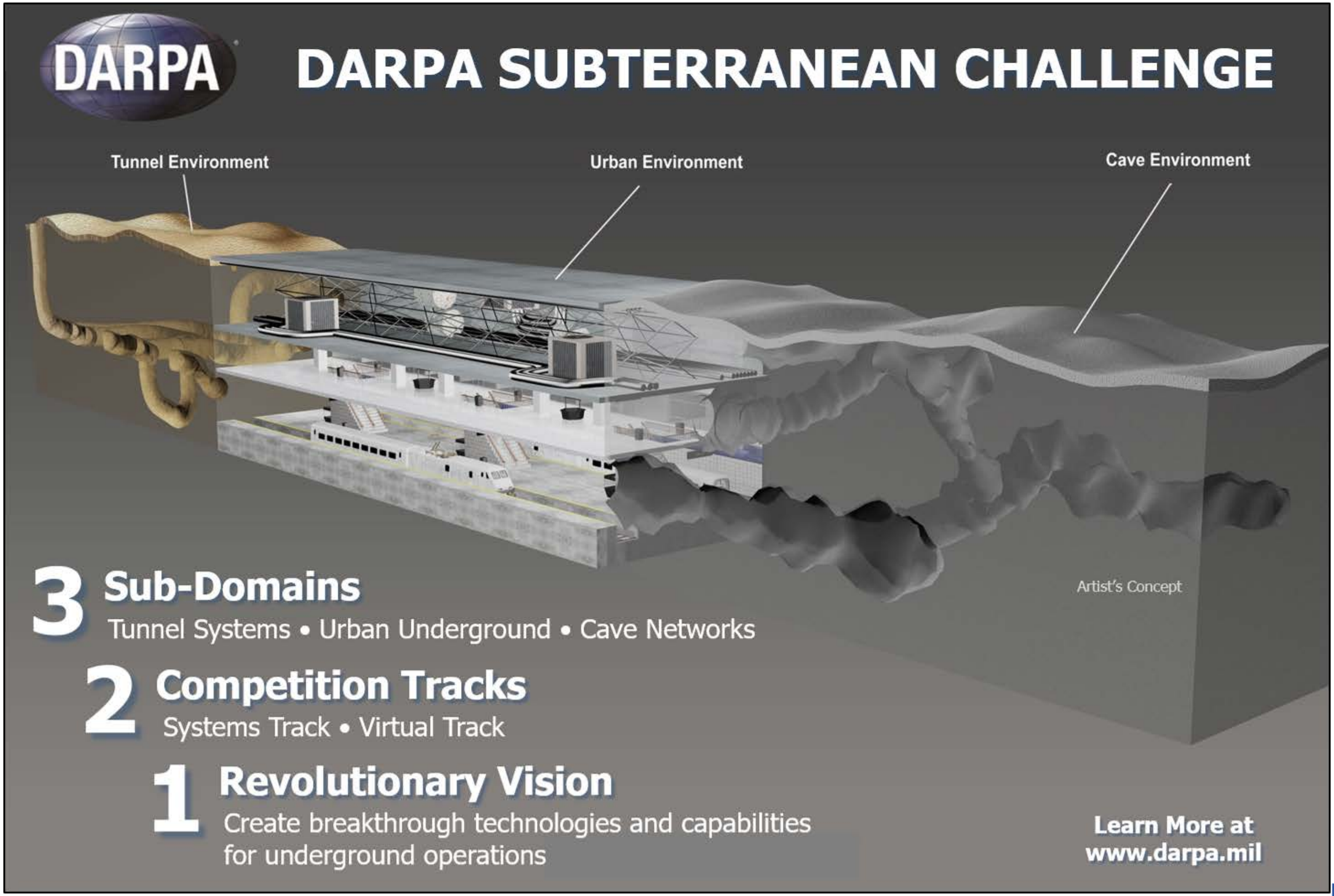
Still many research going on at 2019 !!!



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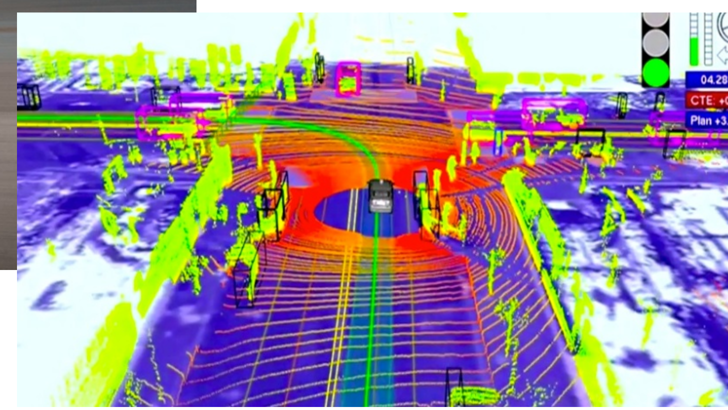
Google Self-Driving Vehicles



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 related to robotics, this course may be 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**
- **Classical motion planning algorithms:**
  - **Complete motion planning**
  - **Randomized approaches**
- **Sampling based and optimization based approaches**
- **Briefly on learning based approaches**

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

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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**
  - **Lunch or dinner for awardees with me and TAs**

- **A high grade will be given to members of the best project**

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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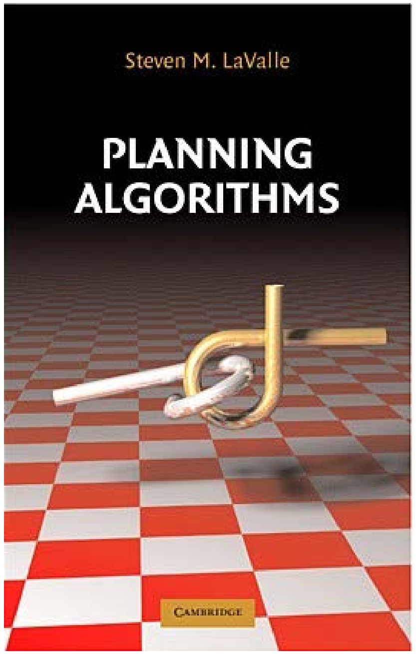
Resource

- Textbook
  - Planning Algorithms, Steven M. LaValle, 2006 (http://msl.cs.uiuc.edu/planning/)
  - My own draft (not well established yet)
- 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)
  - Conf. on Robot Learning (CoRL)



Other Reference

- Vision-related conference (CVPR, ICCV)
  - http://openaccess.thecvf.com/menu.py
- Graphics-related conference (SIGGRAPH, etc)
  - http://kesen.huang.googlepages.com/

- Google or Google scholar
- UDACITY course:
  - Artificial Intelligence for Robotics

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**

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

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Homework

- Browse 2 top-tier conf. / journal papers
  - Prepare two summaries, and submit it online before the Tue. Class
  - See the submission site at the course homepage

- Example of a summary (just a paragraph)

Title: XXX XXXX XXXX
Conf./Journal Name: ICRA, 2019
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**
  - **1 for typical questions**
  - **2 for questions with thoughts or that surprised me**

- **Write a question at least 3 times before the mid-term exam**
  - **Online submission is available at the course webpage**

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

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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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About You

- **Name**
- **What is your major?**

- **Previous experience on motion planning and robotics**