CS686:
Robot Motion Planning and Applications

Sung-Eui Yoon
(윤성의)

Course URL:
http://sgvr.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://sgvr.kaist.ac.kr/papers.htm**
  - **YouTube videos: http://www.youtube.com/user/sglabkaist**

Research Theme: Intelligent Ray Tracing, Image Search, Motion Planning

- **Designing *intelligent and scalable techniques* to efficiently handle massive models on commodity hardware or clouds**

Photo-realistic rendering

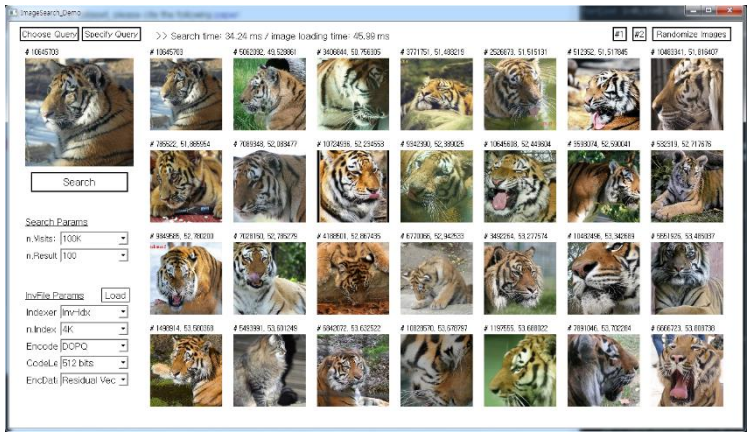

Image search

Motion planning

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Some Achievement

- **Tutorials/Workshop in international conf.**
  - **Workshop on sound source localization at ICRA**
  - **Tutorial on collision detection at SIGGRAPH**
- **차세대 과학자상(IT부문), 2019**
  - **한림원, S-OIL**

- **Best paper award**
  - **Outstanding planning paper award, ICRA 2023**
  - **Test-Of-Time 2006 Award at High Performance Graphics, 2015**
  - **Distinguished paper award at Pacific Graphics 2009**

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Welcome to CS686

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

Class time: 10:30am – 11:45pm on MW
Office hours: Right after class
Course webpage:
http://sgvr.kaist.ac.kr/~sungeui/MPA

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TA

Min-Sung Yoon

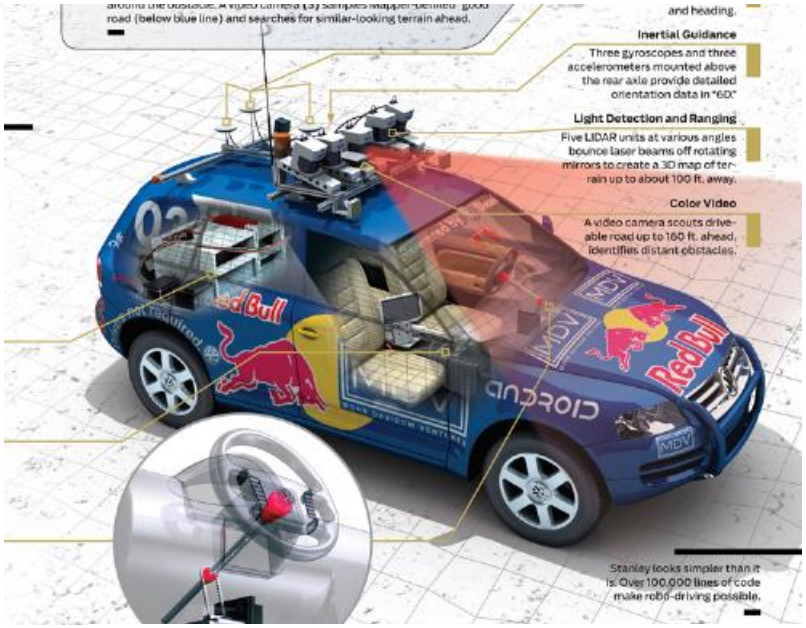
- **Ph.D. student working on RL, task and motion planning**
- **Use KLMS board for communication**
- **E3-1, 3446**

Additional TA for Edu 3.0?

Real World Robots

ASIMO

Sony Aibo



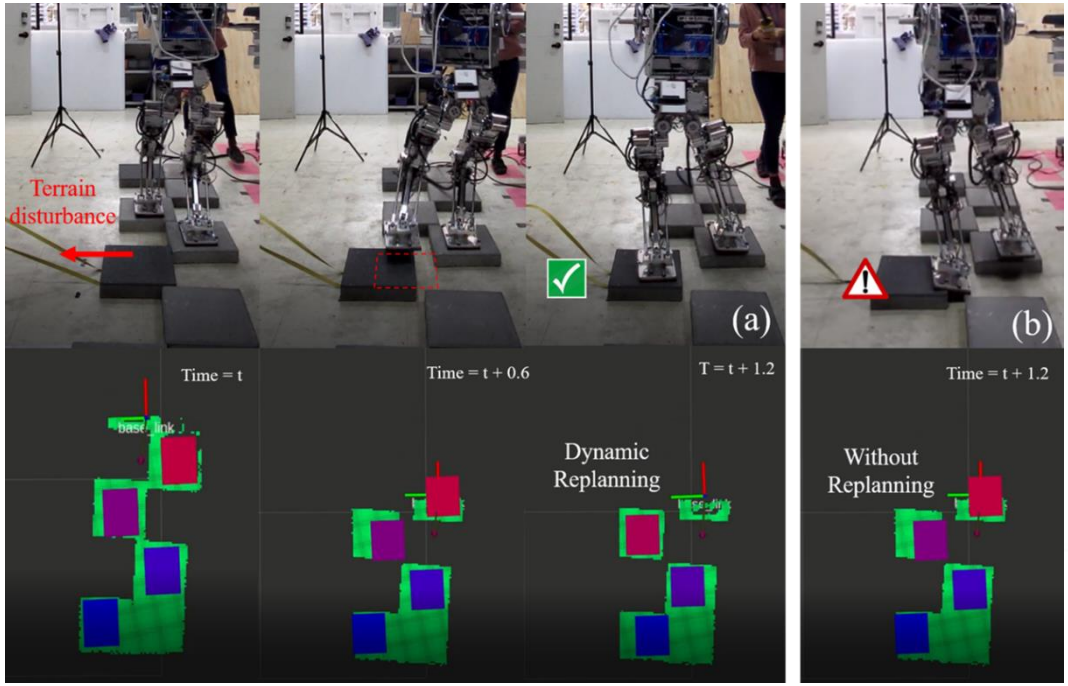
Courtesy of Prof. Dinesh Manocha

Da Vinci

Motion of Real Robots

- **DRC final winner at 2016**

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



- **Dynamic humanoid locomotion, IROS 21**

https://sgvr.kaist.ac.kr/~yskwon/papers/iros21-dynamic-locomotion/

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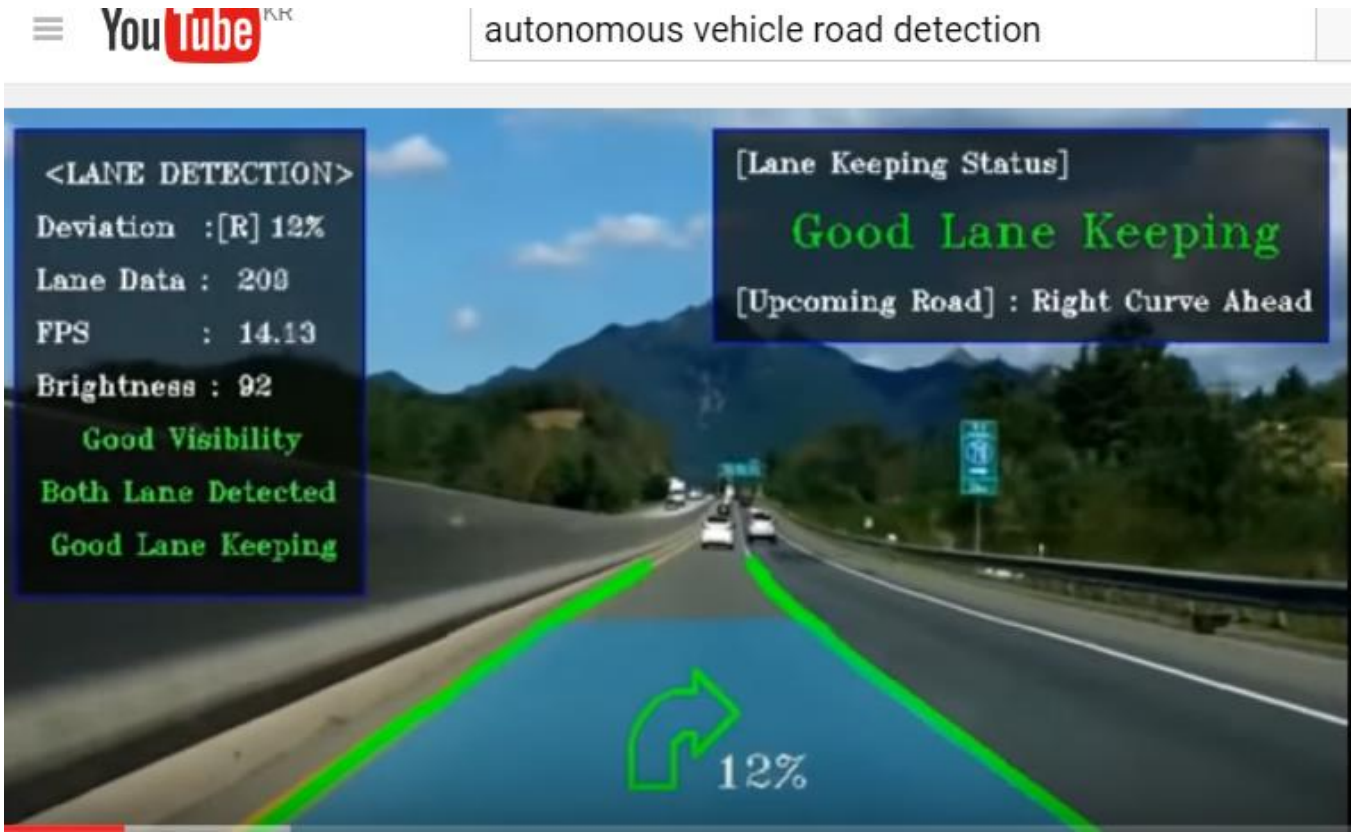
Motion of Real Robots



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

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TurtleBot

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

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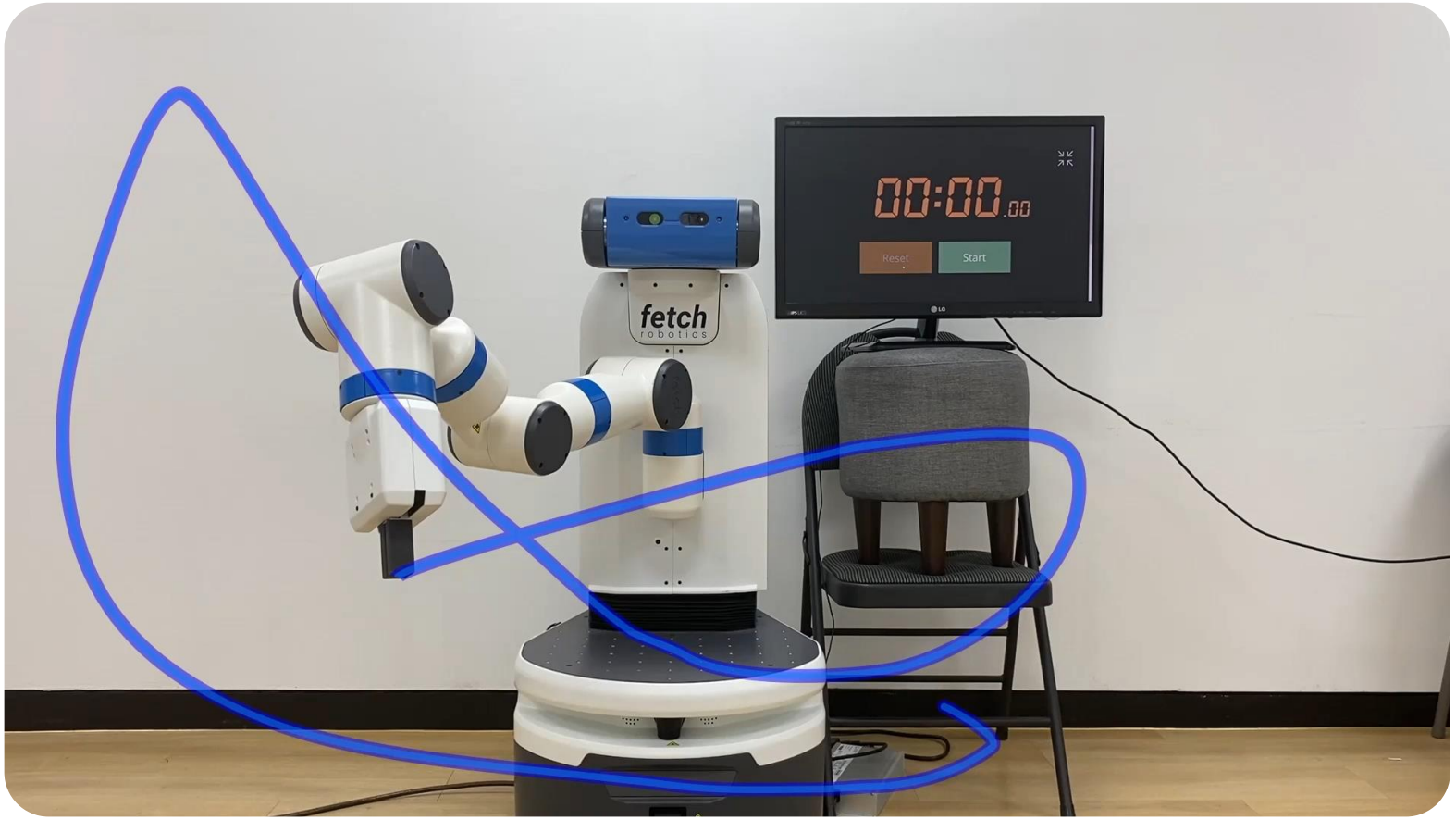
Redundant Manipulator

- **Fetch robot**



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Motion of Virtual Worlds

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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/

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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**

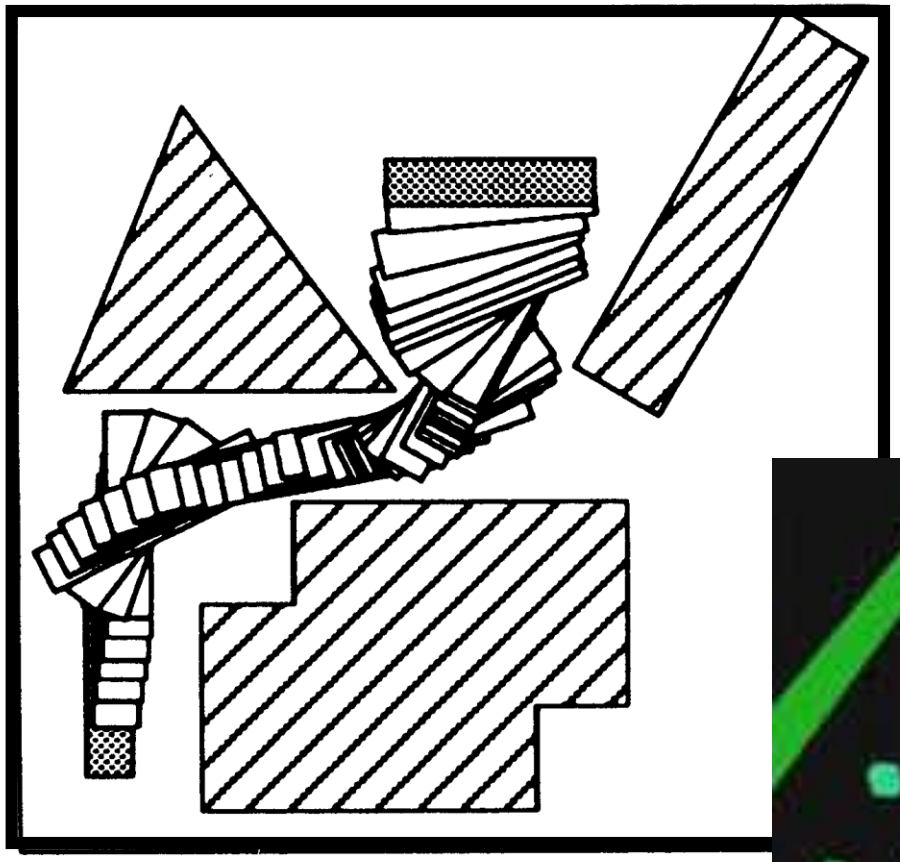
- **Applications:**
  - **Manufacturing**
  - **Mobile robots**
  - **Computational biology**
  - **Computer-assisted surgery**
  - **Digital actors**

Goal of Motion Planning

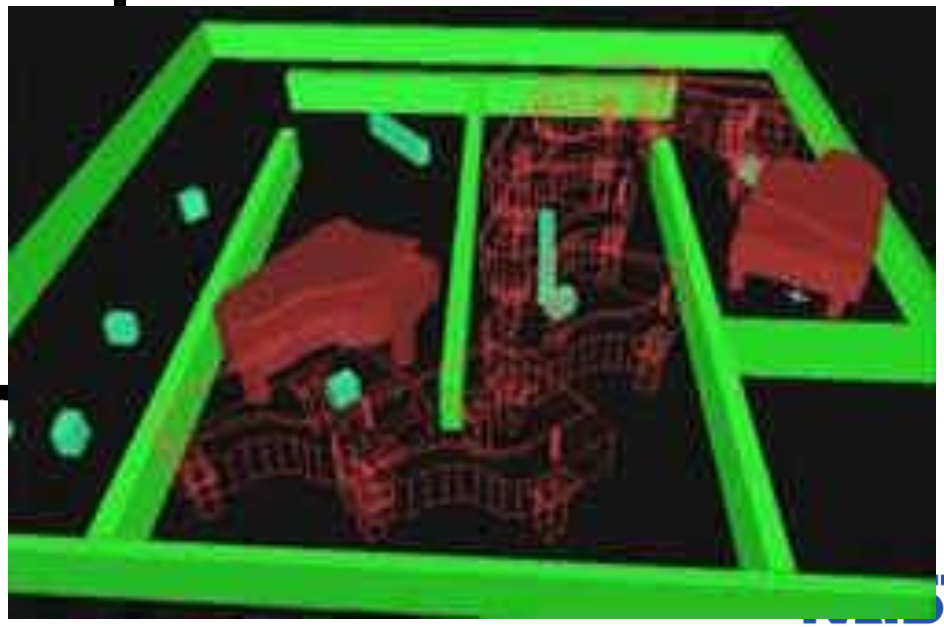
- **Compute motion strategies, e.g.:**
  - **Geometric paths**
  - **Time-parameterized trajectories**
  - **Sequence of sensor-based motion commands**
  - **Aesthetic constraints**

- **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

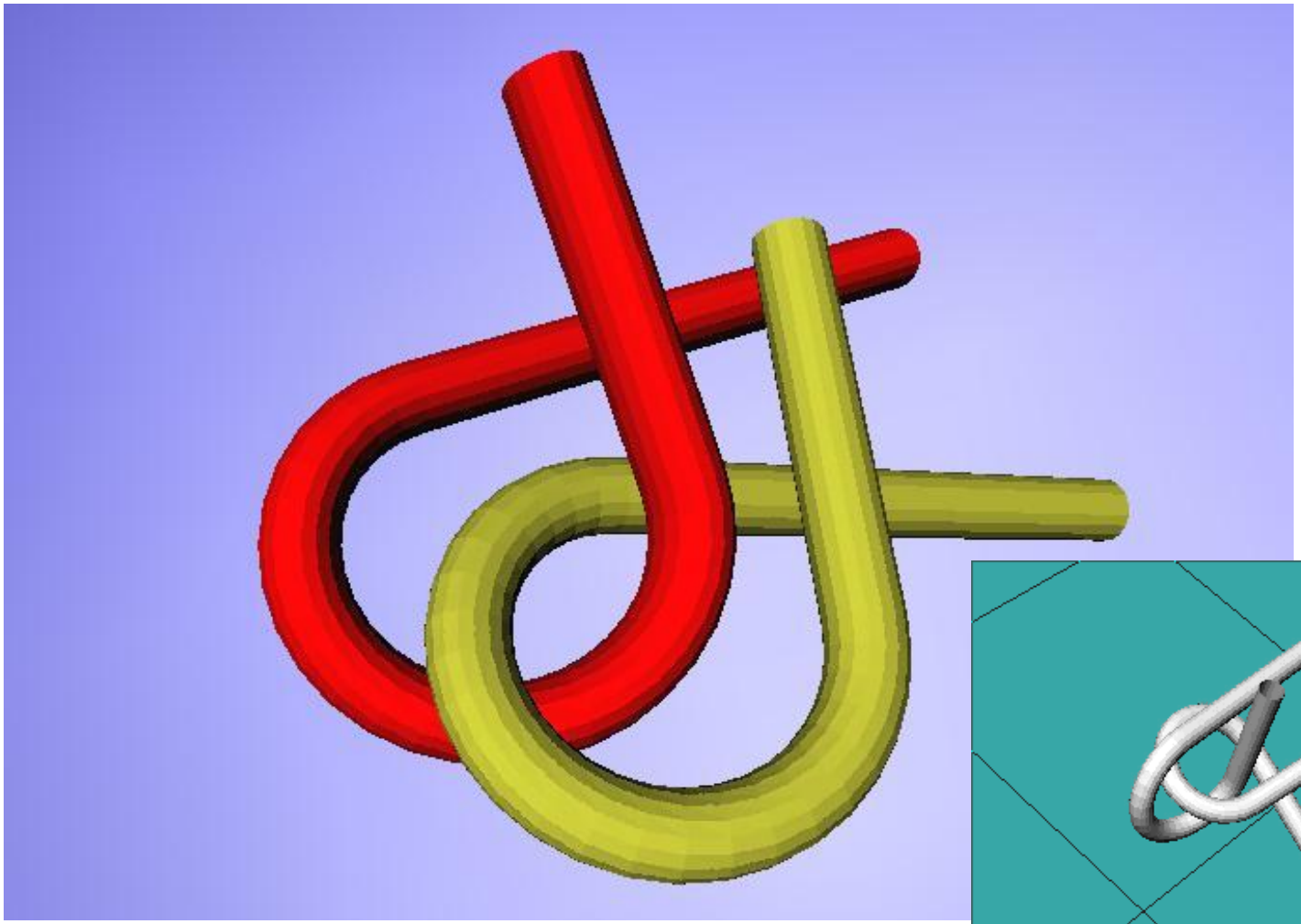


→ Ladder problem

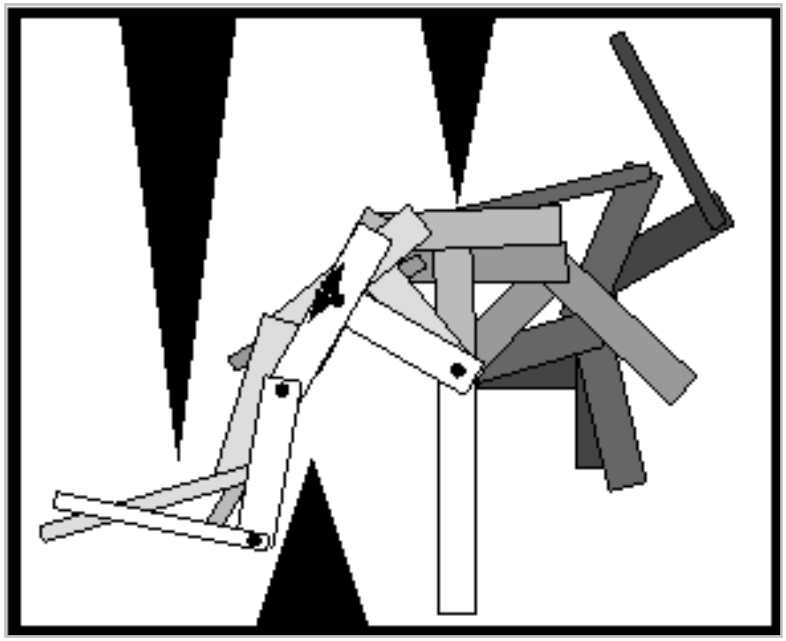


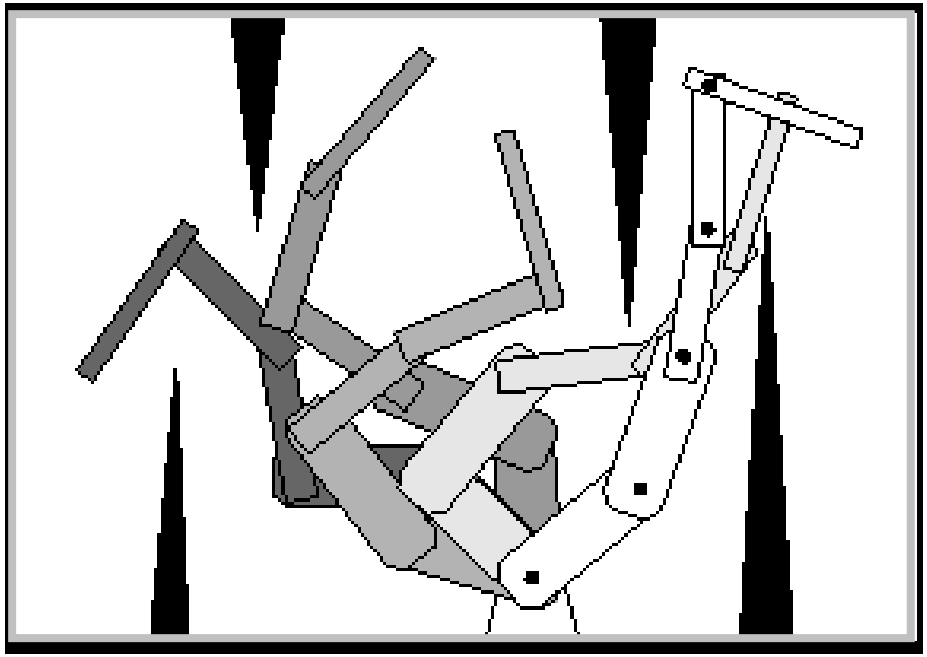
Piano-mover problem ←

Is It Easy?



Example with Articulated Object





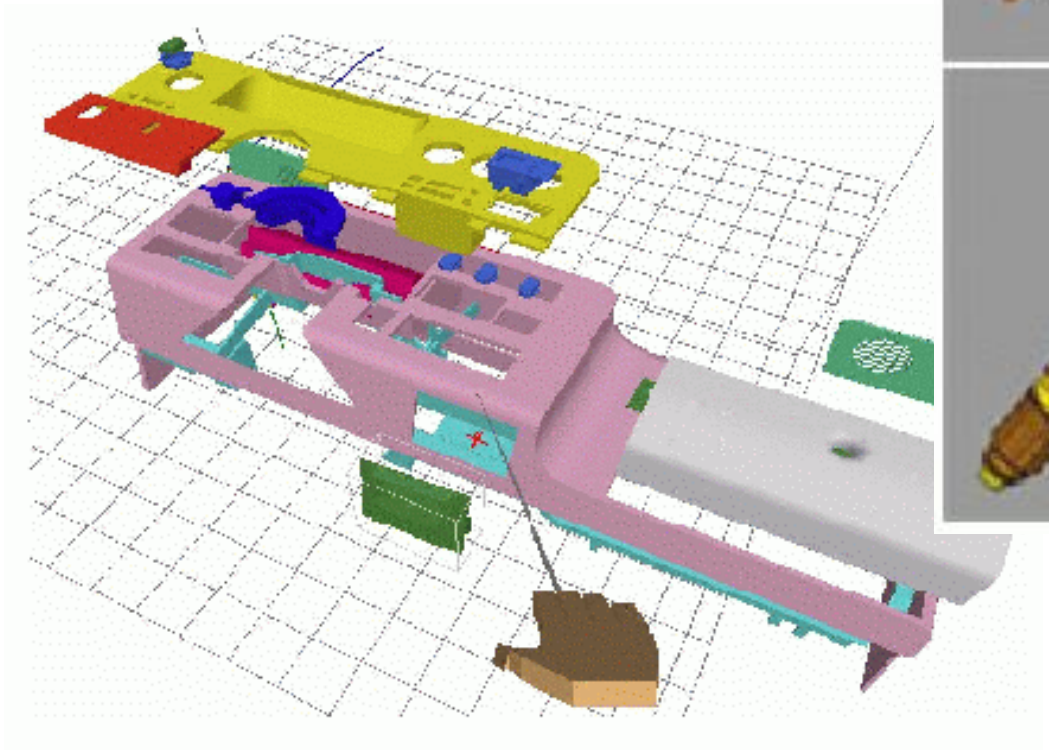
Some Extensions of Basic Problem

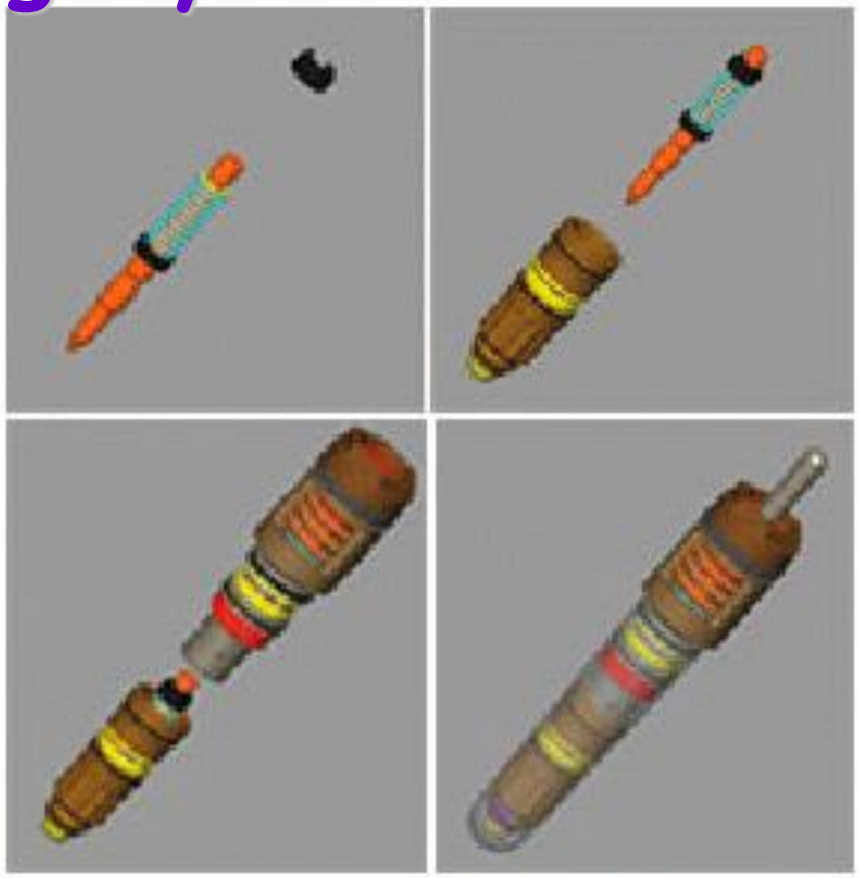
- Multiple robots
- Assembly planning
- Acquire information by sensing
  - Model building
  - Object finding/tracking
  - Inspection
- Nonholonomic constraints
- Dynamic constraints
- Stability constraints
- Optimal planning
- Uncertainty in model, control and sensing
- Exploiting task mechanics (sensorless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

Examples of Applications

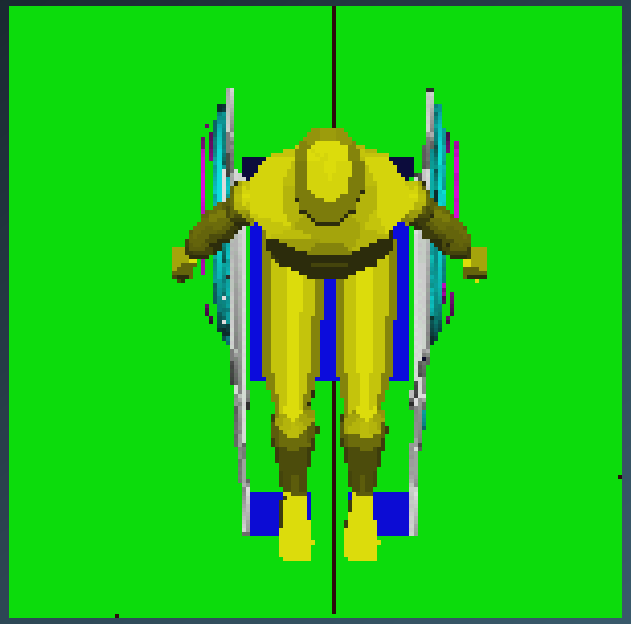
- **Manufacturing:**
  - **Robot programming**
  - **Robot placement**
  - **Design of part feeders**
- **Design for manufacturing and servicing**
- **Design of pipe layouts and cable harnesses**
- **Autonomous mobile robots planetary exploration, surveillance, military scouting**
- **Graphic animation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

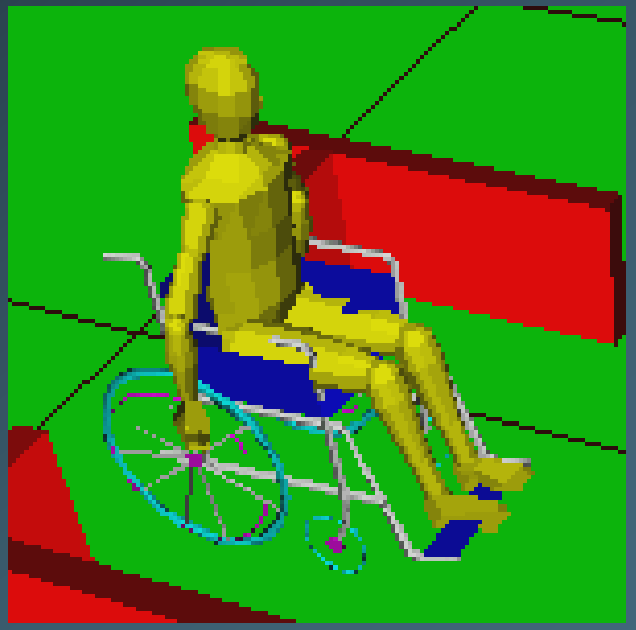
Assembly Planning and Design of Manufacturing Systems



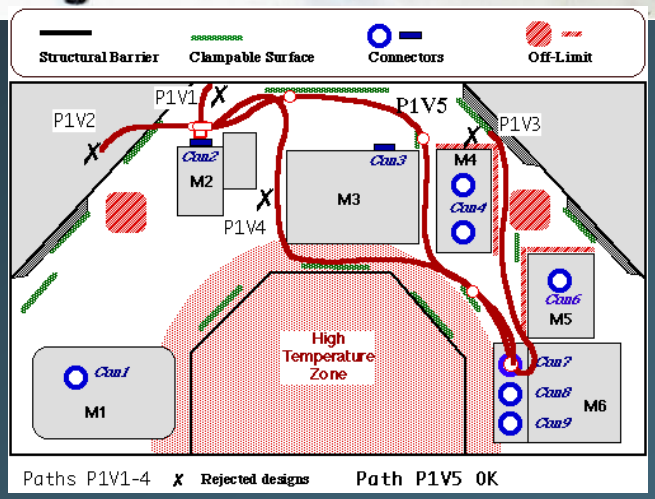


Application: Checking Building Code

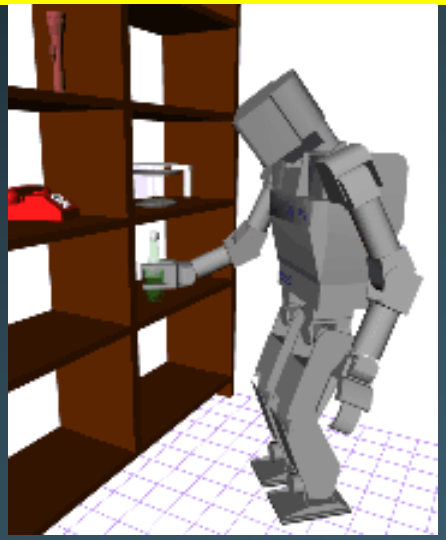


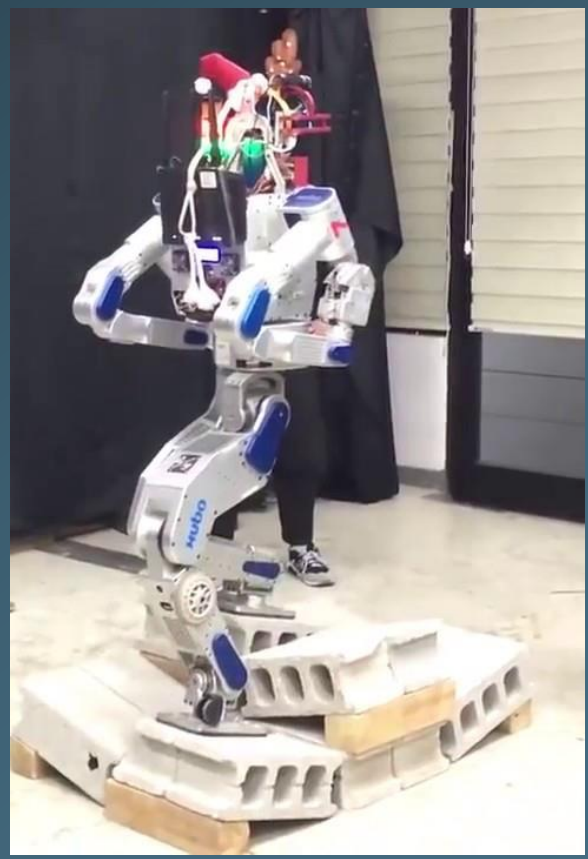


Cable Harness/ Pipe design



Humanoid Robot

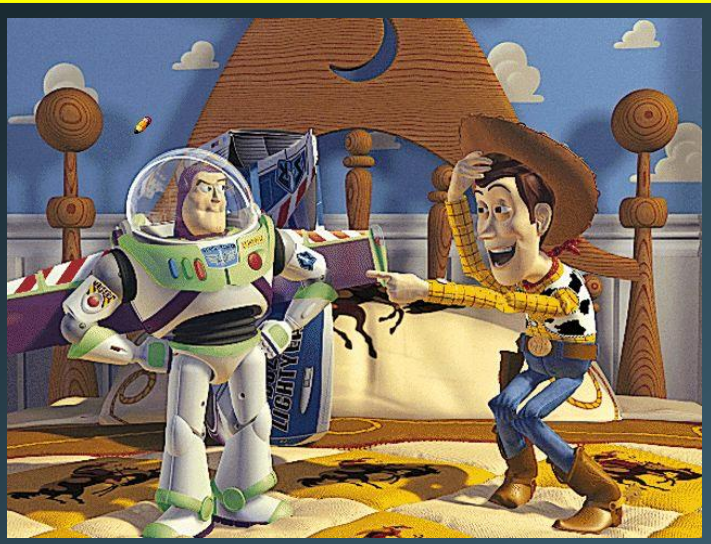




[Kuffner and Inoue, 2000] (U. Tokyo)

Digital Actors

A Bug's Life (Pixar/Disney)



Toy Story (Pixar/Disney)

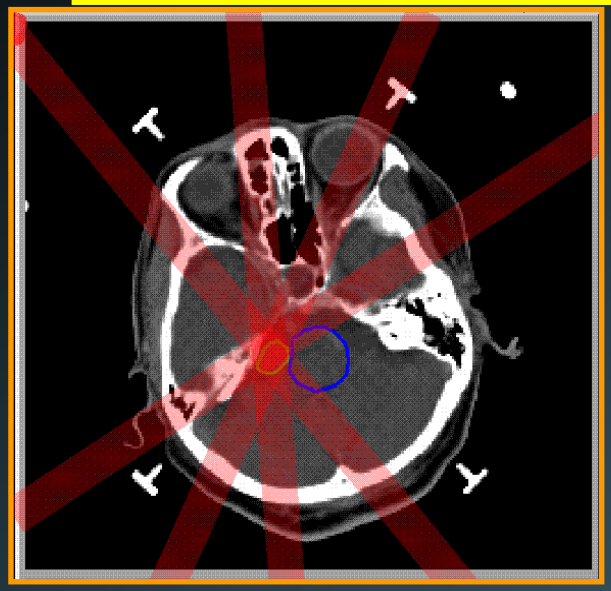
Antz (Dreamworks)

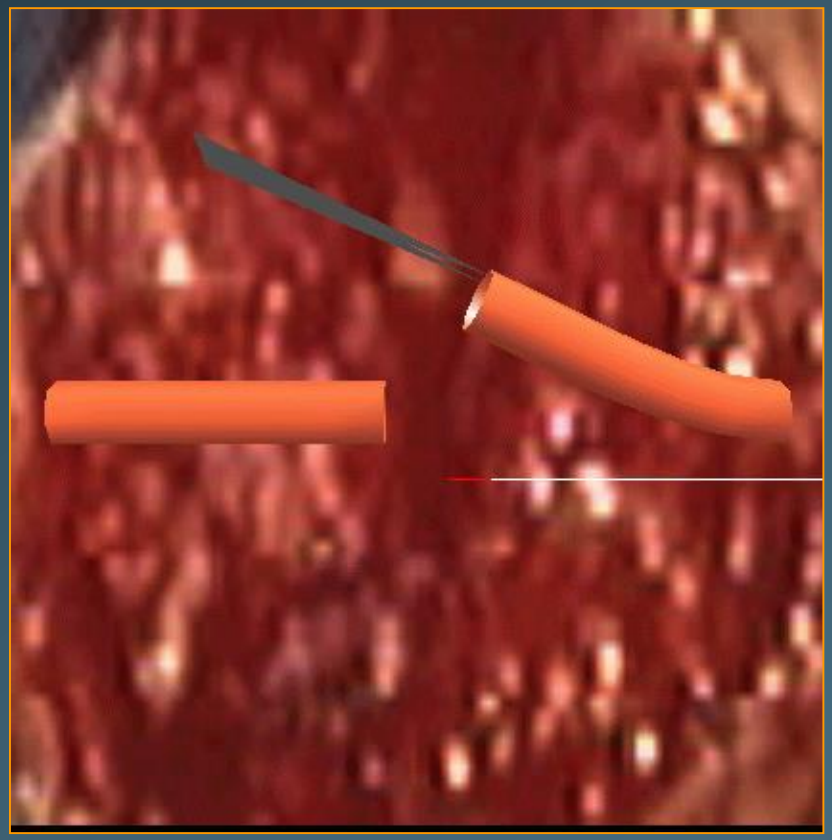
Tomb Raider 3 (Eidos Interactive)

The Legend of Zelda (Nintendo)

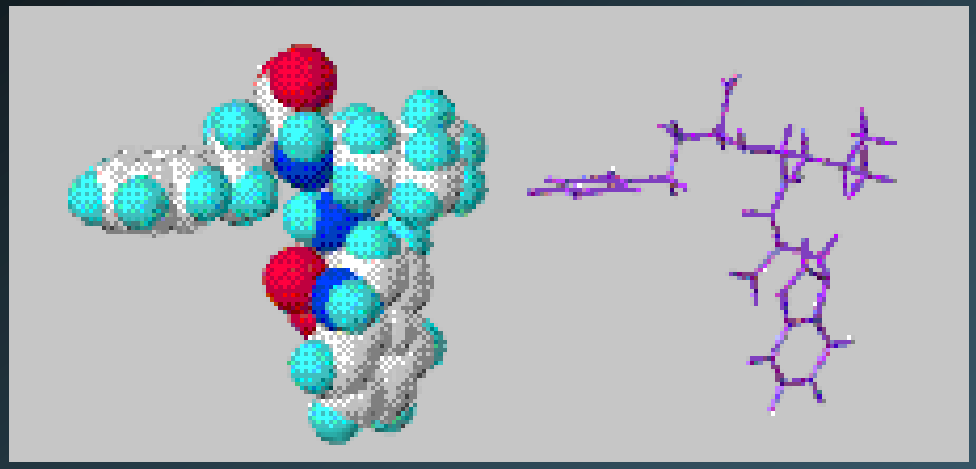
Final Fantasy VIII (SquareOne)

Application: Computer-Assisted Surgical Planning

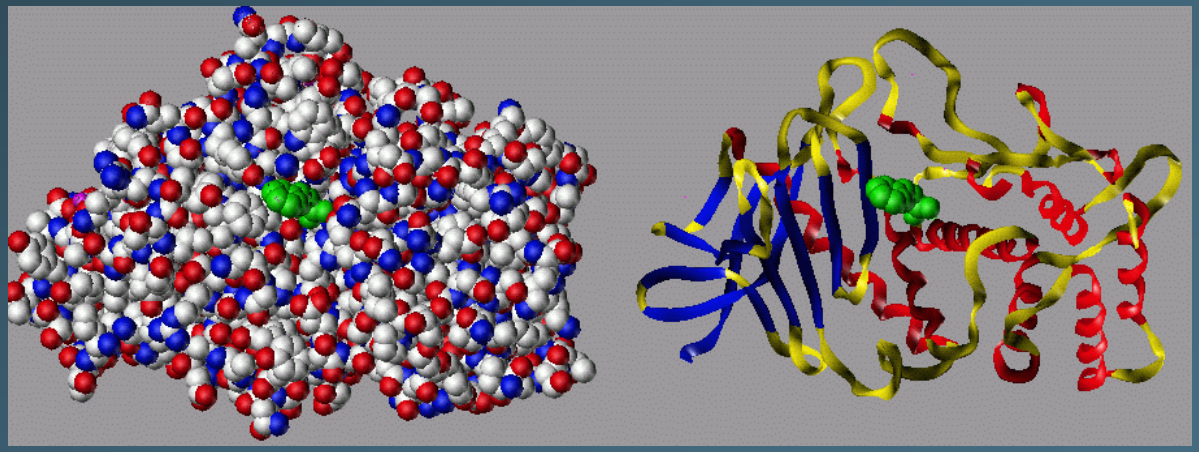




Study of the Motion of Bio-Molecules



- 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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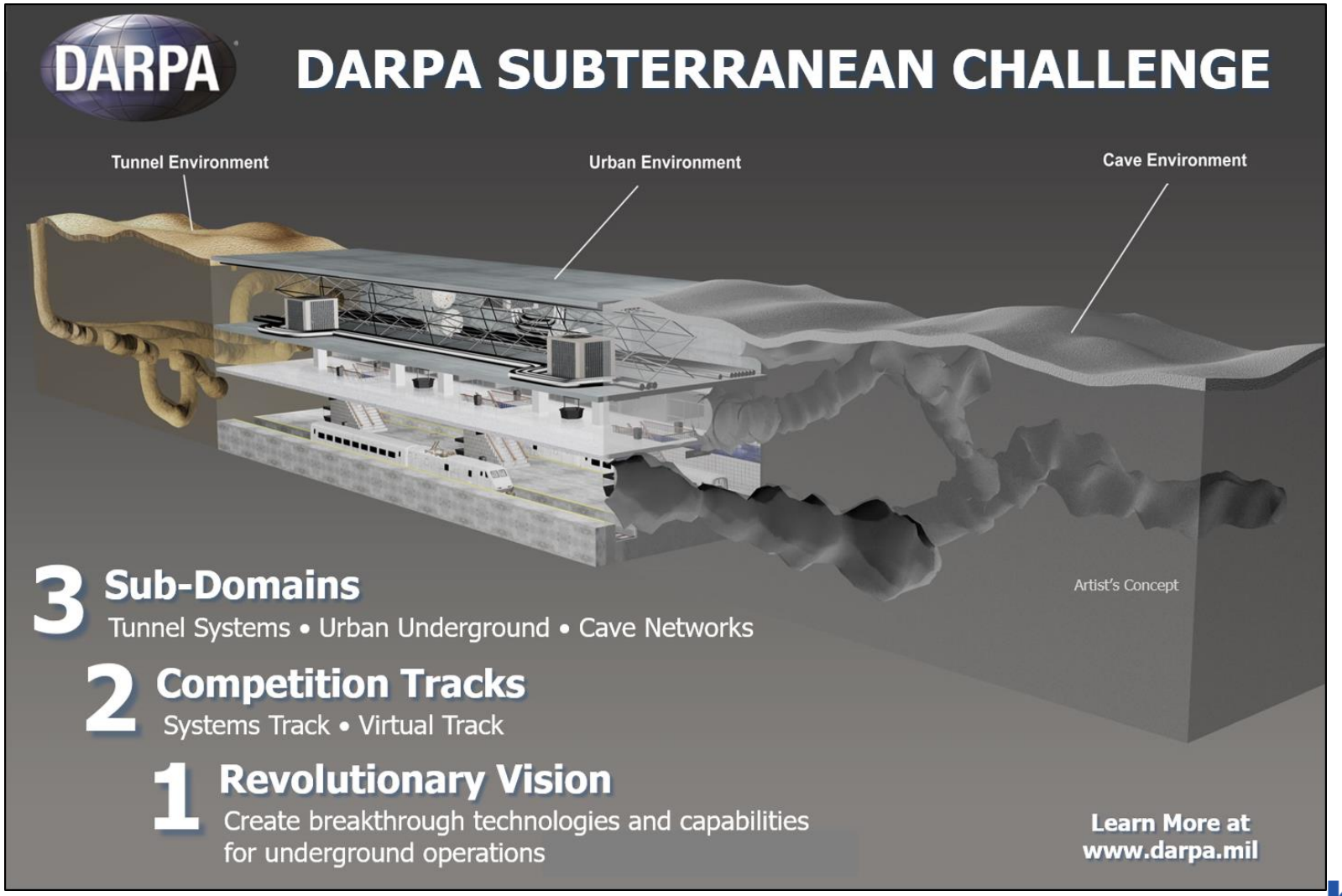
Still many research going on now!



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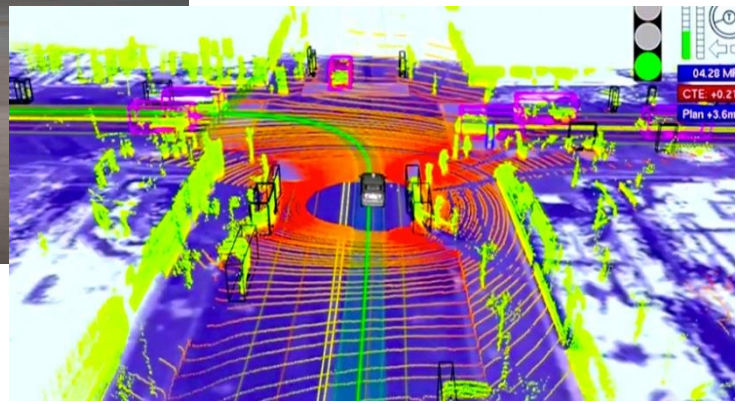
Google Self-Driving Vehicles



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Prerequisites

- **Programing skills**
- **Basic understanding of geometric concepts and deep learning**
- **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**
- **Learning based approaches**

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

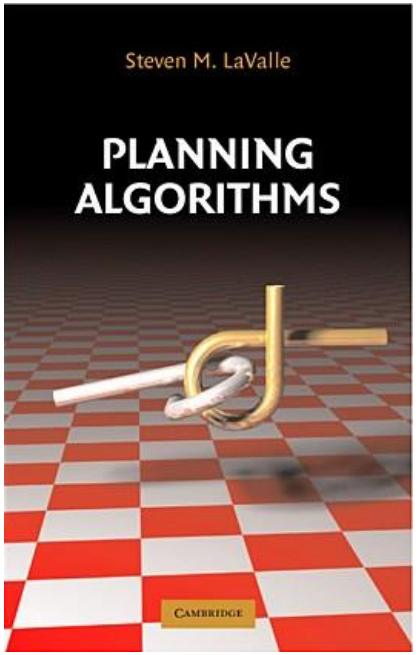
- **Best speaker and best project**
  - **Lunch or dinner for awardees with me and TAs**
- **A high grade will be given to members of the best project**

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+)**

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), many other top-tier papers



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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://sgvr.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 no required to use English, but are recommended**

- **To non-native Korean speakers**
  - **Many Korean students prefer to use Korean for deeper discussions**
  - **In these cases, we will use Korean, but I will summarize main points in English**

My Wish for You

- **Follow up lecture materials and do various class activities/HWs**

- **Hopefully, they will:**
  - **Lead to your next publication, or**
  - **Lead to your next start-up**

Homework

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

- **Example of a summary (just a paragraph)**

  Title: XXX XXXX XXXX
  Conf./Journal Name: ICRA, 2023
  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 two 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 my draft**
  - **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**

Next Time…

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

About You

- **Name**
- **What is your major?**
- **Previous experience on motion planning and robotics**
- **Credit (registering the course) or audit?**