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

- **Joined KAIST at 2007**
  - **Enjoying a lot reading, writing, listening, talking, thinking, and motivating students to create something useful for our society**
- **Main research focus**
  - **Handling of massive data for various computer graphics and geometric problems**

Welcome to CS686

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

Class time: 12:30pm – 1:45pm on MW
Class location: 3445 in the CS building
Office hours: 5~6 MW or right after class
Course webpage:
http://sglab.kaist.ac.kr/~sungeui/MPA

TA

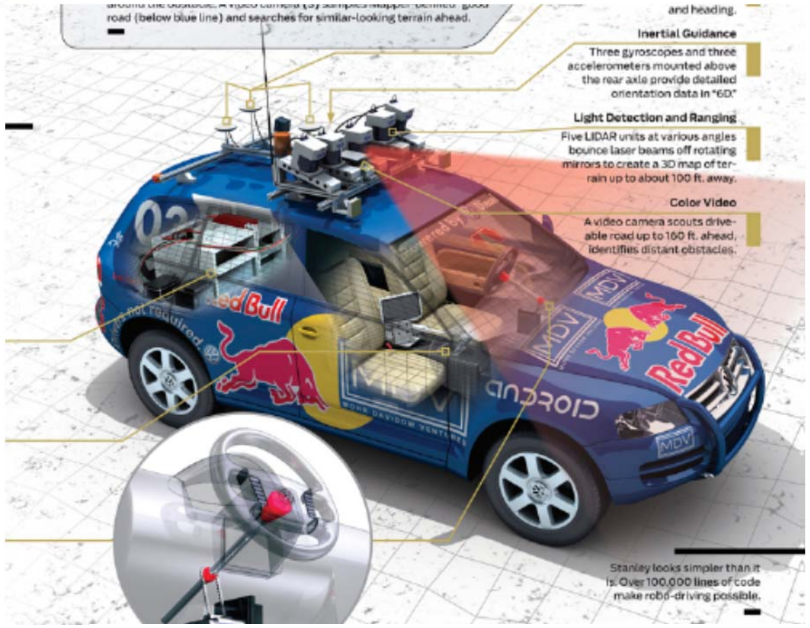
임장관, limg00n@kaist.ac.kr, x7851

N1, 924호

Real World Robots

Sony Aibo

ASIMO



Da Vinci

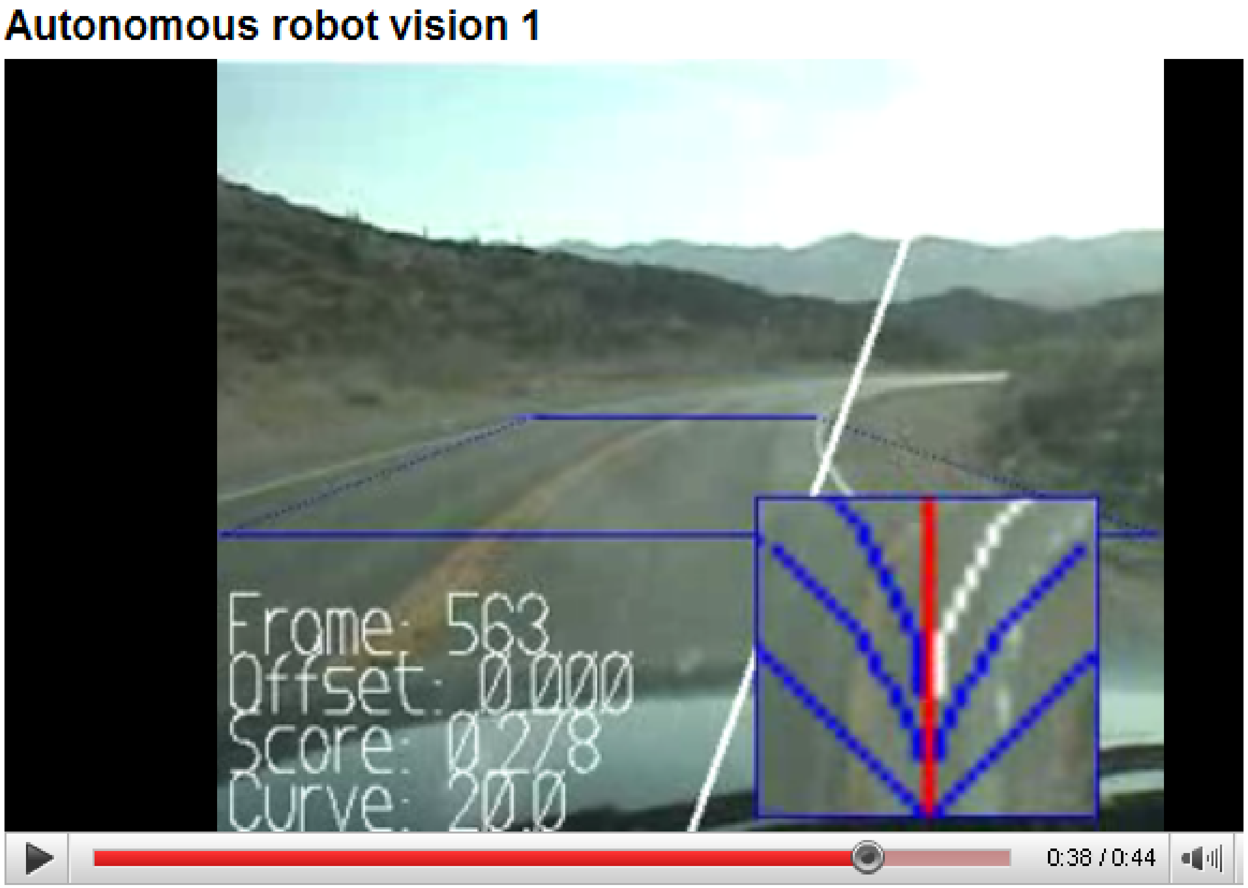
Courtesy of Prof. Dinesh Manocha

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
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

Just USD 8K!

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

TurtleBot

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

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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

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

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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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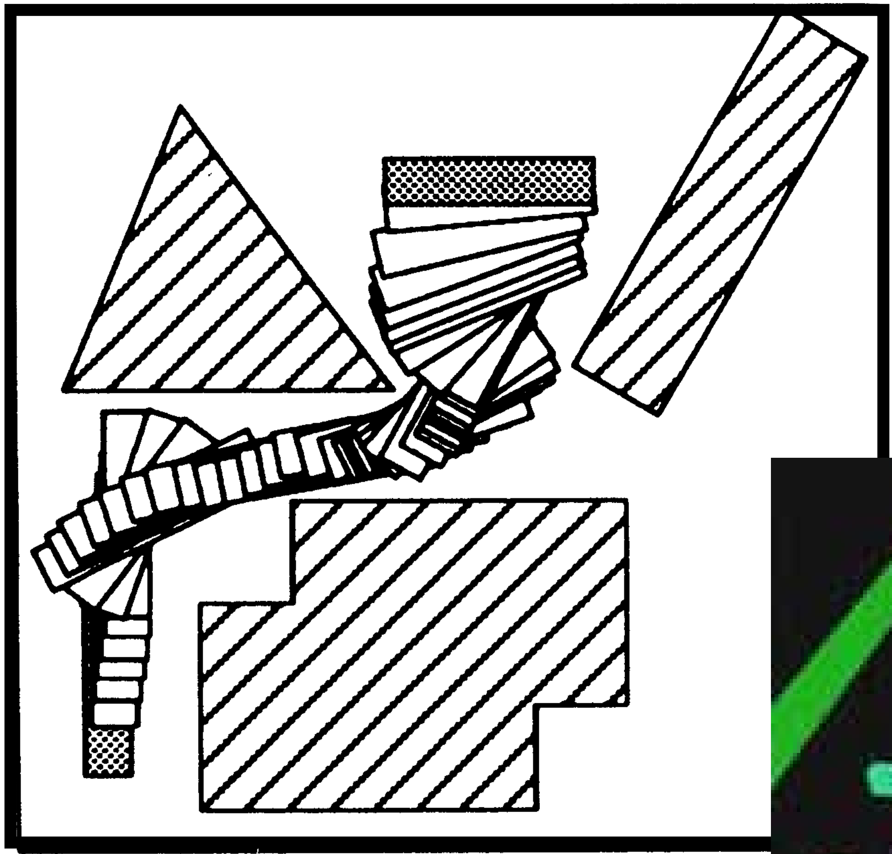
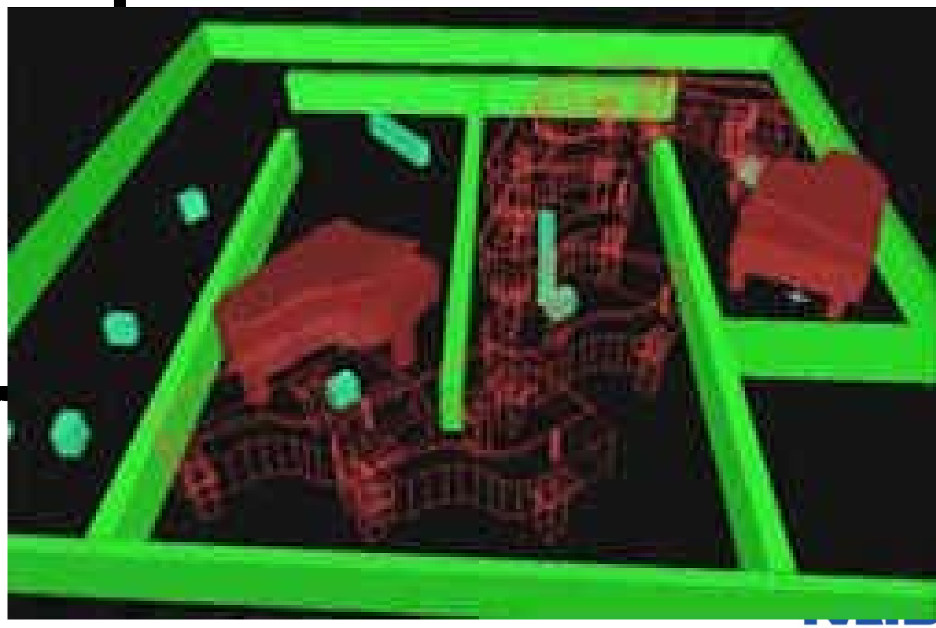
Basic Motion Planning Problem

- **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

Examples with Rigid Object

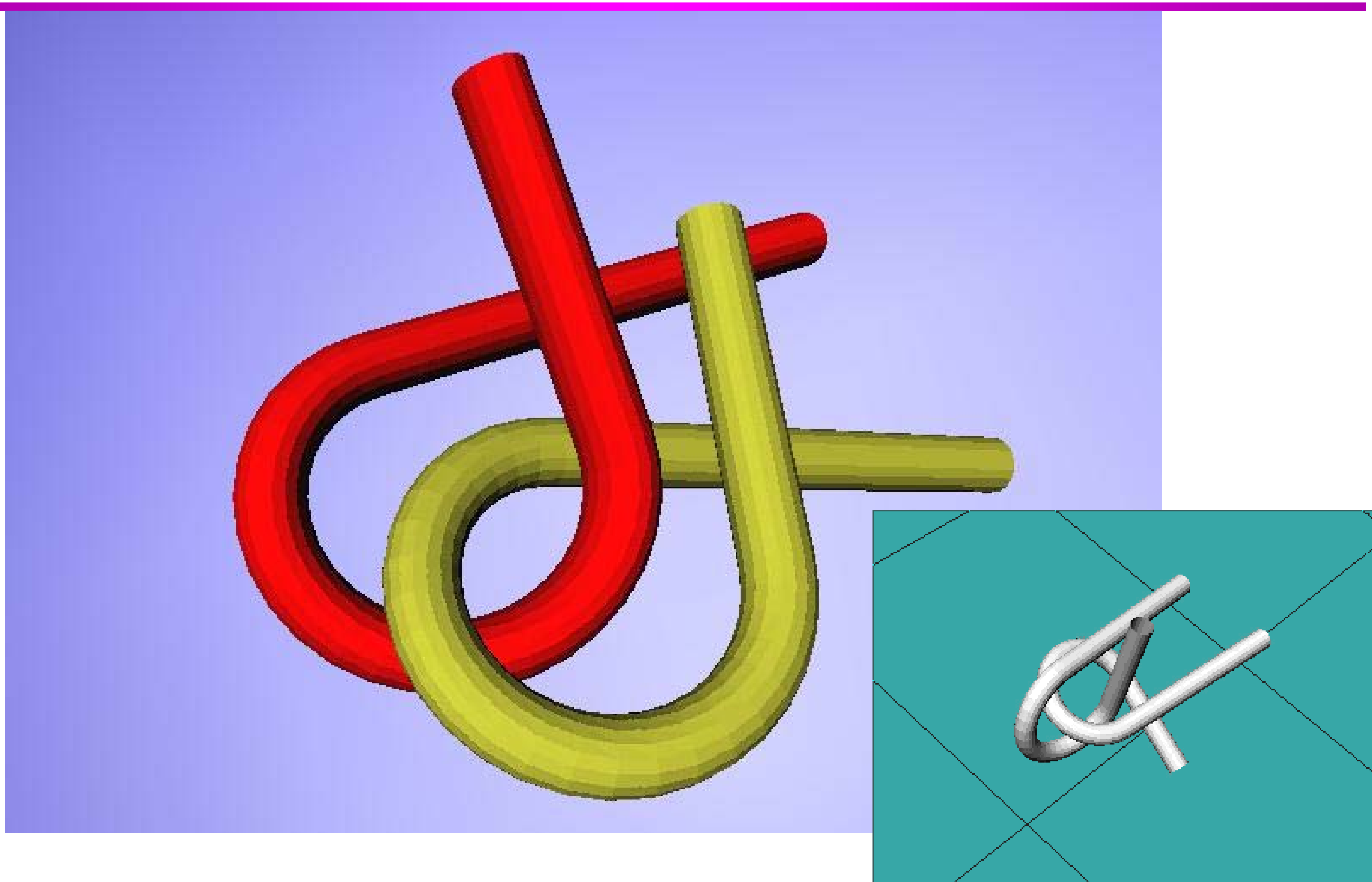


→ Ladder problem

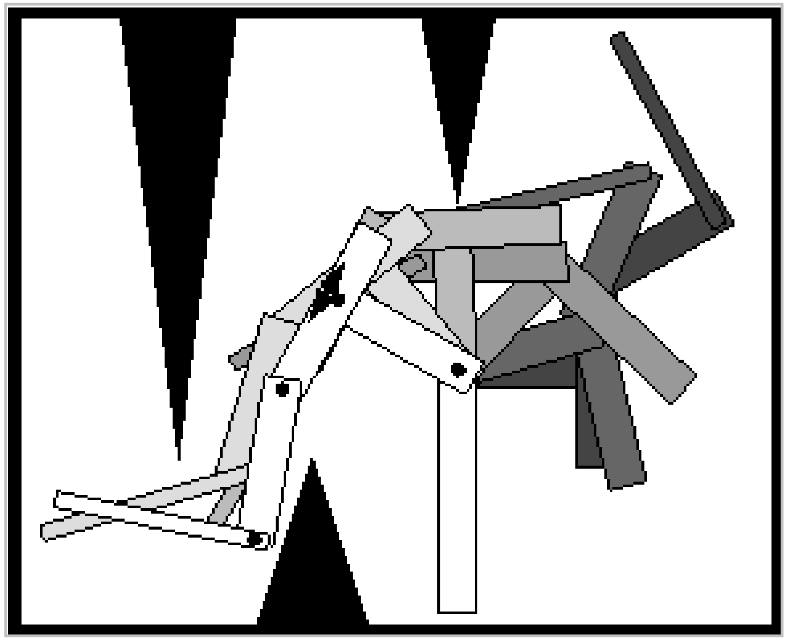


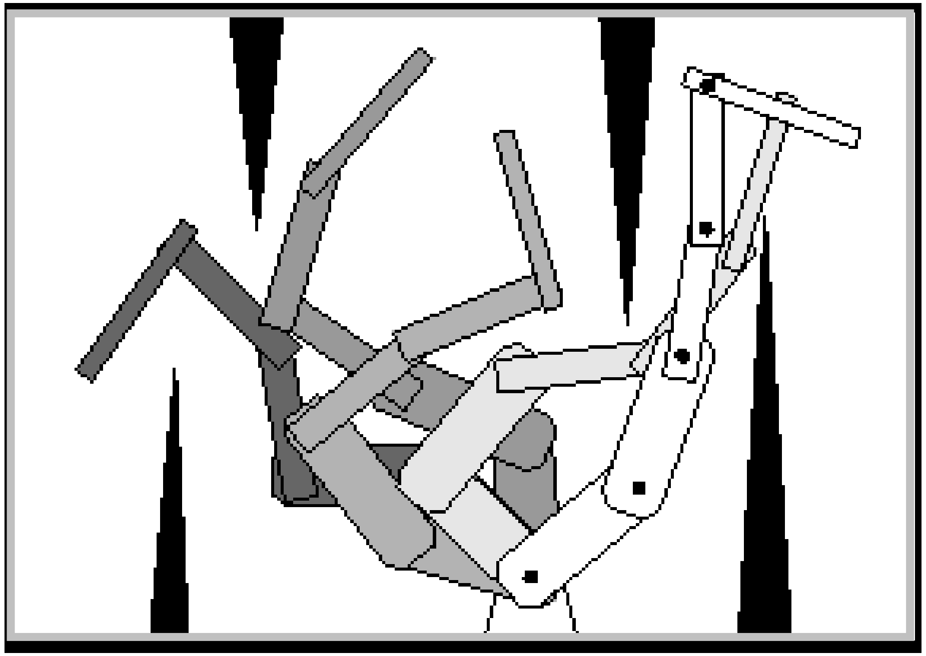
Piano-mover problem ←

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**

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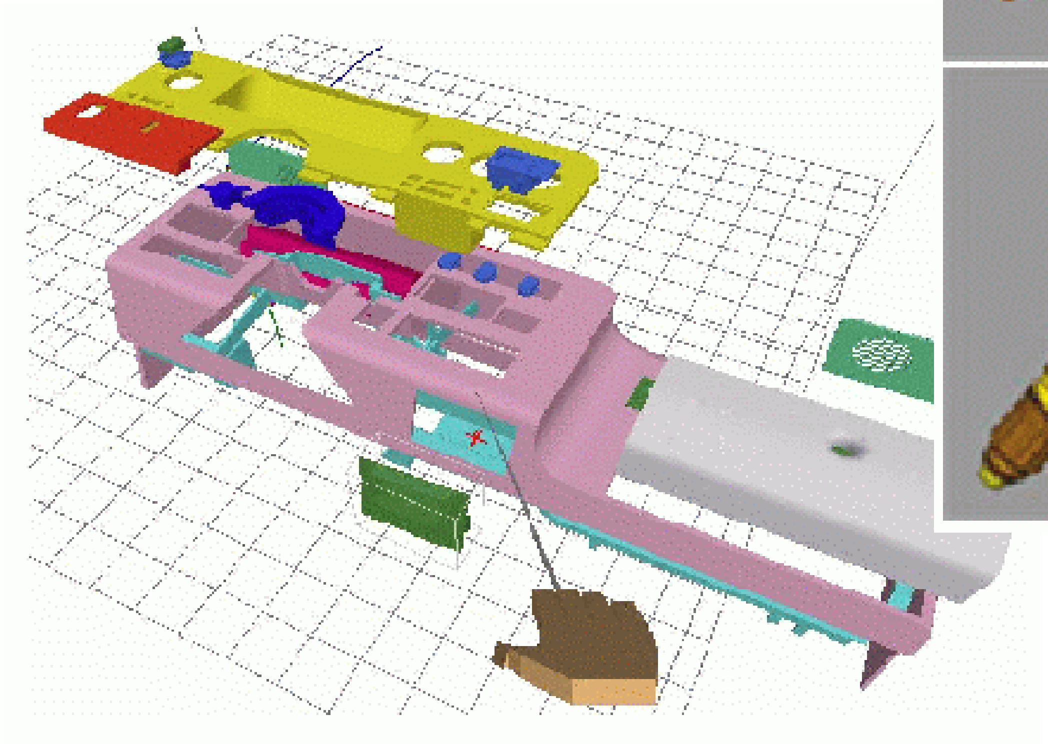
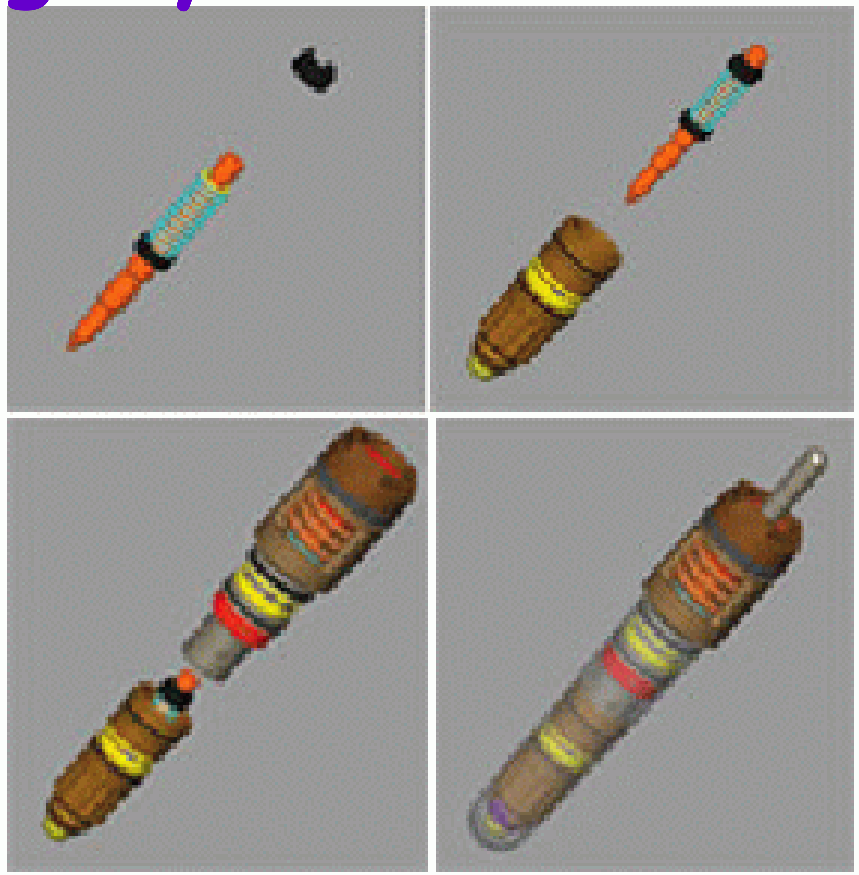
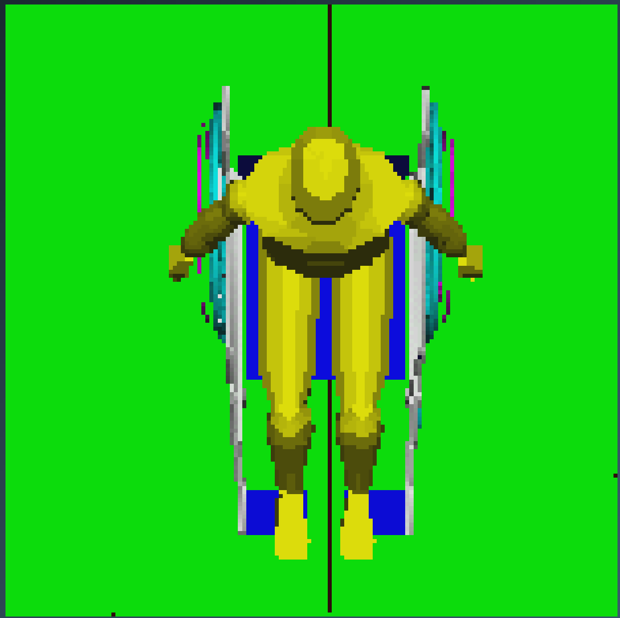
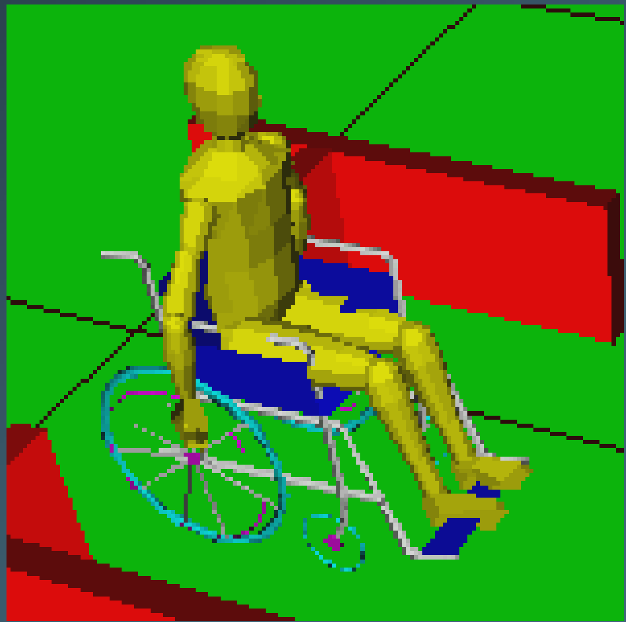
Assembly Planning and Design of Manufacturing Systems



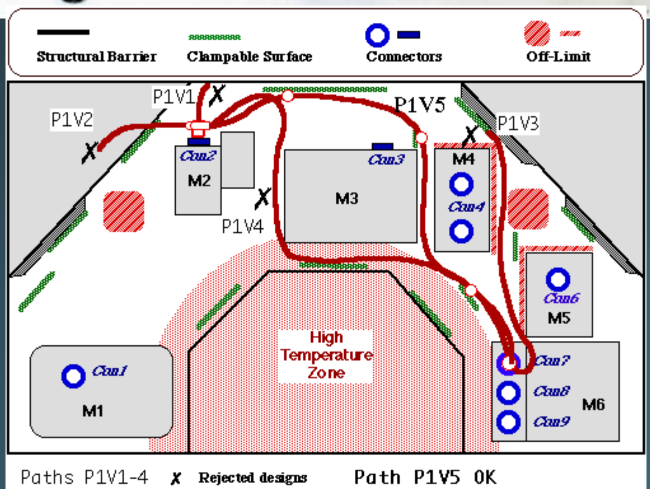


Application: Checking Building Code

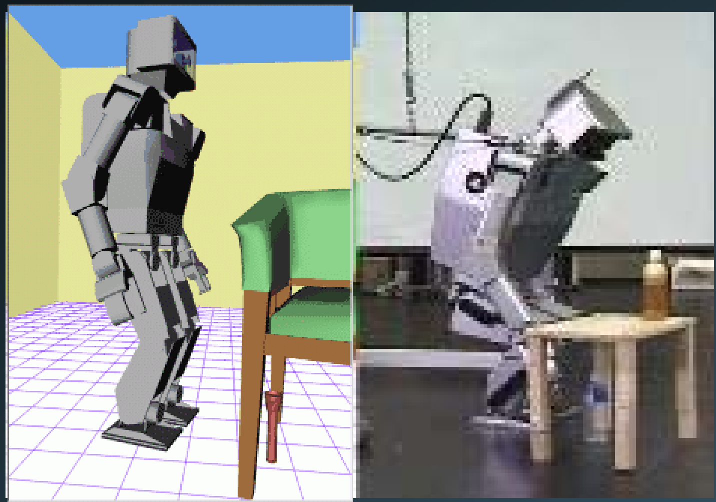


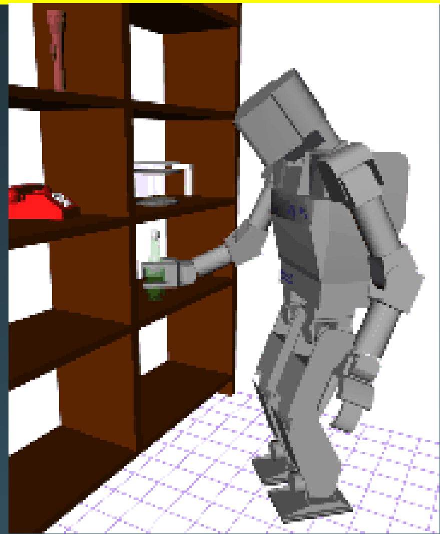


Cable Harness/ Pipe design



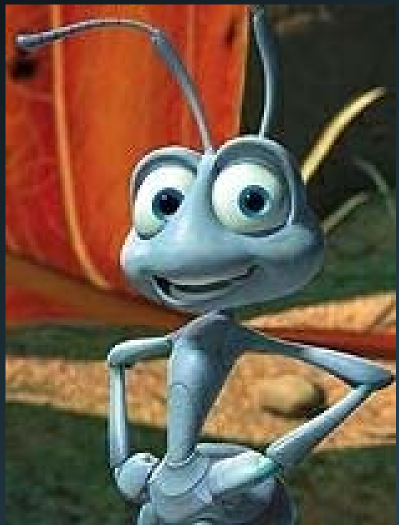
Humanoid Robot

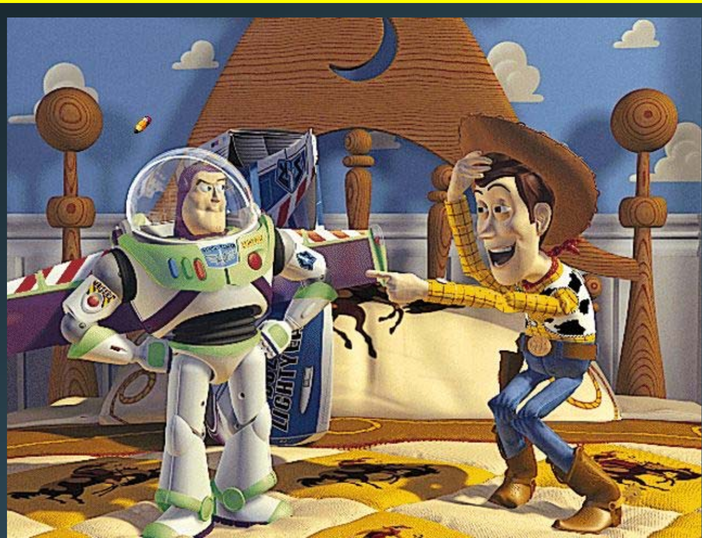




[Kuffner and Inoue, 2000] (U. Tokyo)

Digital Actors


A Bug's Life (Pixar/Disney)


Toy Story (Pixar/Disney)


Antz (Dreamworks)


Tomb Raider 3 (Eidos Interactive)

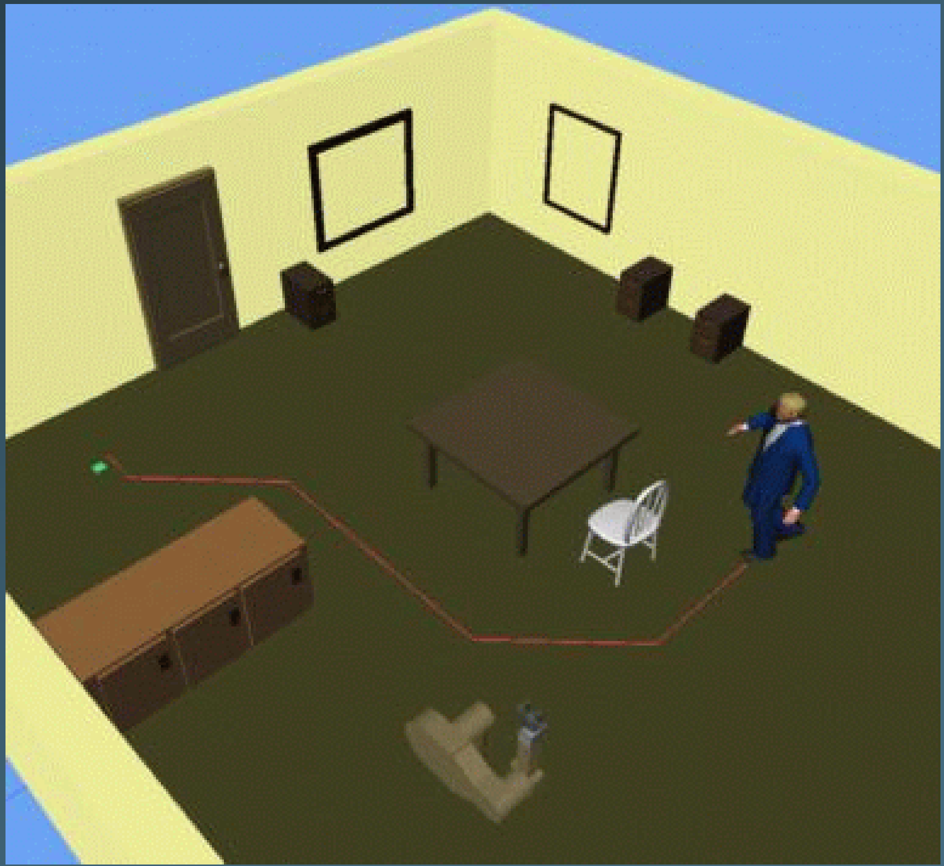
The Legend of Zelda (Nintendo)


Final Fantasy VIII (SquareOne)

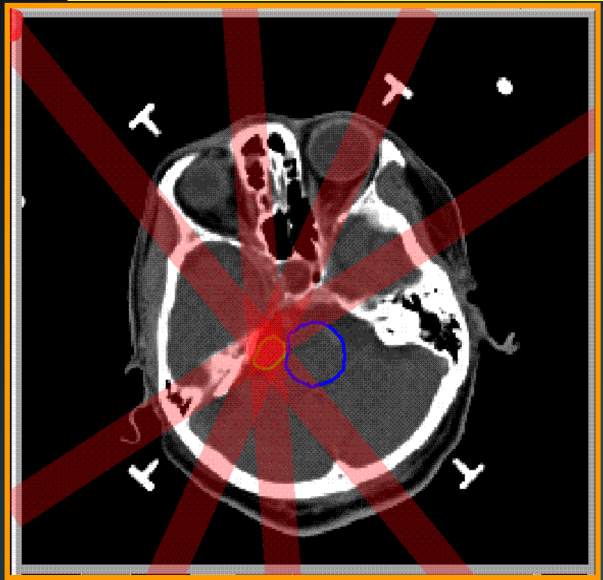
Motion Planning for Digital Actors

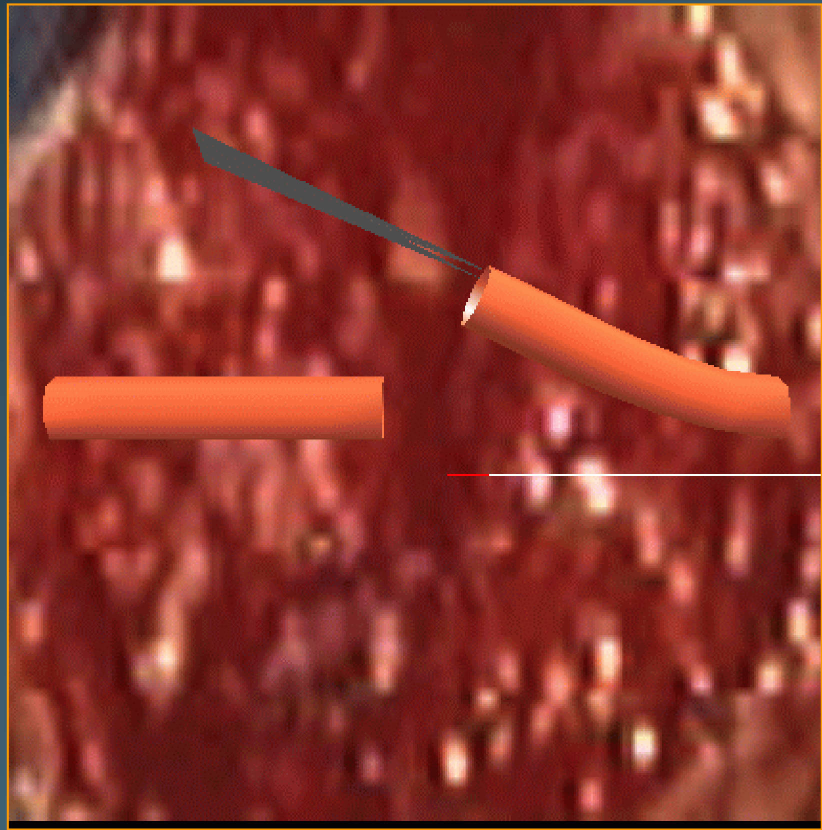
Manipulation

Sensory-based locomotion

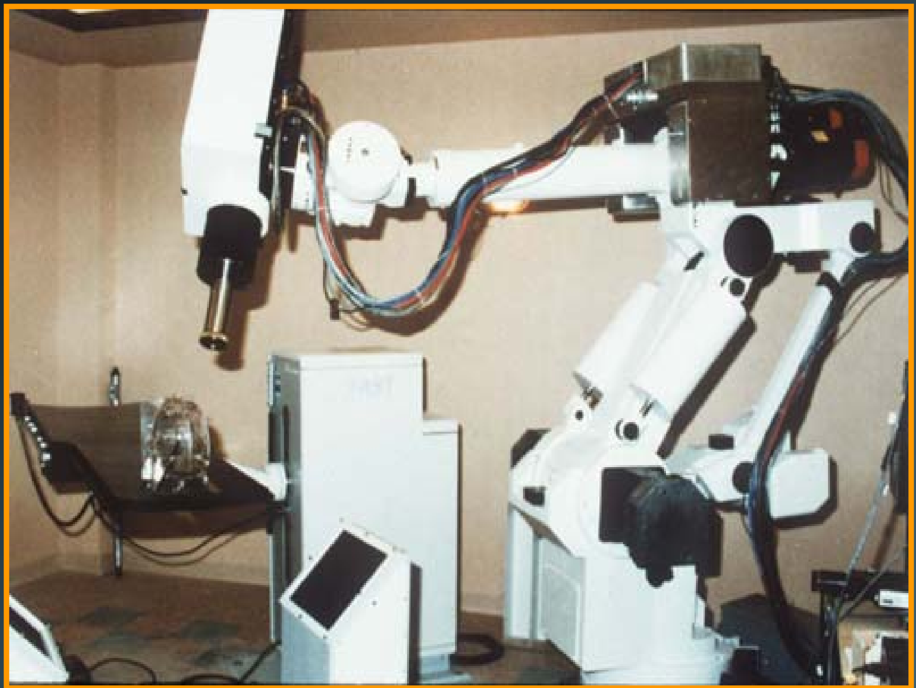


Application: Computer-Assisted Surgical Planning

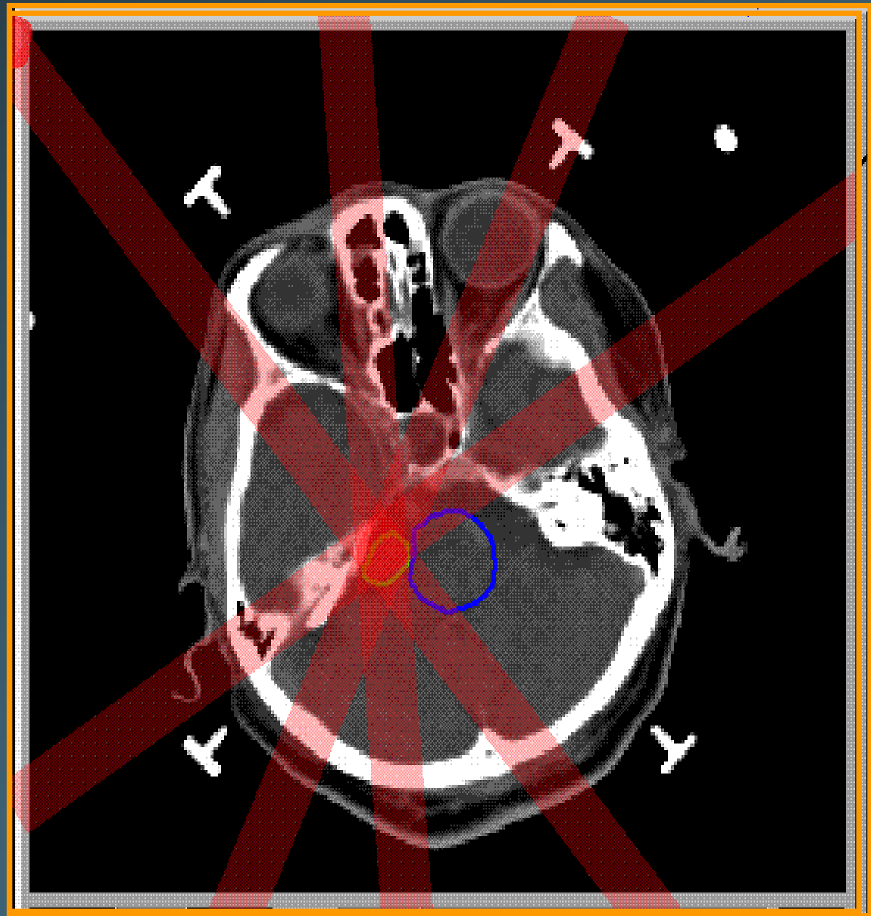




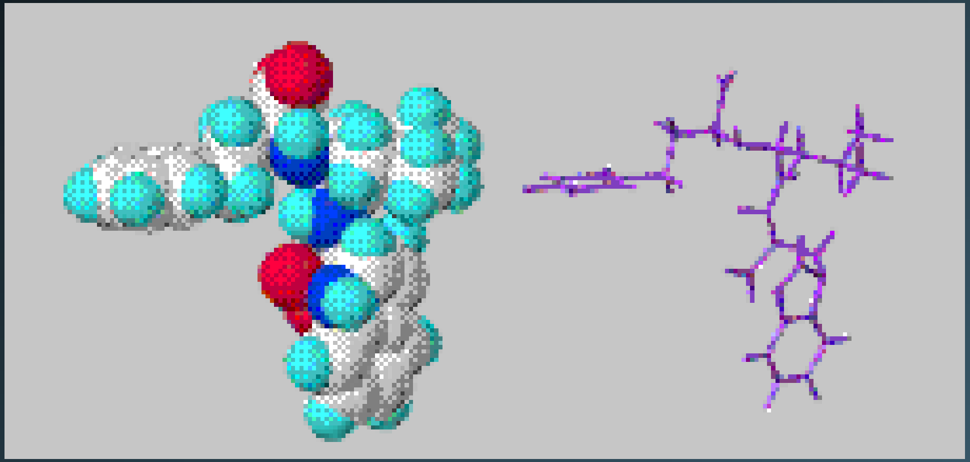
Radiosurgical Planning



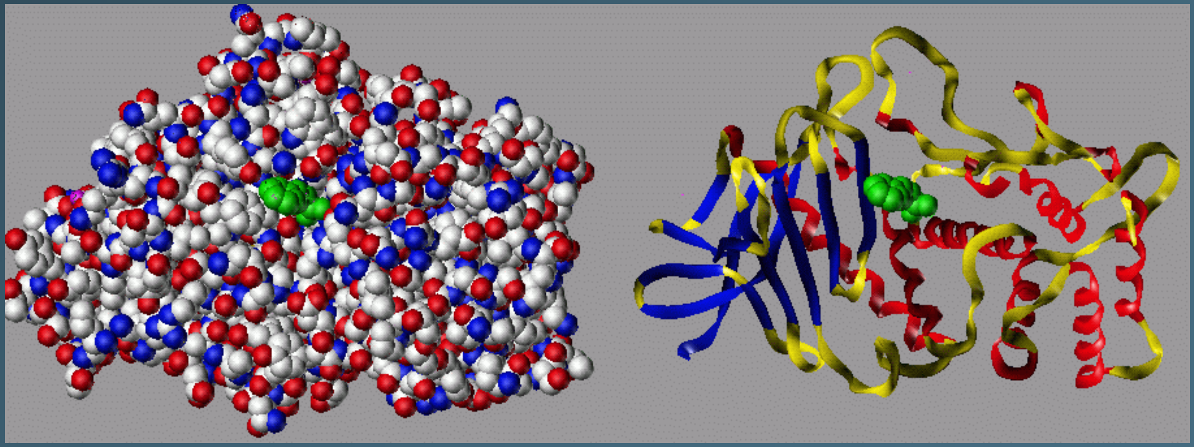
Cyberknife



Study of the Motion of Bio-Molecules



- Protein folding
- Ligand binding



DARPA Grand Challenge

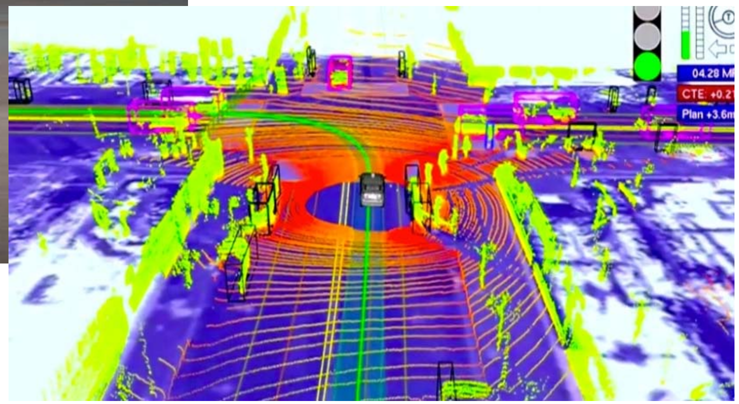
Planning for a collision-free 132 mile path in a desert

DARPA Robotics Challenges, 2014

- Focus on disaster or emergency-response scenarios

From wiki

Google Self-Driving Vehicles



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Car is the next IT platform

WeeklyBiz

[Weekly BIZ] 실리콘밸리는 '자동차 밸리'… 세계 1~8위 車 회사 모두 몰렸다

팰로앨토·벨몬트(캘리포니아)=최원석 기자 ws

기사 | 100자평(0) | +크게 | -작게

입력 : 2013.08.31 03:05

왜 실리콘밸리로 가나
자동차는 갈수록 전자제품化, 첨단 소프트웨어 기술 확보 필요

러브콜 받는 한국 모바일 부품 업체
스마트폰과 연결 시키는 작업 등 실력 뛰어난 한국 업체와 연구 돌입

▲ 구글·애플 등 실리콘밸리의 터줏대감 IT 업체들 사이로 자동차회사 연구소들이 속속 모여들고 있다. ①스탠퍼드대가 있는 팰로앨토에 위치한 GM 연구소 ②벨몬트의 폴크스바겐 연구소 ③레드우드시티에 있는 전기차 업체 테슬라모터스의 전시장 ④실리콘밸리를 남북으로 관통하는 101 고속도로 위를 달리고 있는 구글 무인주행차. /실리콘밸리=최원석 기자

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

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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!

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!

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**
  - **Team of two (or three) is recommended**

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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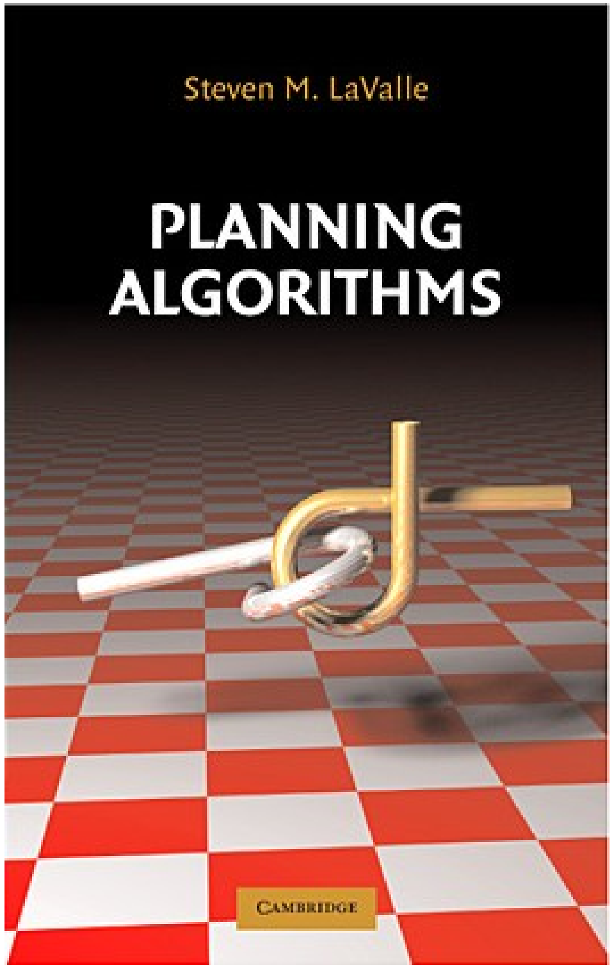
Resource

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



Other Reference

- 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
- 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**

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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

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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

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 end of the class**
  - **1 for typical questions**
  - **2 for questions with thoughts or that surprised me**

- **Write a question more than 10 times**
  - **Do that out of 2 classes**

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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**

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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.**

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Next Time…

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