

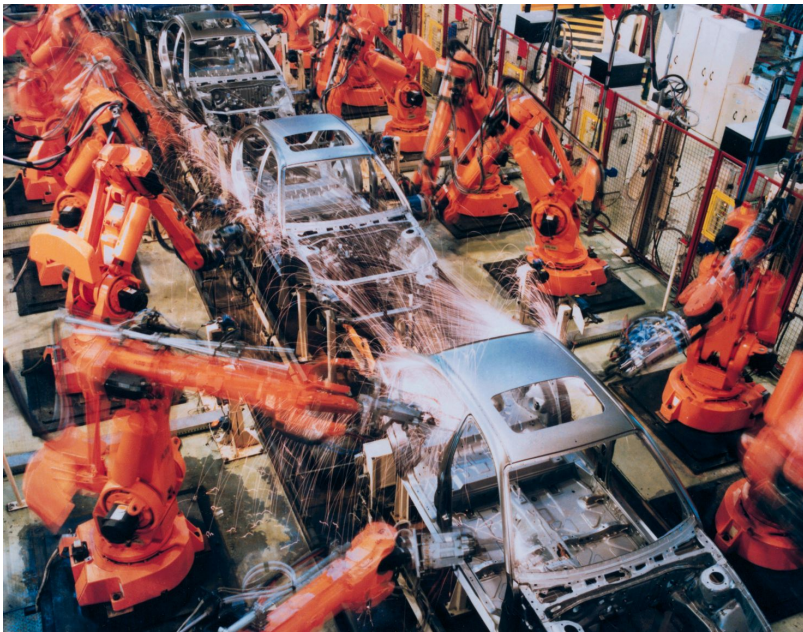


Robotics

Introduction

Marc Toussaint
U Stuttgart

Why Robotics?

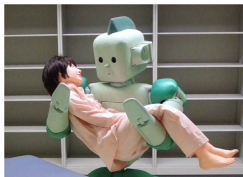


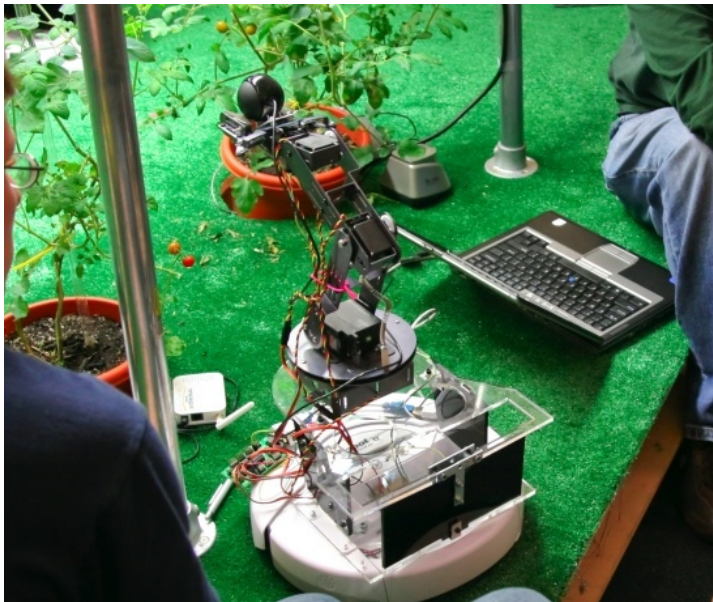


http://www.saintpatrick.org/index.aspx/Health_Services/da_Vinci_Surgery



(robot “wife” aico)





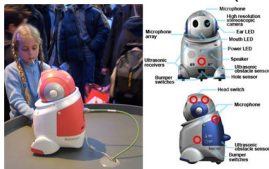
<http://people.csail.mit.edu/nikolaus/drg/>

Why Robotics?

- Commercial:
Industrial, health care, entertainment, agriculture, surgery, etc

Why Robotics?

- Commercial:
Industrial, health care, entertainment, agriculture, surgery, etc
- Critical view:
 - International Committee for Robot Arms Control
<http://www.icrac.co.uk/>
 - Noel Sharkey's articles on robot ethics (Child care robots PePeRo...)



<http://www.nec.co.jp/products/robot/en/>

Robotics as *intelligence research*

AI in the real world

AI: Machine Learning, probabilistic reasoning, optimization

Real World: Interaction, manipulation, perception, navigation, etc

Why AI needs to go real world



Why AI needs to go real world



Tunicates digest their brain once they settled!

- **Motion** was *the* driving force to develop intelligence
 - motion needs control & decision making \leftrightarrow fast information processing
 - motion needs anticipation & planning
 - motion needs perception
 - motion needs spatial representations
- **Manipulation** requires to acknowledge the structure (geometry, physics, objects) of the real world. Classical AI does not

Robotics as *intelligence research*

- Machine Learning and AI are **computational** disciplines, which had great success with statistical modelling, analysis of data sets, symbolic reasoning. But they have not solved *autonomous learning, acting & reasoning in real worlds*.
- Neurosciences and psychology are **descriptive** sciences, either on the biological or cognitive level, e.g. with great successes to describe and cure certain diseases. But they are not sufficient to create intelligent systems.
- Robotics is the only **synthetic** discipline to understand intelligent behavior in natural worlds. Robotics tells us what the actual problems are when trying to organize behavior in natural worlds.

History

- little movie...

(`http://www.csail.mit.edu/videoarchive/history/aifilms`

`http://www.ai.sri.com/shakey/`)

Four chapters

- **Kinematics & Dynamics**

goal: orchestrate joint movements for desired movement in task spaces

Kinematic map, Jacobian, optimality principle of inverse kinematics, singularities, configuration/operational/null space, multiple simultaneous tasks, special task variables, trajectory interpolation, motion profiles; 1D point mass, damping & oscillation, PID, general dynamic systems, Newton-Euler, joint space control, reference trajectory following, optimal operational space control

- **Planning & optimization**

goal: planning around obstacles, optimizing trajectories

Path finding vs. trajectory optimization, local vs. global, Dijkstra, Probabilistic Roadmaps, Rapidly Exploring Random Trees, differential constraints, metrics; trajectory optimization, general cost function, task variables, transition costs, gradient methods, 2nd order methods, Dynamic Programming

- **Control Theory**

theory on designing optimal controllers

Topics in control theory, optimal control, HJB equation, infinite horizon case, Linear-Quadratic optimal control, Riccati equations (differential, algebraic, discrete-time), controllability, stability, eigenvalue analysis, Lyapunov function

- **Mobile robots**

goal: localize and map yourself

State estimation, Bayes filter, odometry, particle filter, Kalman filter, Bayes smoothing, SLAM, joint Bayes filter, EKF SLAM, particle SLAM, graph-based SLAM

- Is this a practical or theoretical course?

“There is nothing more practical than a good theory.”

(Vapnik, others...)

- Is this a practical or theoretical course?

“There is nothing more practical than a good theory.”
(Vapnik, others...)

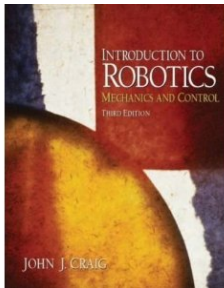
- Essentially, the whole course is about

reducing real-world problems to mathematical problems

that can be solved efficiently

Books

There is no reference book for this lecture. But a basic well-known standard text book is:



Craig, J.J.: *Introduction to robotics: mechanics and control*. Addison-Wesley New York, 1989. (3rd edition 2006)

Books

An advanced text book on planning is this:



Steven M. LaValle: *Planning Algorithms*. Cambridge University Press, 2006.

online: <http://planning.cs.uiuc.edu/>

Online resources

- VideoLecture by Oussama Khatib:
<http://academicearth.org/courses/introduction-to-robotics> <http://www.virtualprofessors.com/introduction-to-robotics-stanford-cs223a-khatib>
(focus on kinematics, dynamics, control)
- Oliver Brock's lecture
http://courses.robotics.tu-berlin.de/mediawiki/index.php/Robotics:_Schedule_WT09
- Stefan Schaal's lecture Introduction to Robotics:
<http://www-clmc.usc.edu/Teaching/TeachingIntroductionToRoboticsSyllabus>
(focus on control, useful: Basic Linear Control Theory (analytic solution to simple dynamic model → PID), chapter on dynamics)
- Chris Atkeson's "Kinematics, Dynamic Systems, and Control"
<http://www.cs.cmu.edu/~cga/kdc/>
(uses Schaal's slides and LaValle's book, useful: slides on 3d kinematics
<http://www.cs.cmu.edu/~cga/kdc/ewhitman1.pptx>)
- CMU lecture "introduction to robotics" <http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/syllabus.html>
(useful: PID control, simple BUGs algorithms for motion planning, non-holonomic constraints)
- *Handbook of Robotics* (partially online at Google books) <http://tiny.cc/u6tzl1>
- LaValle's *Planning Algorithms* <http://planning.cs.uiuc.edu/>

Organization

- Course webpage:

 - `http://ipvs.informatik.uni-stuttgart.de/mlr/marc/teaching/`

 - Slides, exercises & software (C++)
 - Links to books and other resources

- Secretary, admin issues:

 - Carola Stahl, `Carola.Stahl@ipvs.uni-stuttgart.de`, room 2.217

- Rules for the tutorials:

 - Doing the exercises is crucial!
 - At the beginning of each tutorial:
 - sign into a list
 - mark which exercises you have (successfully) worked on
 - Students are randomly selected to present their solutions
 - You need 50% of completed exercises to be allowed to the exam