ETH Master Course: 151-0854-00L

Autonomous Mobile Robots

Lecture: Monday 14.15 - 16.00, HG D 3.2
Exercises: Monday 16.15 - 18.00, HG K32 (VisDome)

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AMR 2nd Edition Available Now!

- Revised and extended
  - 150+ pages heavier
  - Perception treated more thoroughly

- Accompanies this course

Today’s Lecture

Part 1

- Introduction to & motivation for studying mobile robotics
  - What precisely is mobile robotics and where does it come from
  - Examples of milestone developments
  - Snapshot of state-of-the-art systems

Part 2

- Introduction to basic terminology and concepts behind robotics
  - Robot kinematics
  - Environment representation and modeling
  - Localization and map-building
  - Planning and control
  - Each of these topics will be treated more in-depth throughout the course
- Organizational
  - Format of lectures and exercises
  - Testat and final exam

Robotics: Origin and Meaning

- Robot etymology
  - Robota: Czech for useful (and forced) forms of labor
  - Coined by Karel Čapek in his 1921 play „Rossums Universal Robots“
  - Represents today‘s understanding of an android
- By this definition, the field of robotics is ancient
  - Clepsydra: water clocks of ancient greece
  - Windmills
  - Steam engine

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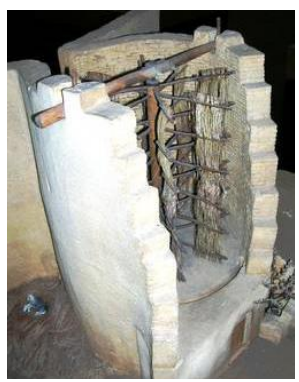

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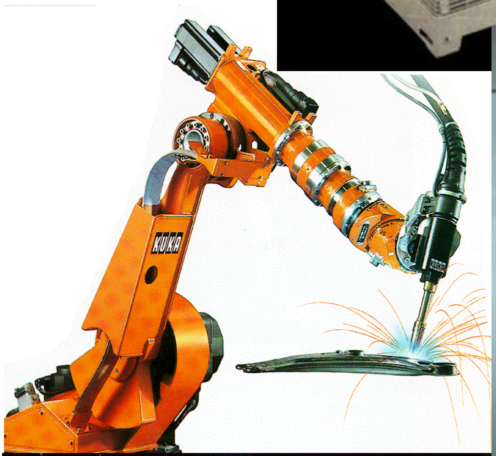
4000 BC — 800 AD — 1763 AD

Robotics: Modern Developments (1950 – 1990)

- Milestones in stationary robotics (industry)
  - Pick and place Unimates, 1956
  - Stanford arm, 6 dof, 1969
  - ABB and KUKA industrial arms, 1973
  - ...

- Milestones in mobile robotics
  - Shakey the robot, 1966
  - NASA Viking program, 1975
  - Brooks „subsumption architecture“, 1986
  - ...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Robotics: Modern Developments (1950 – 1990)

- Shakey the robot

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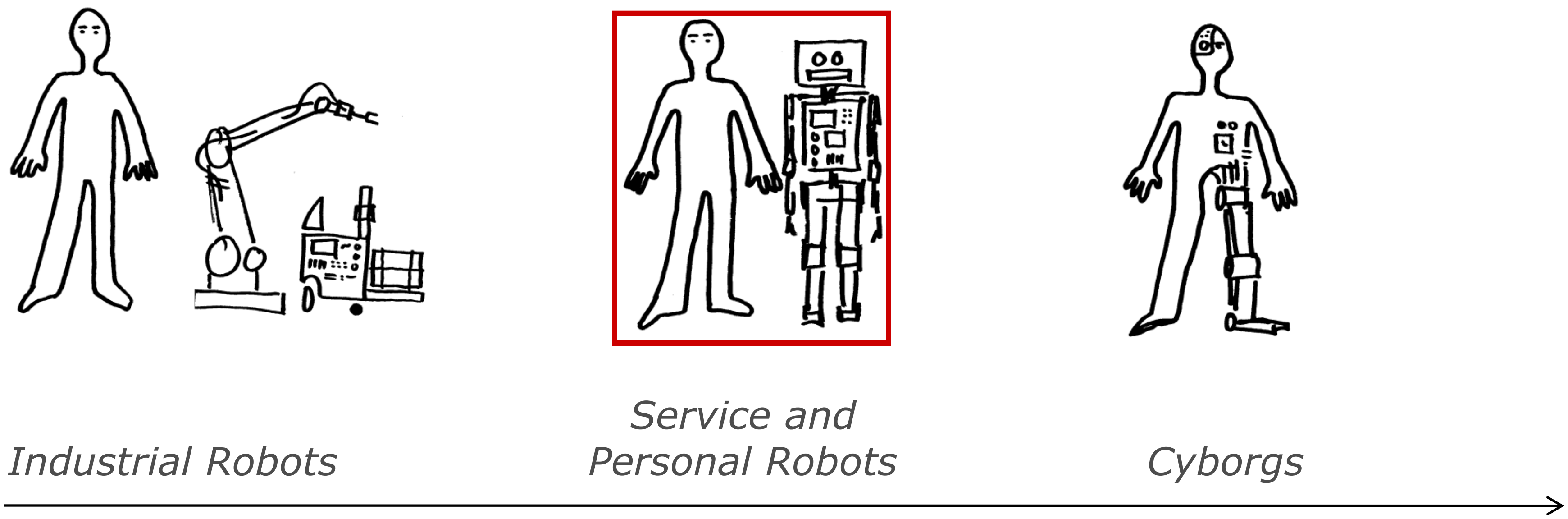
Robotics: Modern Developments (1950 – 1990)

- Brooks‘ subsumption architecture

Trend: Robots are Getting Closer

- Technical systems can be characterized by the increasing physical and psychological closeness and interaction between man and machine



Mobile Robotics: Case Studies from the Last Two Decades

- Space Rovers
  - NASA and ESA Mars programs
  - Key issues: mobility in rough terrain, time delay, temperatures

- Autonomous Robotic Cars
  - DARPA grand and urban challenges
  - Autonomous Google car
  - Key issues: dynamic environments, safety

- Flying Robots
  - sFly
  - Key issues: limited computation power and payload

- Personal Robots
  - Humanoids: ASIMO
  - Willow Garage PR2
  - Key issues: safety, human-friendliness

NASA: Mars Exploration Rover Mission

- Mission overview
  - Two rovers: Spirit and Oppurtunity to survey Martian surface & geology
  - Original mission duration was set to 90 sol
  - Total cost of close to 1 Billion US$

Spirit

- Communication
  - X band radio, ca. 20 minutes delay (two ways)
  - Thus, remote real-time operation is not feasible
- Autonomous Systems
  - Horizontal velocity control via vision system before landing (DIMES)
  - Stereo vision for local mapping and reactive planning (GESTALT)
  - Visual odometry in areas of high slippage
  - On May 01, 2009 Spirit got stuck in soft soil
  - On Jan. 26, 2010 it was reassigned as a stationary science platform

NASA: Mars Exploration Rover Mission

ETH-ASL: Autonomous Robot for Planetary Exploration

DARPA: Grand & Urban Challenges

- Darpa Grand Challenge 2004
  - 130 mile course in Mojave desert
  - None of the teams finished the course

- Darpa Grand Challenge 2005
  - Again a desert course, but with added complications
  - 5 Teams finished

- DARPA Urban Challenge 2007
  - Inner-city course
  - Obeyance of traffic rules
  - Frequent denial of global positioning (GPS)

DARPA: Grand & Urban Challenges

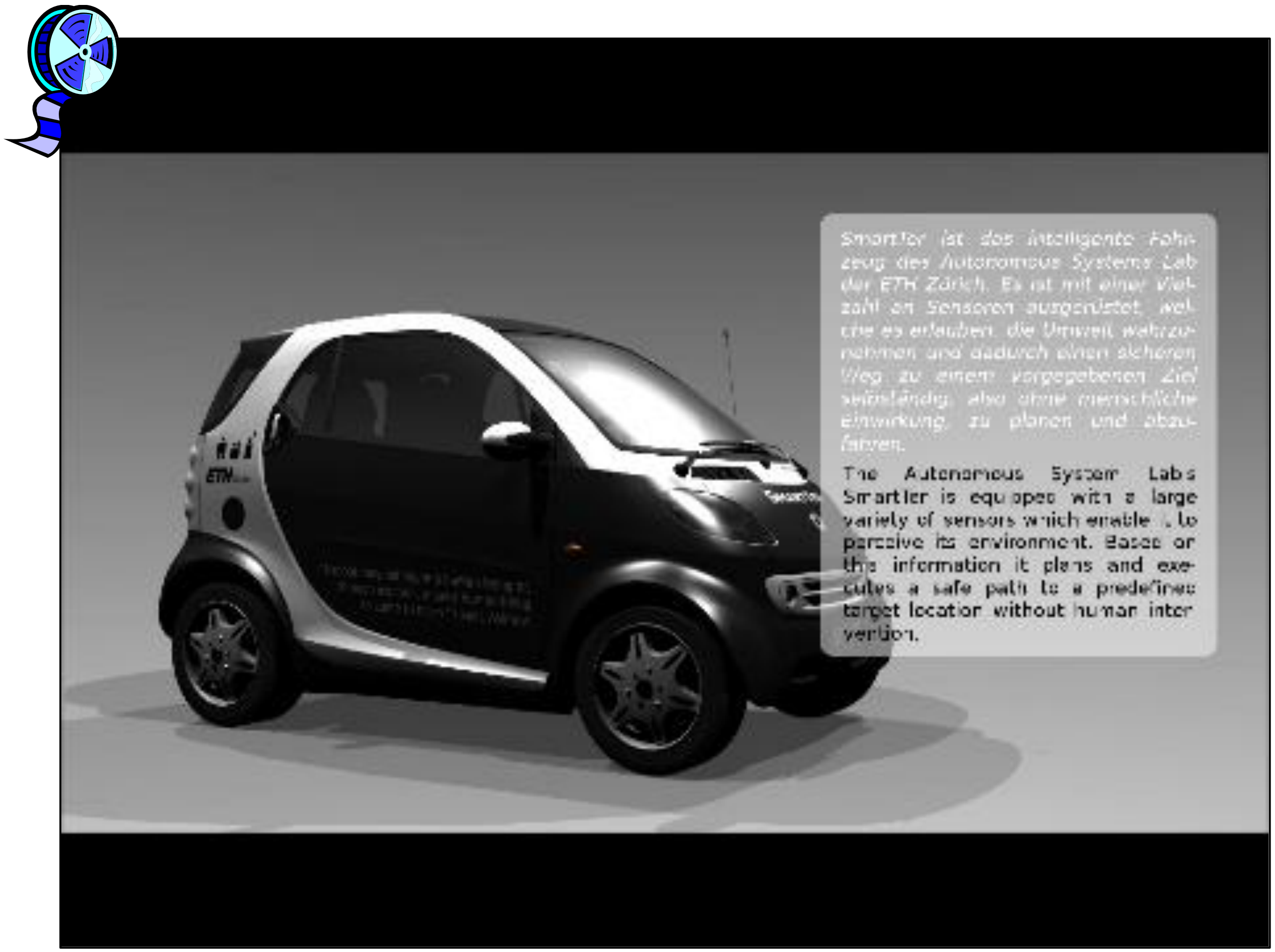
- Grand Challenge 2005 Trials

DARPA: Grand & Urban Challenges

- Urban Challenge 2007

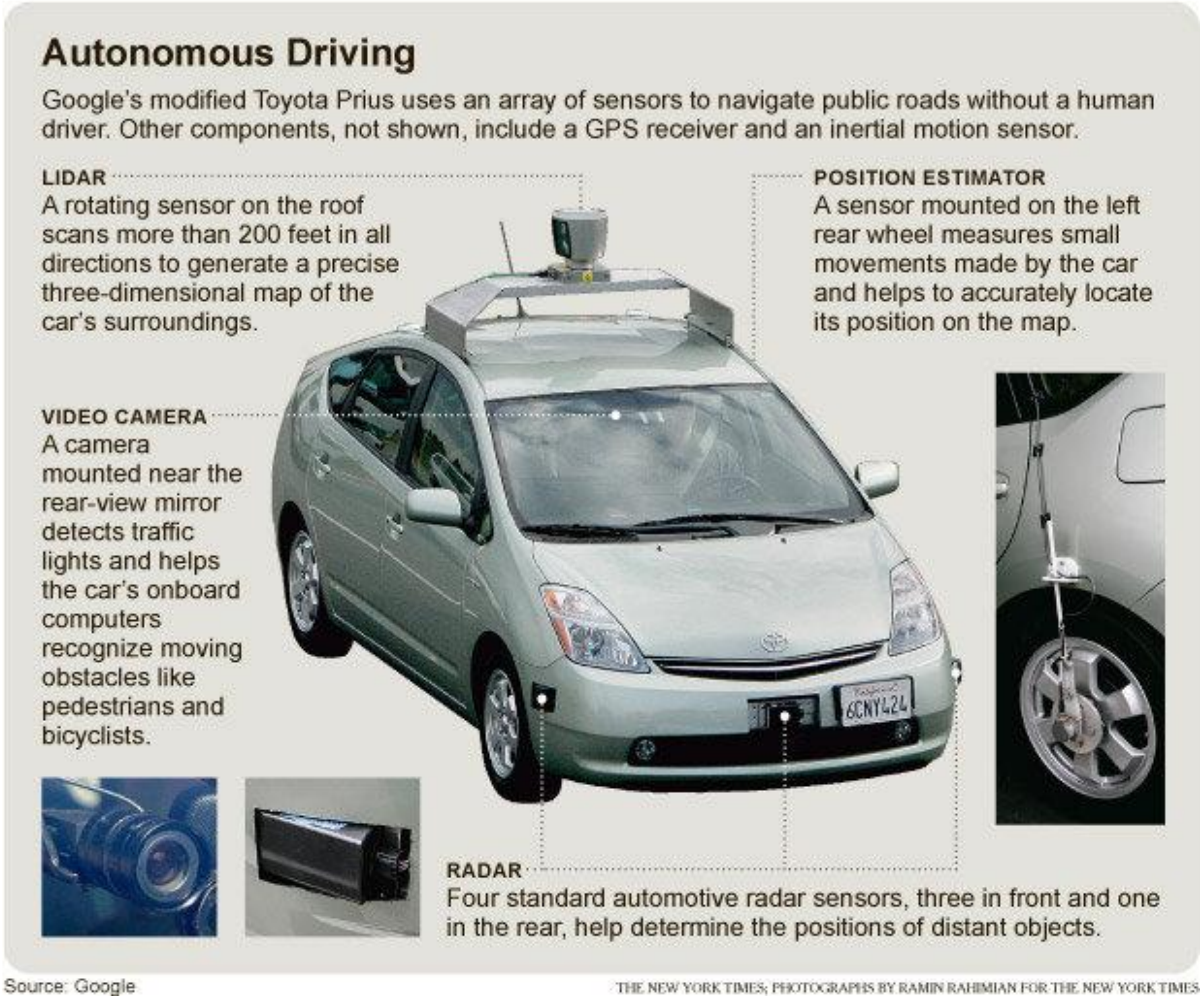
ETHZ-ASL: SmartTer

- Visualization



Google: Autonomous Driving in traffic

- October 2010
- Self-driving car in real traffic
- Toyota Prius + a variety of sensors:
  - Lidar,
  - Video camera,
  - Radars,
  - GPS receiver,
  - etc.
- Autonomous Driving:
  - sense the surroundings
  - mimic the decisions of a human driver



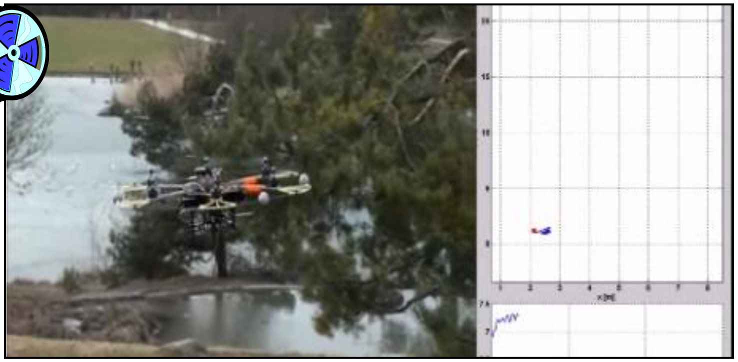
Google: Autonomous Driving in traffic

- Plan route like a GPS navigator but use extra data to decide on driving actions
- Boost safety & efficiency
- 7 cars,140 000 miles with minimal human intervention
- Autonomous cars are still years from mass production

Video: ABC News

sFly: Swarm of micro Flying Robots

- Ongoing EU project
- Coordinated flight in small swarms over previously unknown areas
- Autonomous micro helicopters for:
  - inspection,
  - exploration,
  - search & rescue,
  - monitoring & surveillance
- Access to:
  - environments where no human or other vehicles can get access to
  - GPS-denied environments
- Vision-based fully autonomous navigation



Humanoid Robot: ASIMO

- Honda's ASIMO:
  Advanced **S**tep in **I**nnovative **MO**bility
- Designed to help people in their everyday lives
- One of the most advanced humanoid robots
  - Compact, lightweight
  - Sophisticated walk technology
  - Human-friendly design

Video: Honda

PR2: Personal Robot 2

Willow Garage

- Robot for reasearch and experimentation
- Development platform:
  - Cameras, Laser scanners, Accelerometer, Tactile sensors
  - 16 CPU cores
  - Sophisticated joints design for safety
  - Variety of networking tools for communicating data
- ROS: Robot Operating System **free**, **open source**, software development platform integrating libraries and tools
- Cost: $400 000

PR2: applications

Fold towels

Fetch beer

Clean-up with cart

Navigation