

# **Introduction to Mobile Robotics**

## **Welcome**

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Maren Bennewitz, Kai Arras



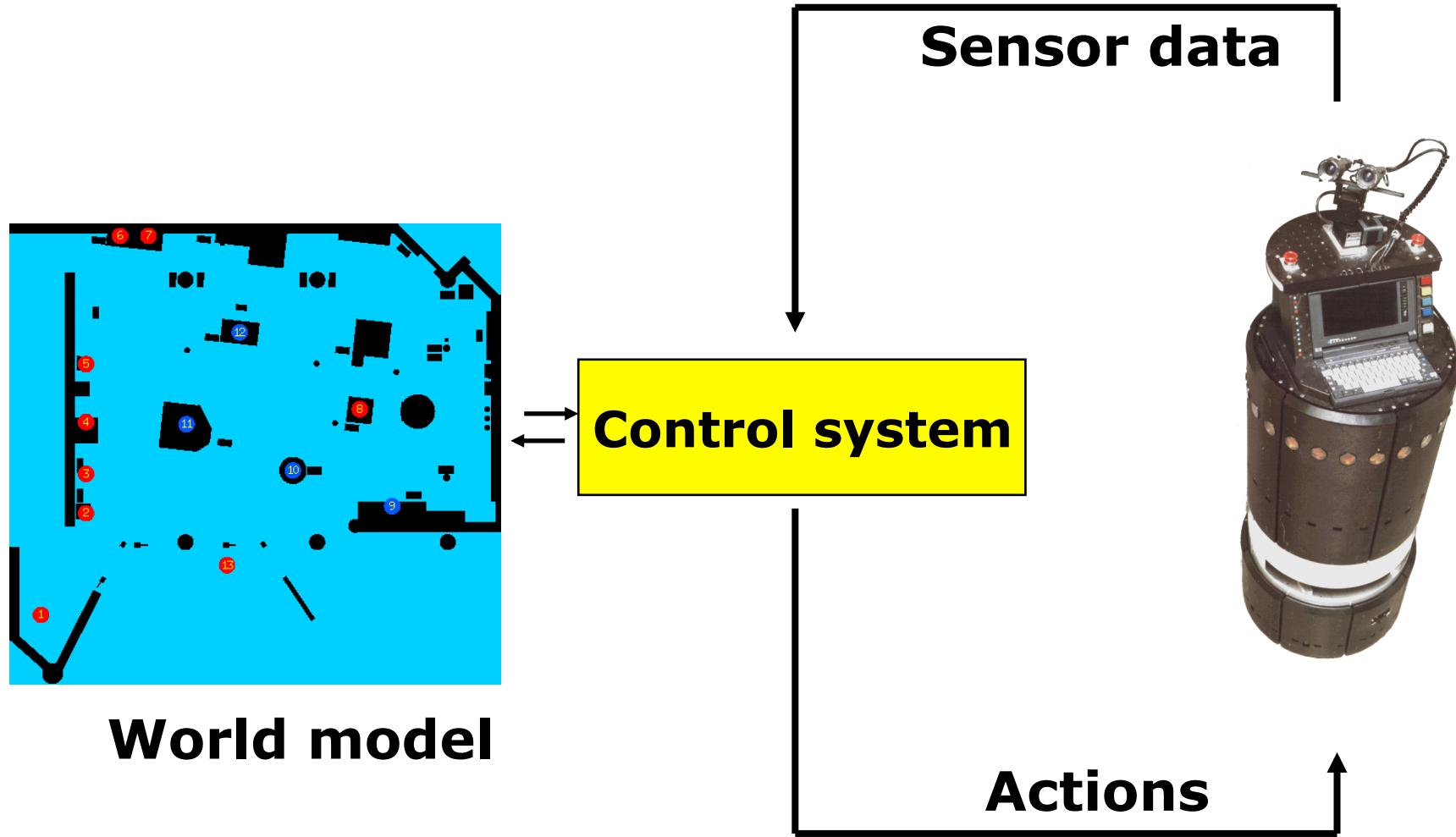
# Organization

- Tue 2pm – 4pm  
Fr 2pm – 3pm
  - lectures, discussions
- Fr 3pm – 4pm
  - homework, practical exercises
- Web page:
  - [www.informatik.uni-freiburg.de/~ais/](http://www.informatik.uni-freiburg.de/~ais/)

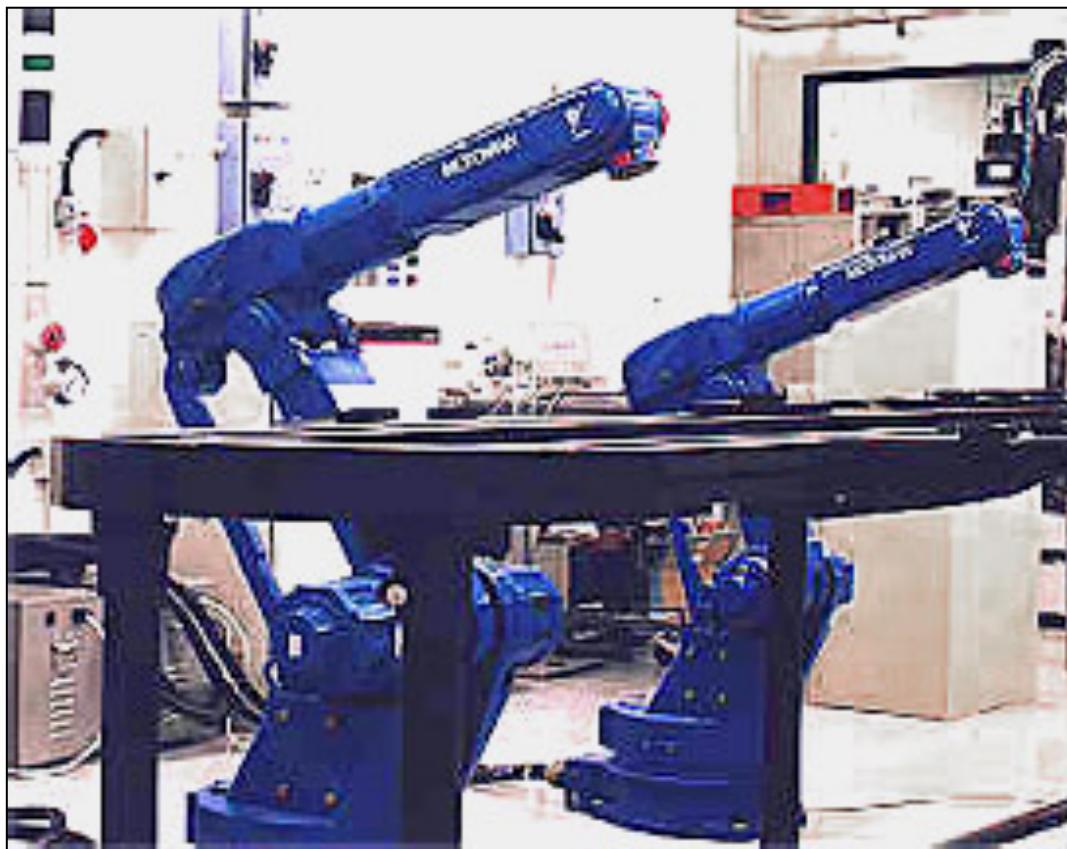
# Goal of this course

- Provide an overview of problems / approaches in mobile robotics
- Probabilistic reasoning: Dealing with noisy data
- Hands-on experience

# AI View on Mobile Robotics



# Robotics Yesterday

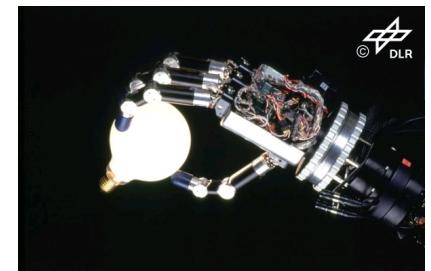


# Current Trends in Robotics

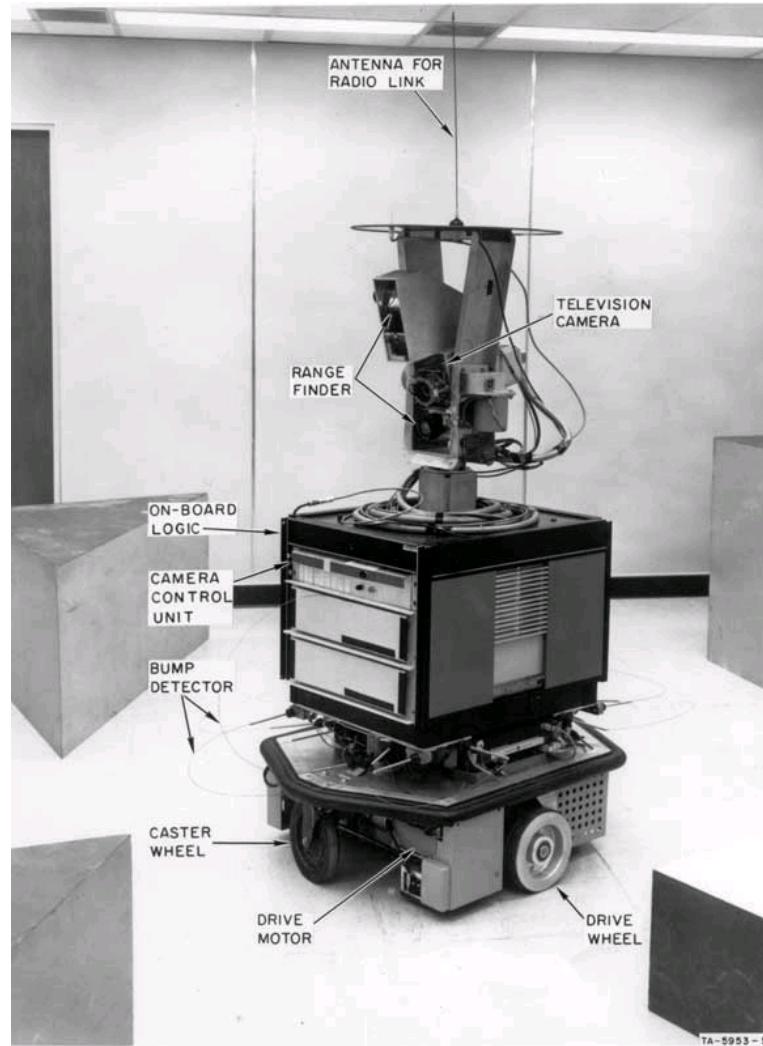
Robots are moving away from factory floors to

- Entertainment, toys
- Personal services
- Medical, surgery
- Industrial automation  
(mining, harvesting, ...)
- Hazardous environments  
(space, underwater)

# Robotics Today



# Shakey the Robot



[Shortcut to Shakey.ram.lnk](#)



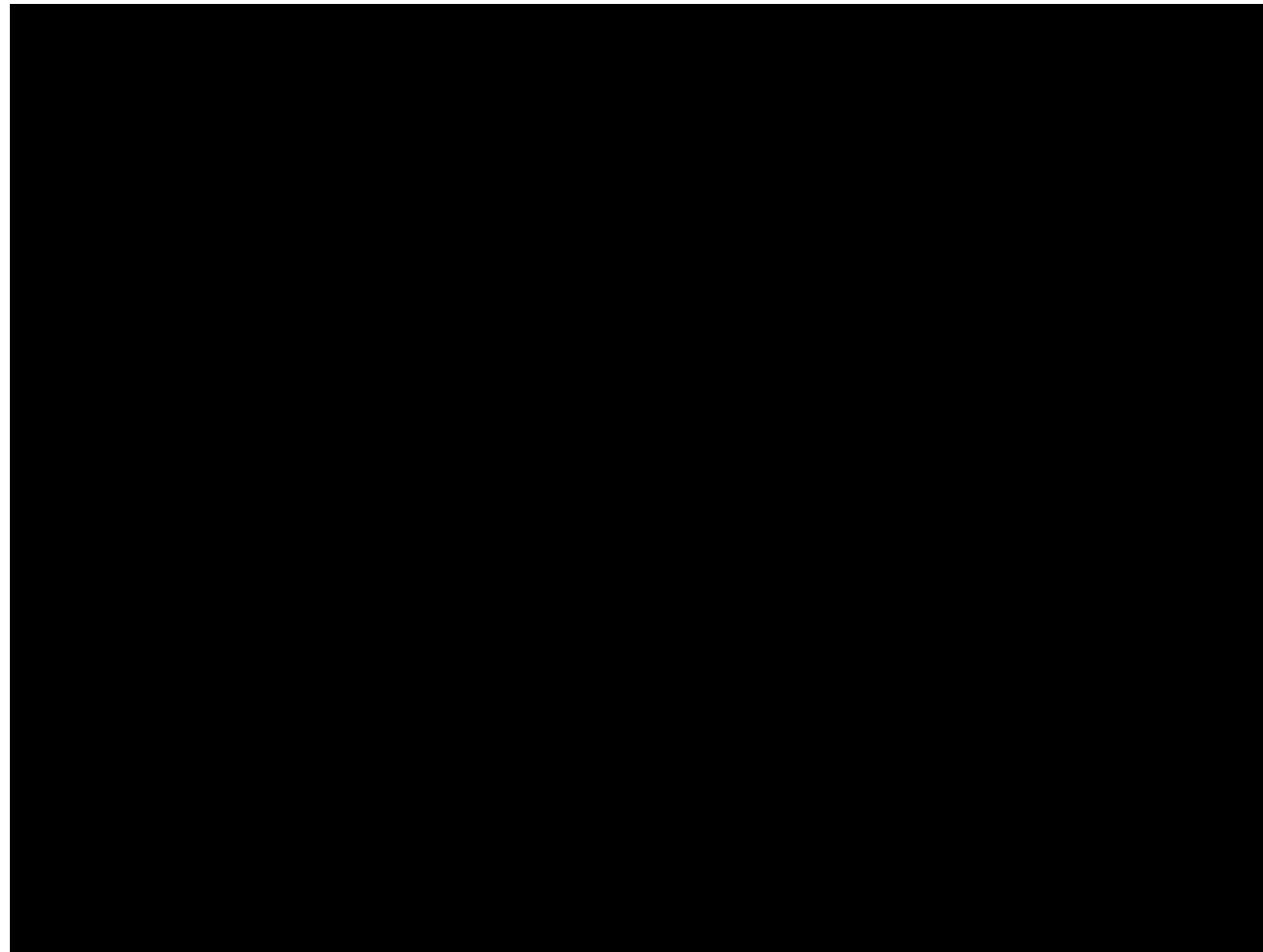
# Shakey the Robot



# The Helpmate System



# Mobile Manipulation



[Brock et al.]

# DARPA Grand Challenge

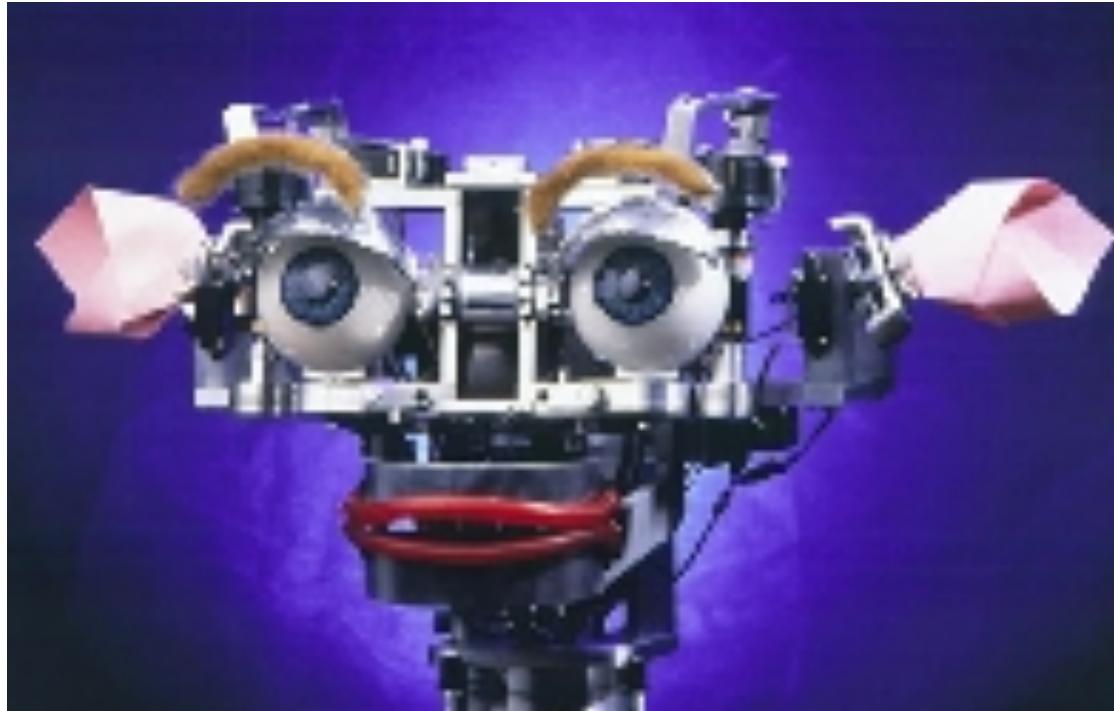


[Courtesy by Sebastian Thrun]

# RoboCup-99, Stockholm, Sweden



# Emotional Robots: Cog & Kismet



[Brooks et al., MIT AI Lab, 1993]

# PR2 Robot



pr2-drawing.m4v

# General Background

- Autonomous, automaton
  - self-willed (Greek, auto+matos)
- Robot
  - Karel Capek in 1923 play R.U.R.  
(Rossum's Universal Robots)
    - labor (Czech or Polish, robota)
    - workman (Czech or Polish, robotnik)

# Asimov's Three Laws of Robotics

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except when such orders would conflict with the first law.
3. A robot must protect its own existence as long as such protection does not conflict with the first or second law.

[Runaround, 1942]

# Wiener, Cybernetics

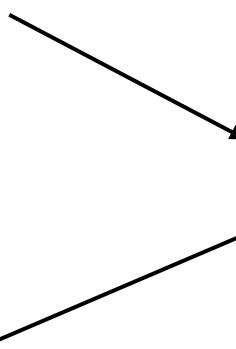
- Studied regulatory systems and their application to control (antiaircraft gun)
- “it has long been clear to me that the modern ultra-rapid computing machine was in principle an ideal central nervous system to an apparatus for automatic control; and its input and output need not be in the form of numbers or diagrams, but might very well be, respectively, the readings of artificial sensors such as photoelectric cells or thermometers, and the performance of motors or solenoids”.

[Electronics, 1949]

# Trends in Robotics Research

## Classical Robotics (mid-70' s)

- exact models
- no sensing necessary

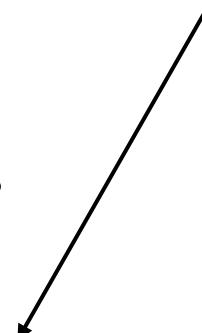


## Reactive Paradigm (mid-80' s)

- no models
- relies heavily on good sensing

## Hybrids (since 90' s)

- model-based at higher levels
- reactive at lower levels



## Probabilistic Robotics (since mid-90' s)

- seamless integration of models and sensing
- inaccurate models, inaccurate sensors

# Brief Case Study: Museum Tour-Guide Robots



Rhino, 1997



Minerva, 1998

# Rhino

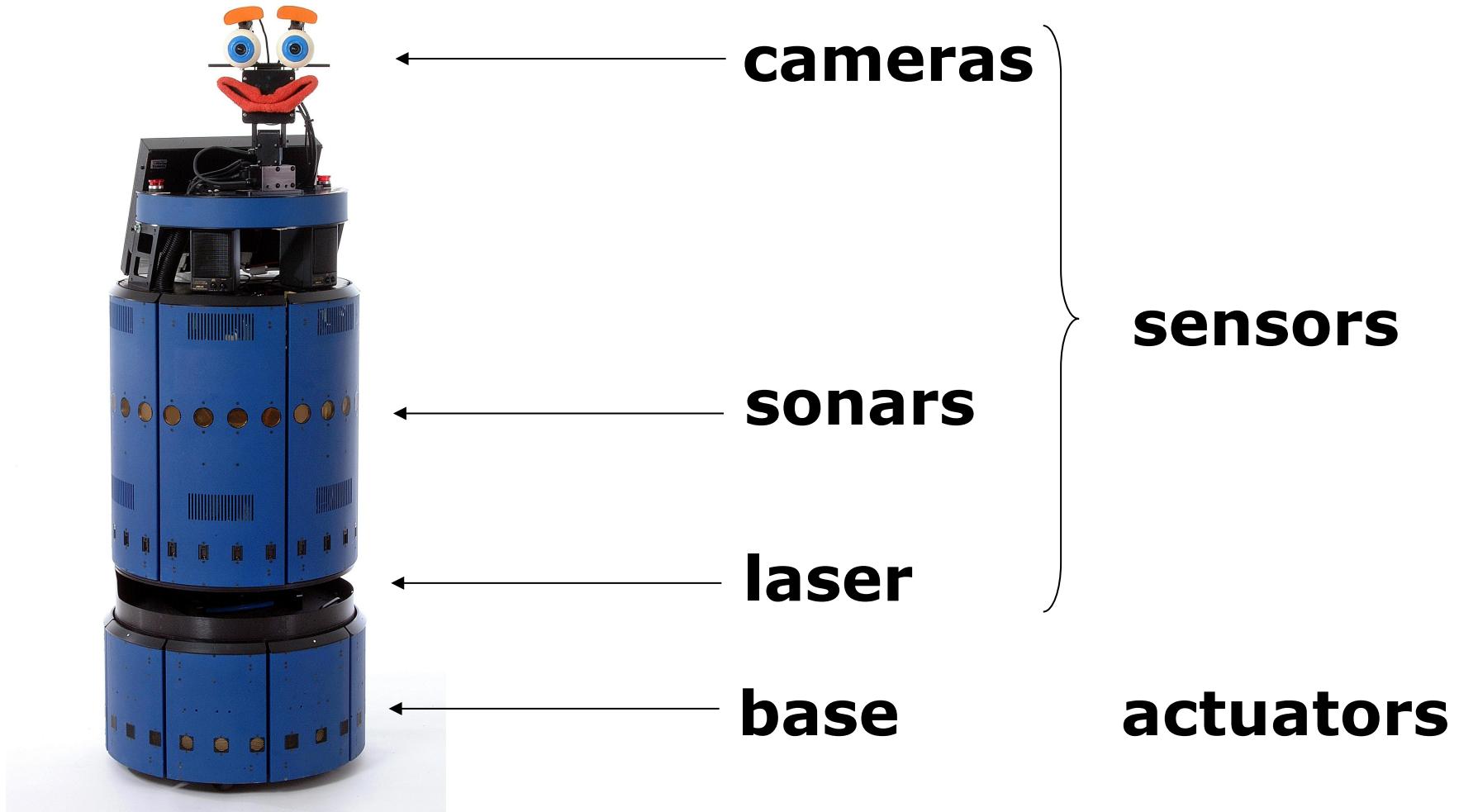
(Univ. Bonn + CMU, 1997)



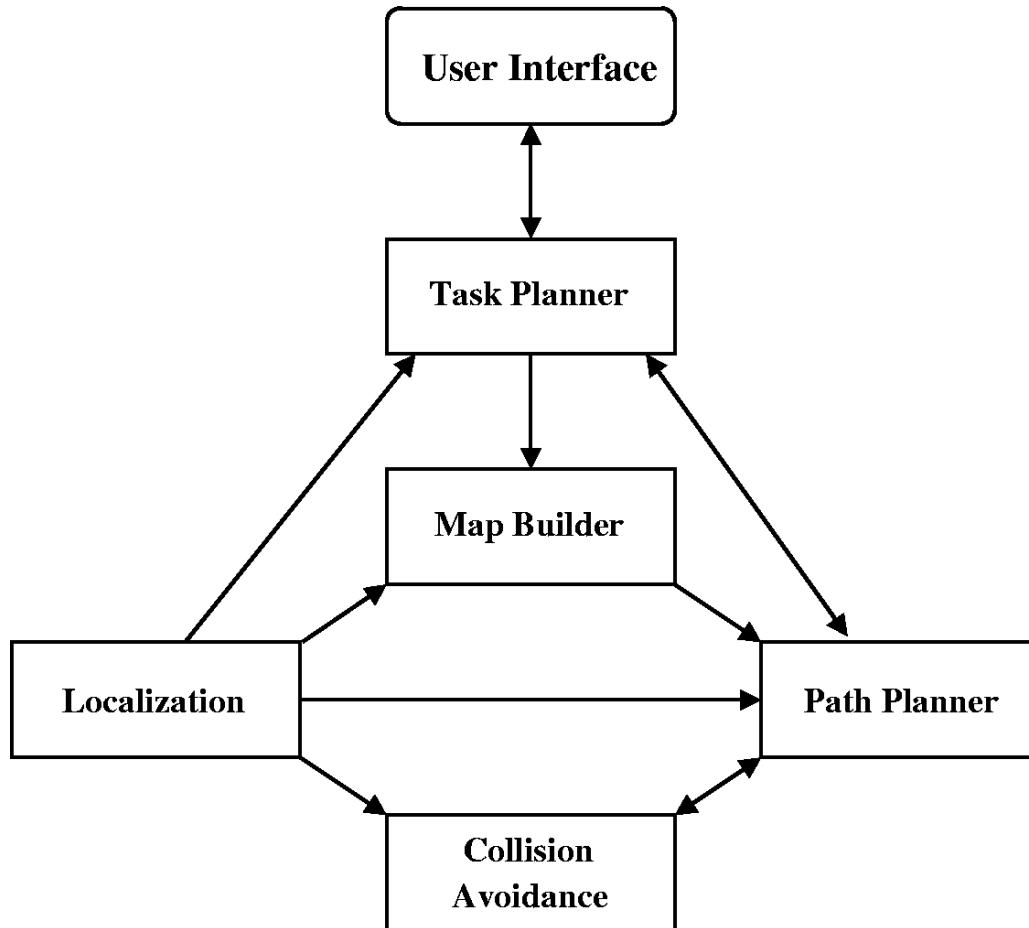
# **Minerva**      (CMU + Univ. Bonn, 1998)



# Components of Typical Robots



# Architecture of a Typical Control System



# Robotics in Freiburg



Foundations of Artificial Intelligence  
Bernhard Nebel



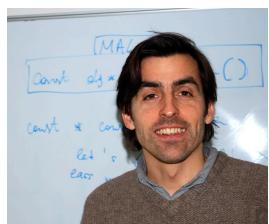
Machine Learning  
Martin Riedmiller



Autonomous Intelligent Systems  
Cyrill Stachniss



Autonomous Intelligent Systems  
Wolfram Burgard



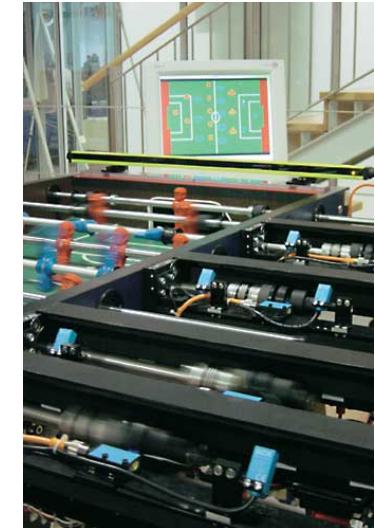
Social Robotics  
Kai Arras



Humanoid Robots  
Maren Bennewitz

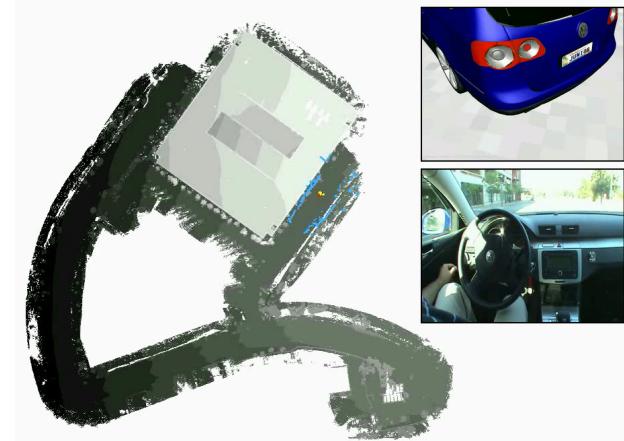
# Foundations of Artificial Intelligence

- Action Planning: Theory and Practice
  - Fast planning systems (intern. competitions!)
  - Applications at airports and for lift systems
  - Theoretical results (see new Russell/Norvig)
  - SFB AVACS
- Qualitative Temporal-Spatial Reasoning
  - Theory and reasoning algorithms
  - Application in qualitative layout description
  - SFB “Spatial Cognition”
- RoboCup
  - World champion three times
  - Autonomous table soccer
  - RoboCup Rescue  
(Multi-Agent-System for disaster relief)



# Autonomous Intelligent Systems

- Mobile robots
- State estimation and models
- Adaptive techniques and learning
- Multi-robot systems
- Applications of mobile robots
- Robots and embedded systems
- Interaction and Web interfaces
- Probabilistic robotics



# Machine Learning Lab

- Reinforcement Learning
- Supervised Learning
- Efficient Learning Algorithms
- Learning in Multi-Agent systems
- Self-learning robots
- Neural Forecasting Systems
- Neural Controllers
- Learning soccer robots in RoboCup
- Industrial Applications



# Humanoid Robots

- Development of techniques for robots with
  - human-like body plan
  - human-like senses
- Navigation in complex indoor environments
  - 3D environment modeling
  - Path planning
  - Classification and learning
- Natural human-robot interaction
  - State estimation and modeling of people
  - Speech, gestures, facial expression, etc.



# Social Robotics Lab

- Towards socially compatible robots
- Social learning, learning by observation
- People detection and tracking
- Motion planning
- Robot navigation
- Spatio-temporal models of human social behavior
- Human–robot interaction

"Free robots from their social isolation"

