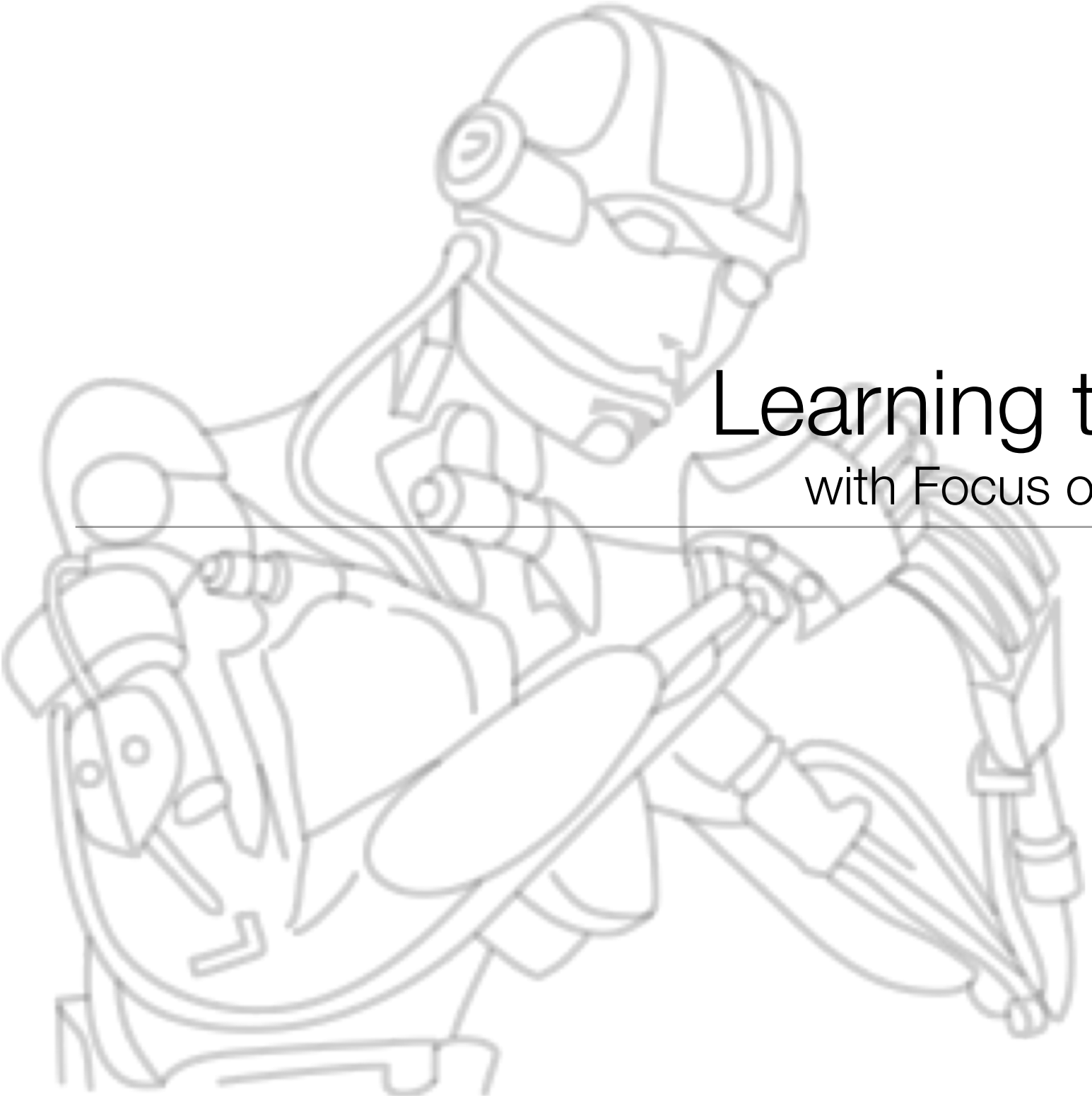


Learning to Control

with Focus on Robot Control

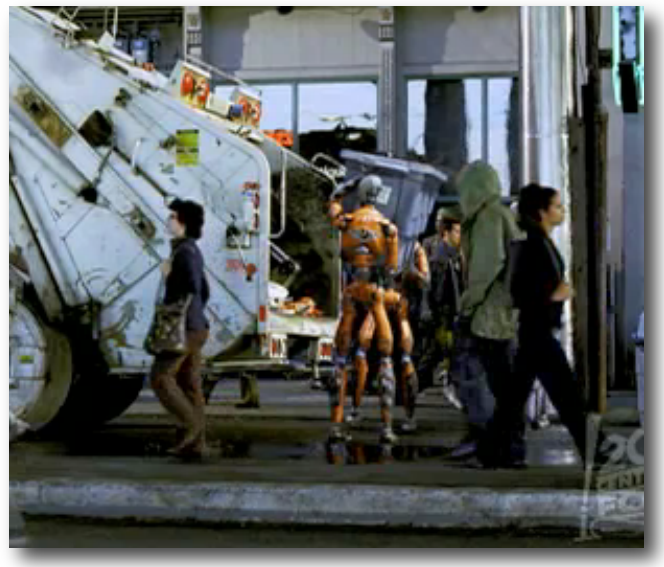
Jan Peters
Gerhard Neumann

TECHNISCHE
UNIVERSITÄT
DARMSTADT

Motivation

Source: Movie iRobot

Future of Robotics
from Hollywood's Perspective

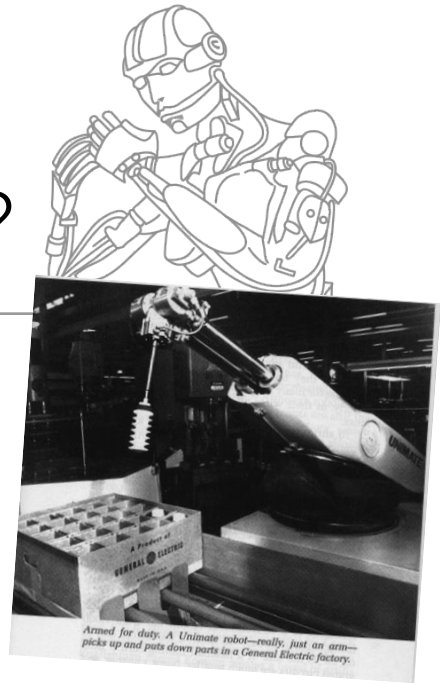


Can we create humanoid robots like this?

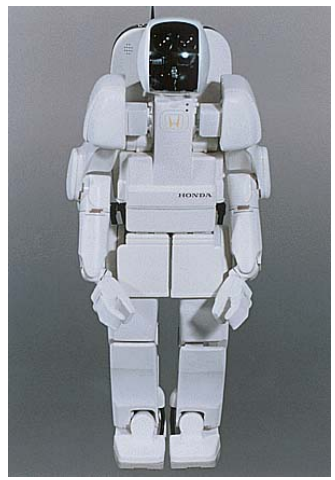
Humanoid Robots: Are they becoming reality?

- 1921 Karel Capek's play "Rossums Universial Robots"
- 1927 Years after Fritz Langs movie "Metropolis"
- 1961 Joseph Engelberger's first industrial robot arm
- 1977 C3PO and R2D2 win our hearts...
- 1996 Honda represents the first full humanoid robot

R2D2 & C3PO

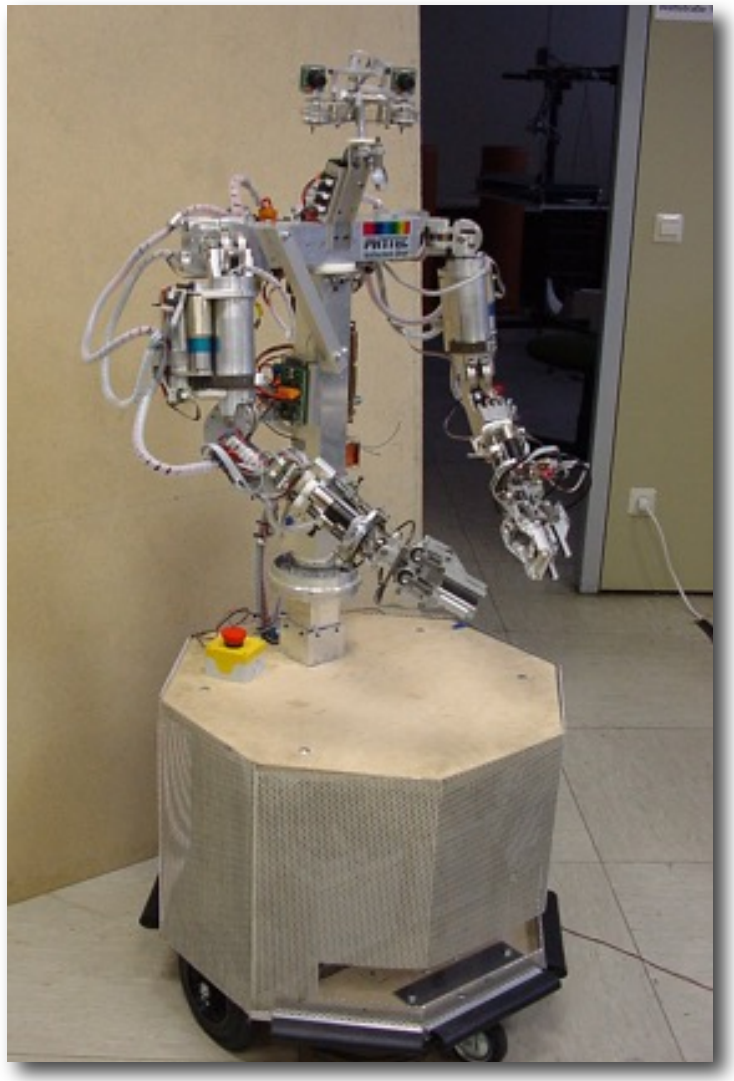


Engelberger's Unimate

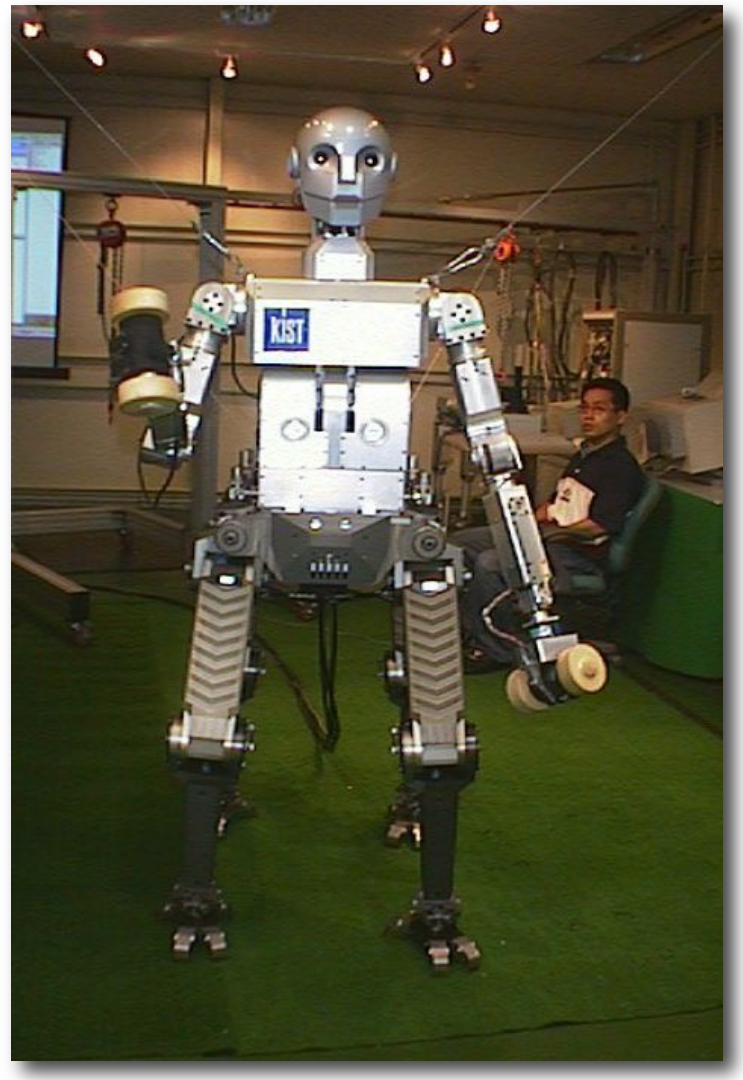


Honda's P3 Robot

More Humanoid Robots…!



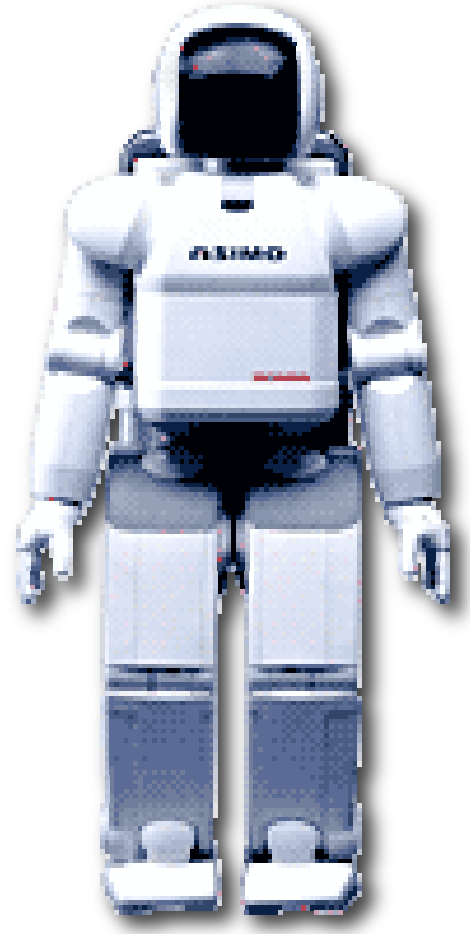
Amar–FZI, Karlsruhe



Centaur–KIST, Korea

More Humanoid Robots…!

Hoap–Fujitsu, Japan



Asimo–Honda, Japan

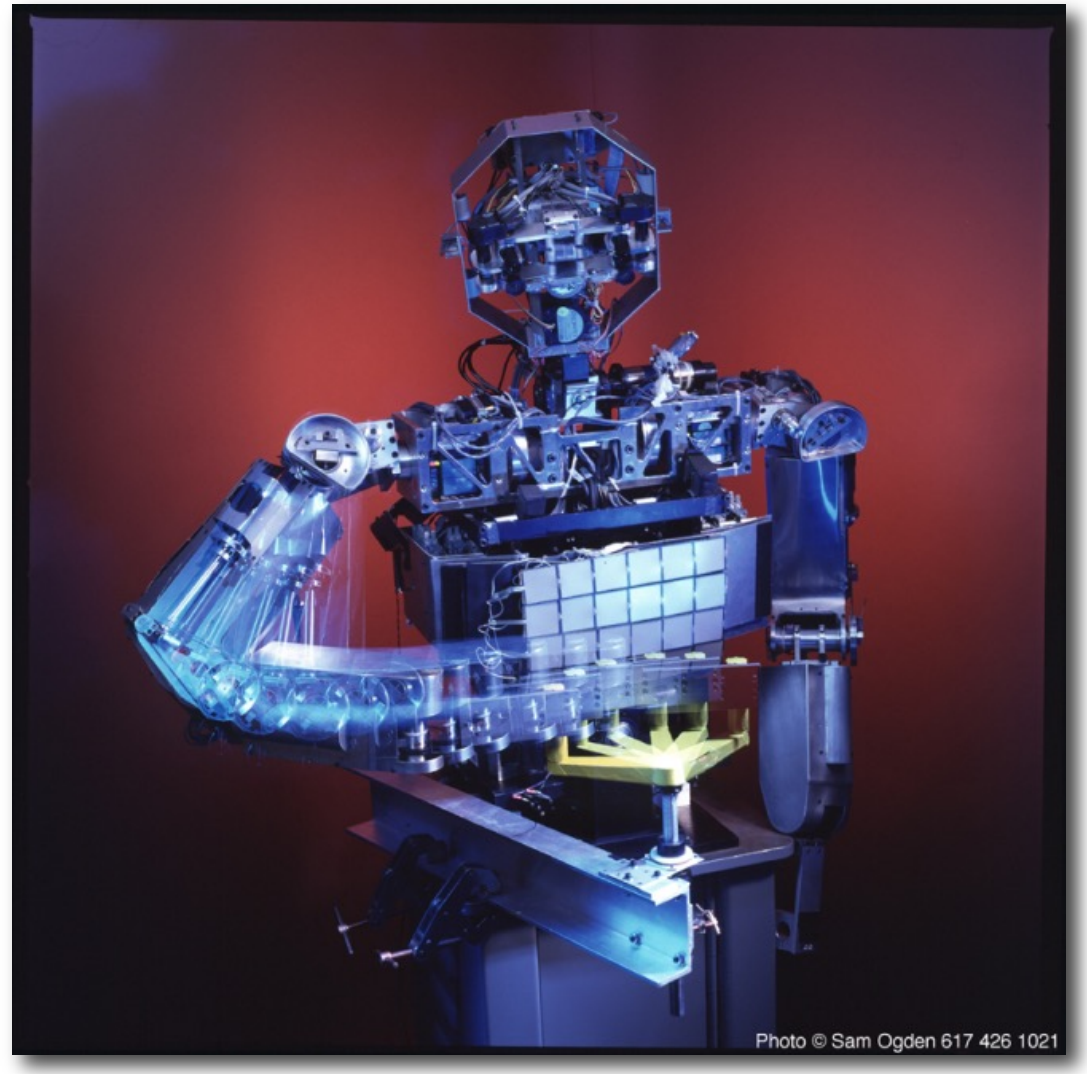
More Humanoid Robots…!

HRP-2P–Kawada, Japan

Isamu–Kawada, Japan

More Sophisticated Humanoids…

Jack–ETL, Japan



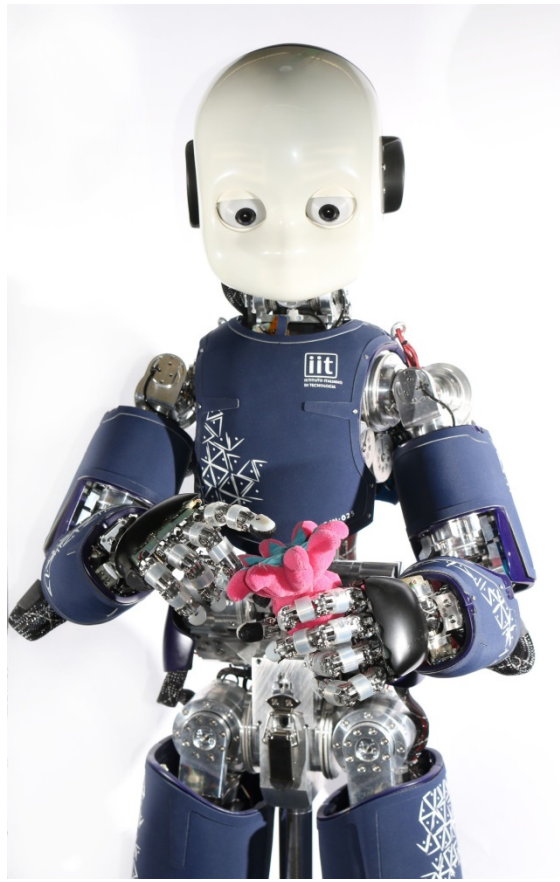
Cog–MIT

Human-Like Humanoid Robots…

Ishiguro Androids, ATR + University of Osaka

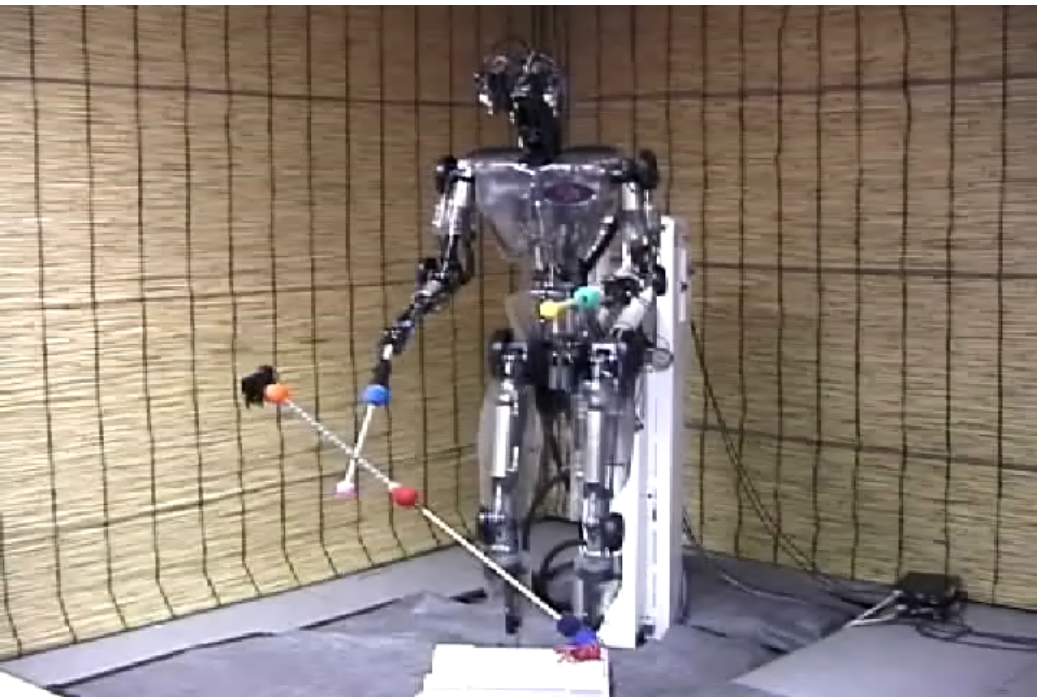
Humanoid Robots: Design is feasible!

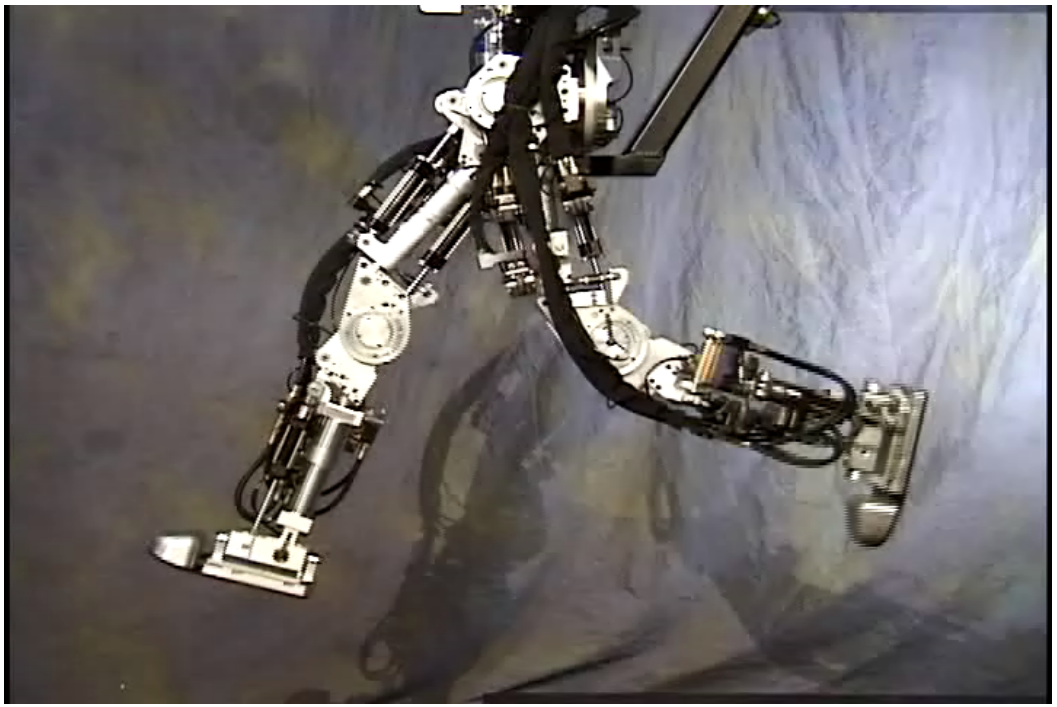
Justin, DLR,Germany



ICub

Humanoid Robots: Design is feasible!





Sarcos Humanoid Robots

State of the art in robotics: Wildcat

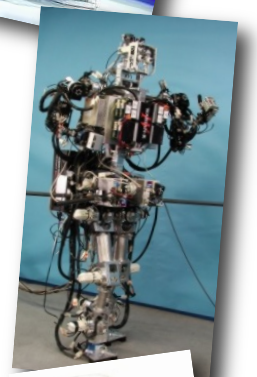
State of the art in robotics: Petman

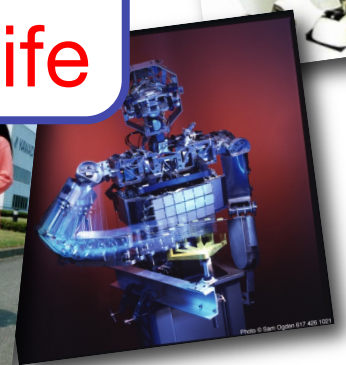
State of the art in robotics: (The all new) Asimo

State of the art in robotics: (The all new) Asimo

State of the art in robotics: (The all new) Asimo

Humanoid Robotics: How can we make them do something?

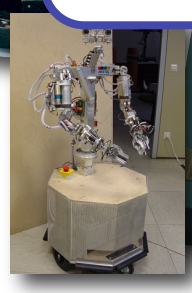


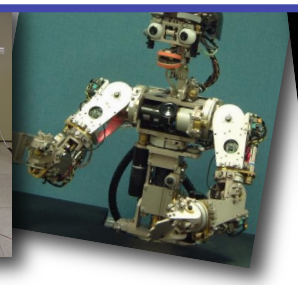


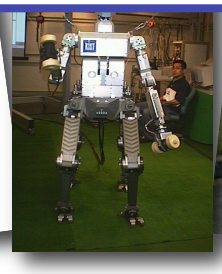
- Several hundred different humanoid robots have been designed!

- Why don't we see them outside research labs?
  - Programming robots is a LOT of work
  - There is no general concept of how we can automatically create motor skills to date!

Learning is needed to incorporate autonomous robots in our every-day's life







Robots needs Machine Learning!

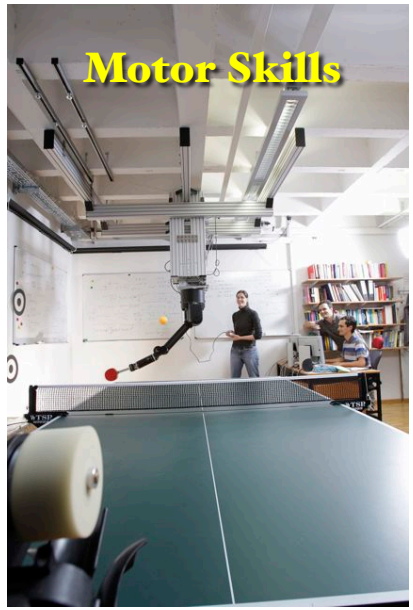
- “I have always said that the time for robot learning would come later. [...] Analytical robotics has barely moved for ten years. The time for learning is now.”

Oussama Khatib, Stanford University, 10/17/2006

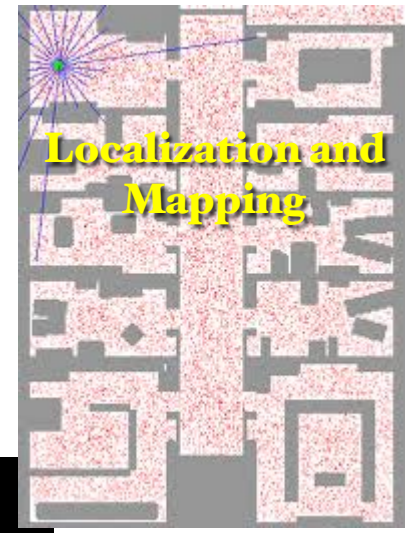
- “Robot learning is the single most important problem in robotics.”

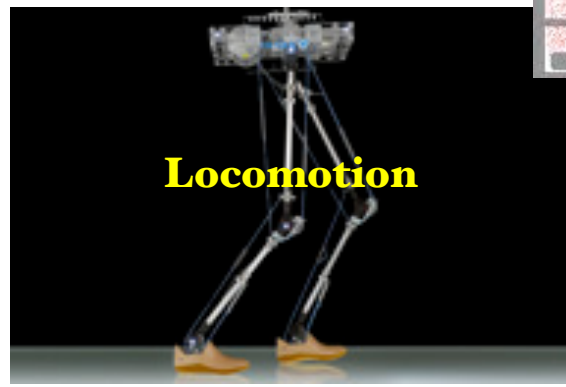
John Hollerbach, University of Utah, 12/7/2007

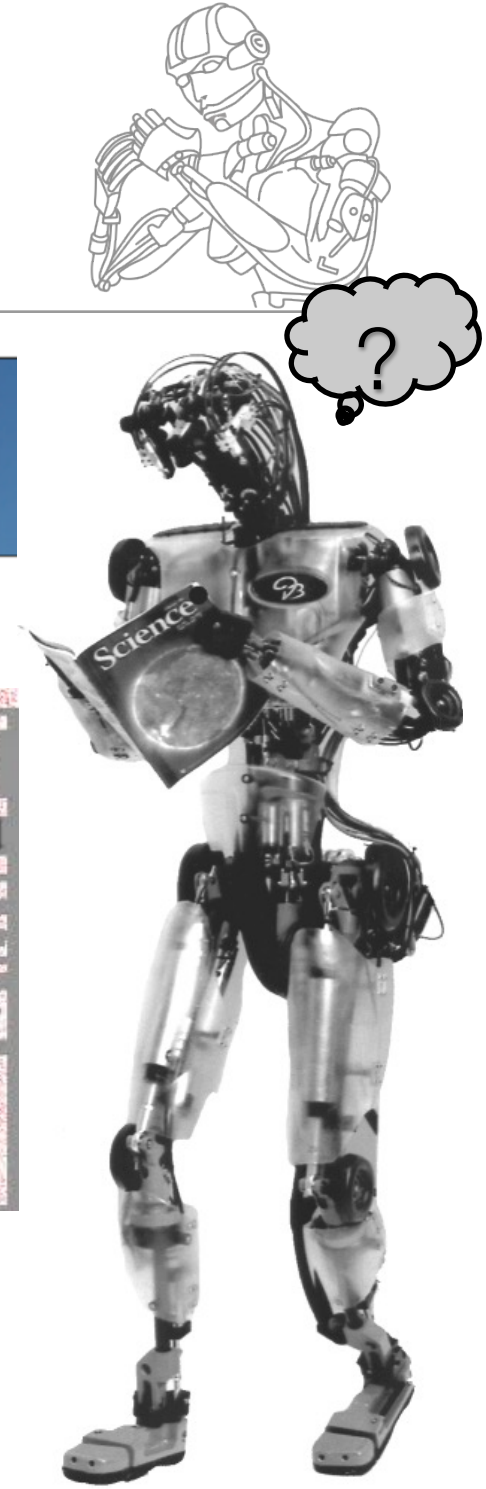
What can robots learn?



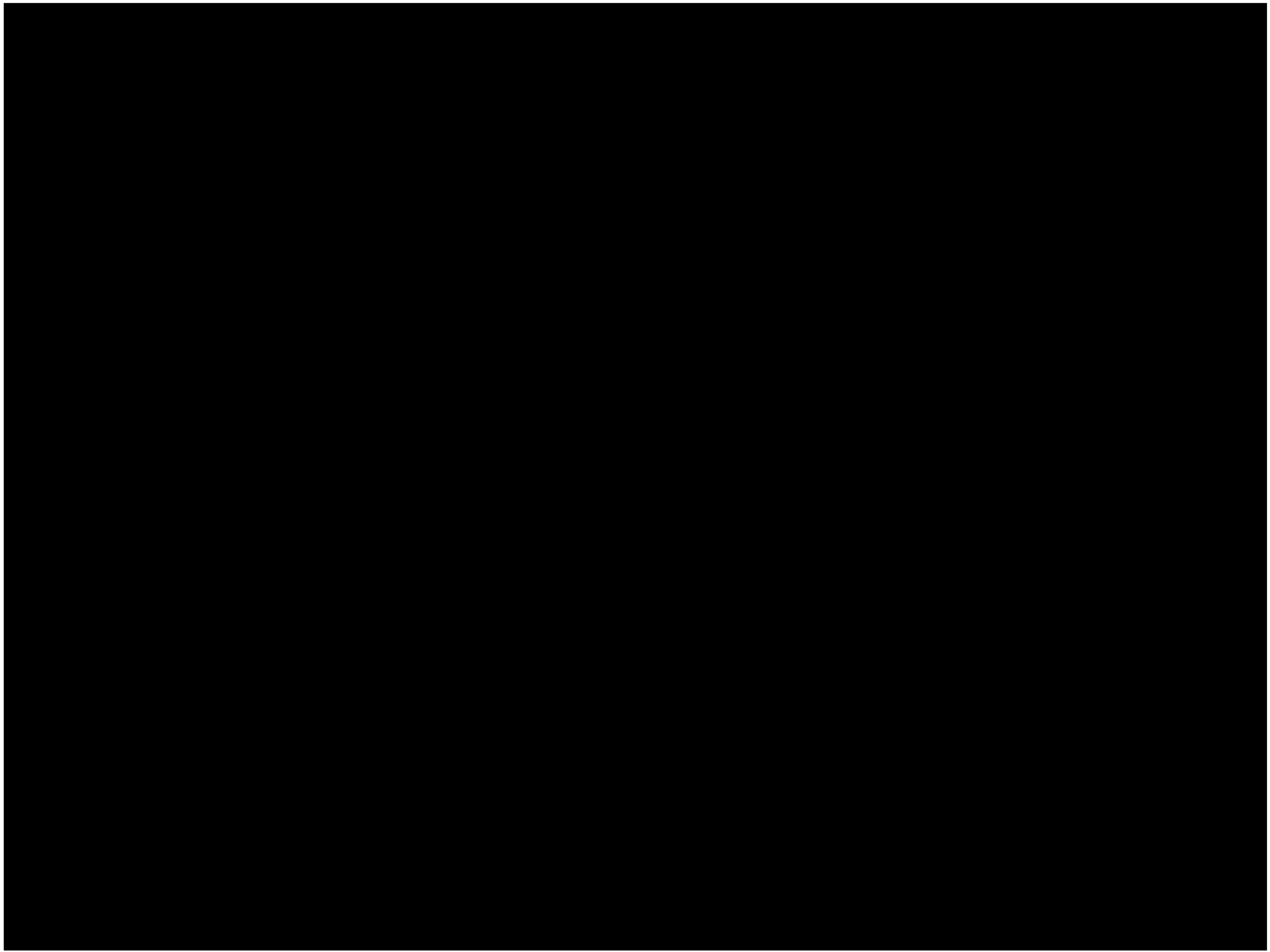
Acrobatik in der Luft kann mit Apprenticeship Learning gelernt werden wie hier von Pieter Abeel [University of California in Berkeley] sowie Adam Coates, Morgan Quigley und Andrew Ng [Stanford University].



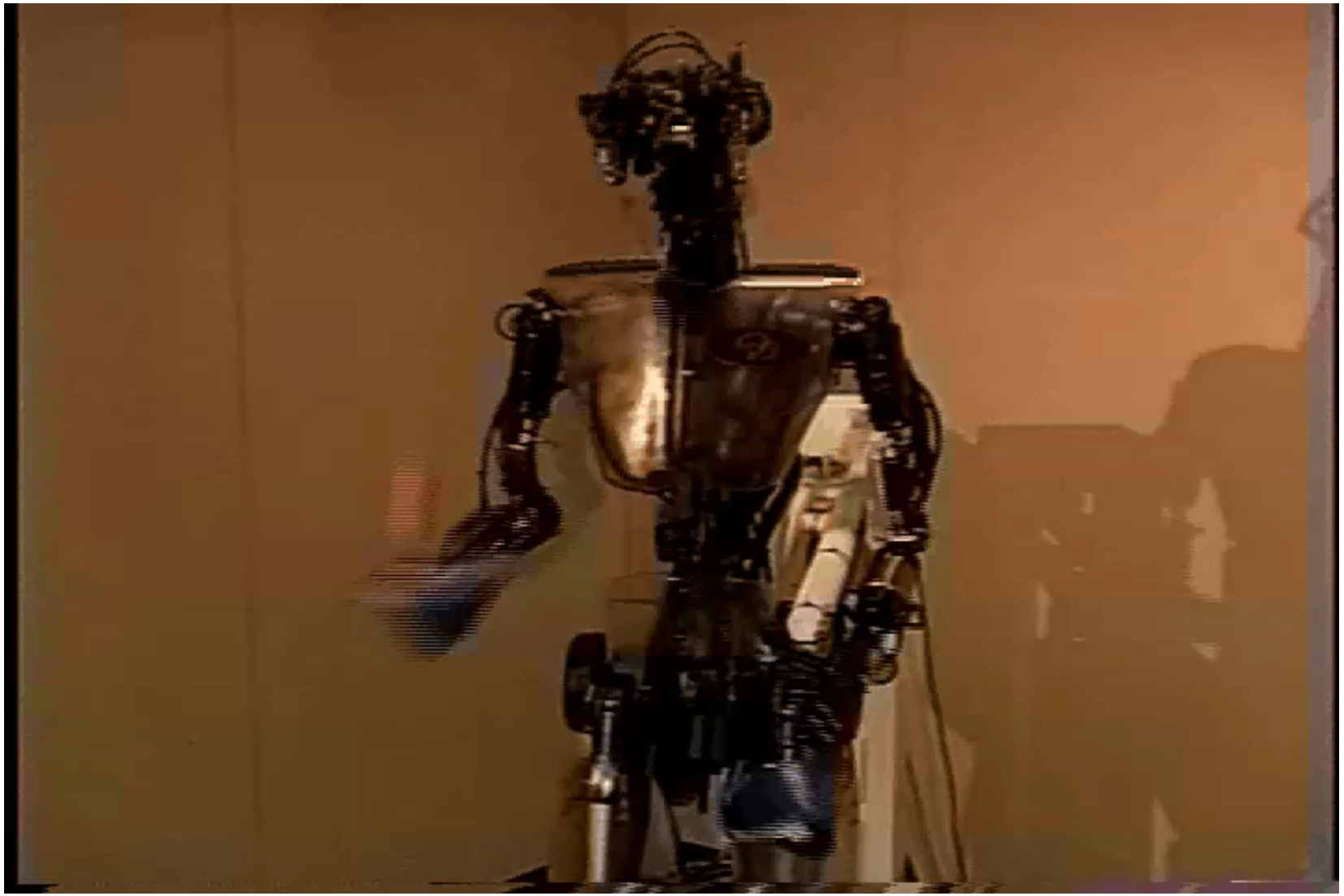




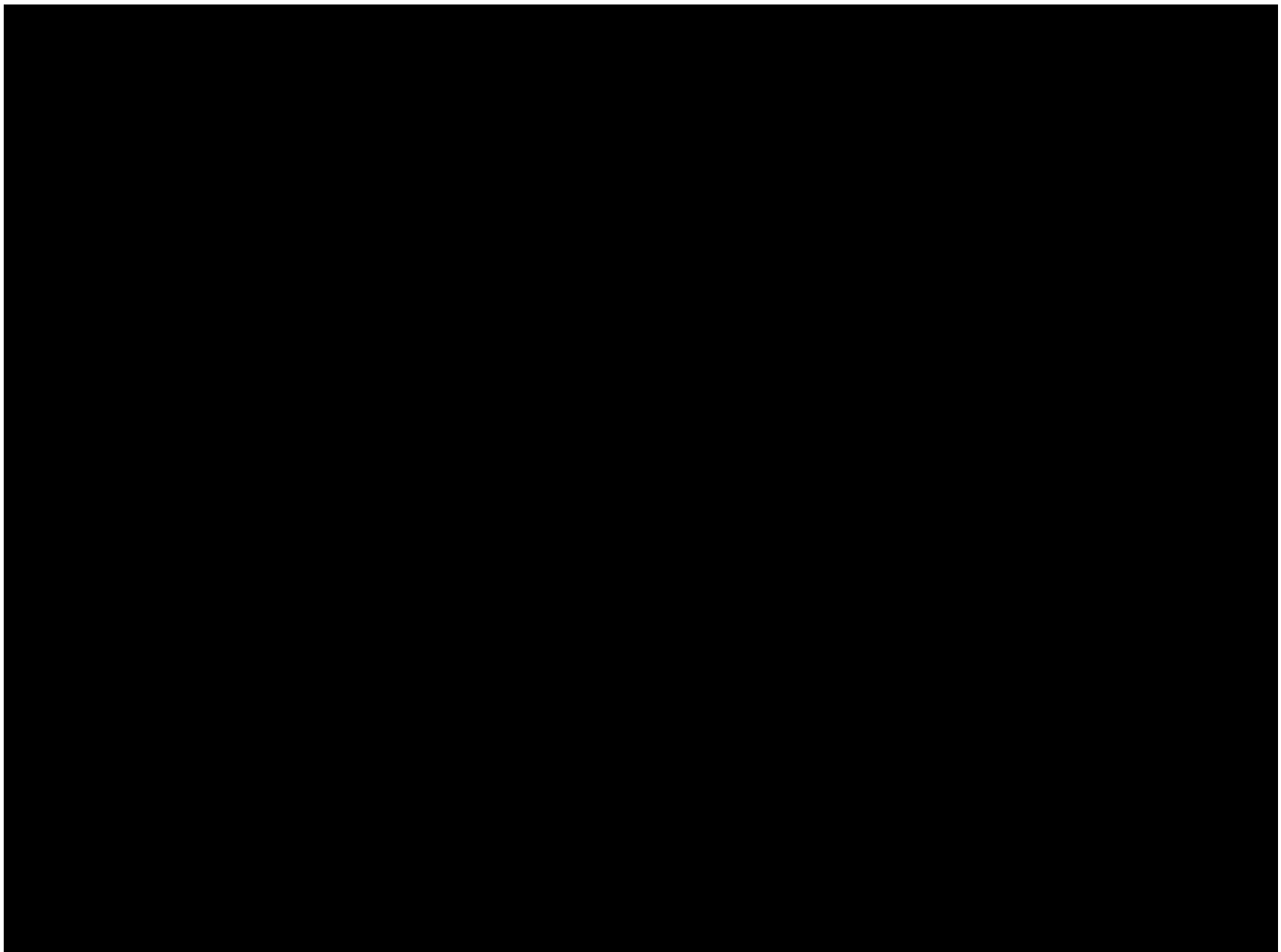
What can robots learn? Motor Skills!



What can robots learn? Motor Skills!



What can robots learn? Motor Skills



What can robots learn? Motor Skills

What can robots learn? Games

What can robots learn? Locomotion

Topics of the Lectures

- Introduction
- Foundations: **Robotics in a Nutshell**
- Foundations: **Machine Learning in just a few minutes…?**
- **Model Learning** in Control & Robotics
- **Representations of Control Policies for Machine Learning**
- Imitation by **Behavioral Cloning**
- Reinforcement Learning I: **Optimal Control** with Approximate Learned Models
- Reinforcement Learning II: **Value Function Methods**
- Reinforcement Learning III: **Policy Search Methods**
- Imitation by **Inverse Reinforcement Learning**
- Outlook and Challenges