Humanoid Robots

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Outline

- Motivation
- Humanoid Projects
- RoboCup Humanoid League
- Team NimbRo
- Robots
  - Alpha
  - RoboSapien
  - Kondo
  - Toni
- Personal Robots

Sony QRIO

Need for Humanoid Robots


Automated production

Karlsruhe ARMAR

- Industrial robots not flexible enough for unmodified environments
- Separated from humans
- New applications: Service, household helper, entertainment, ...
- Interaction with people needed
- Human-like body helps when acting in environments designed for humans
- Intuitive multimodal communication
- Programming by demonstration, imitation learning

Artificial Intelligence Research

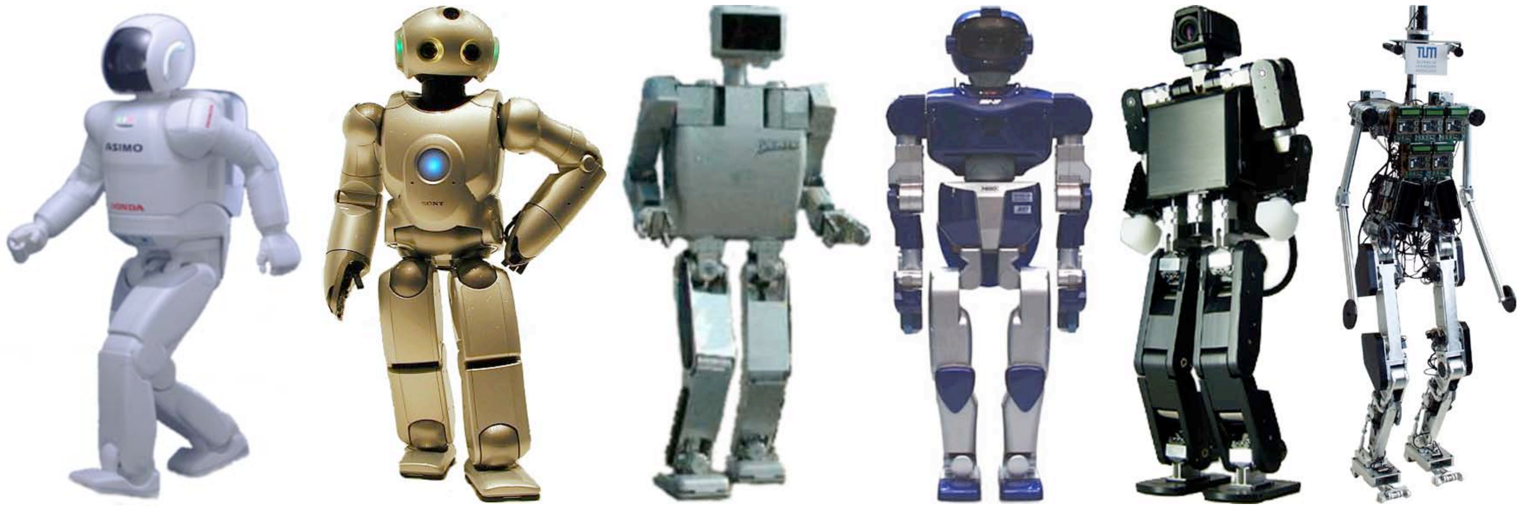
- Intelligence needs body (Embodiment) and interaction with environment (Situatedness)
- Since 1997 RoboCup competitions
- Soccer as new AI benchmark, successor of chess

	Chess	**RoboCup**
Environment	Static	Dynamic
State change	Turn taking	Real-time
Info. accessibility	Complete	Incomplete
Sensor readings	Symbolic	Signals
Control	Central	Distributed

Fungus Eaters

- Humanoid robots as a tool to understand human

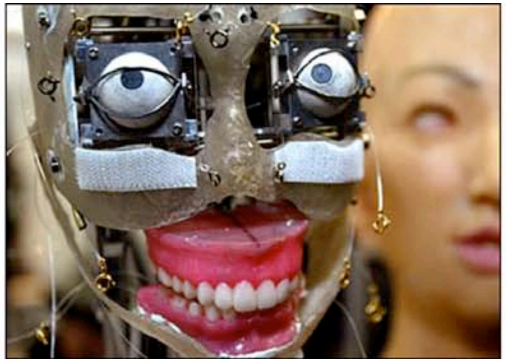
Some Humanoid Robots



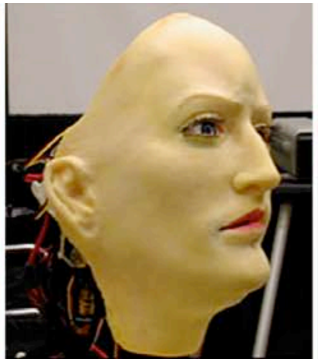
	Asimo	QRIO	H7	HRP-2P	Silf-H2	Johnnie
Manufacturer	Honda	Sony	Univ. Tokyo	AIST/Kawada	K. Ito	TU München
Size	130cm	58cm	147cm	154cm	25cm	180cm
Weight	54kg	7kg	58kg	58kg	730g	40kg
Speed	0.69/0.83m/s	0.33m/s	0.5m/s	0.55m/s	0.1m/s	0.61m/s
DOF	34	28	30	30	20	19
Leg	6	6	7	6	6	6
Arm	7+2	5+Fingers	7	7	3	2
Trunk	1	-	-	2	1	1
Head	3	4	2	2	1	2

Communication Robots

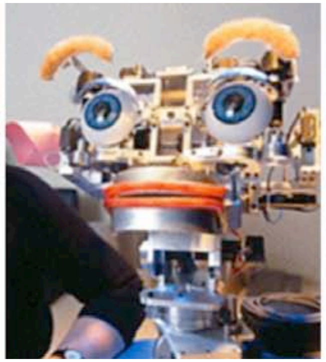
WE-4



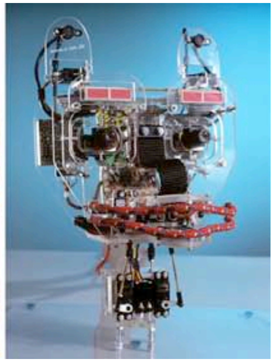
Saya in front of rubber skin



K-bot

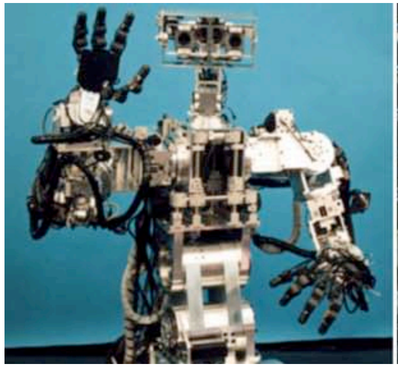


Kismet

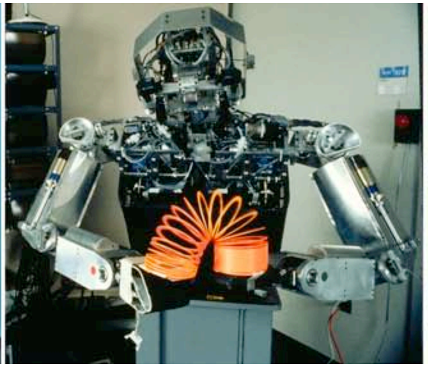


Mexi

Manipulation Robots

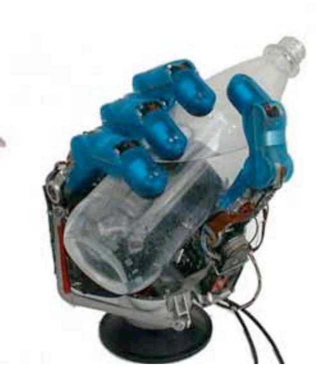


Wendy



Cog

ARMAR



DLR Hand II

FZK-Hand

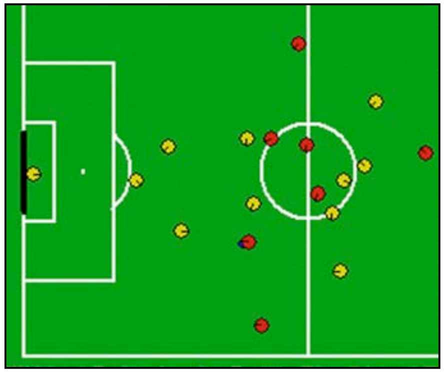
Humanoid Robot Projects

- Waseda Univ.: Wabot-1 (1973), WE-4, Wendy
- Honda: Asimo, since 1986, > $100M
- Sony: QRIO (near production, entertainment)
- Toyota: Trumpet player announced for Expo 2005
- Japan: Atom-Project, Time: 30 years
- USA: Cog, Kismet, Leo, Nursebot
- Germany:
  - Johnnie (TU München)
  - ARMAR (SFB 588 Karlsruhe)
  - Mexi (C-Lab Paderborn)
  - DLR hand, lightweight arm
  - BW Univ. München Hermes

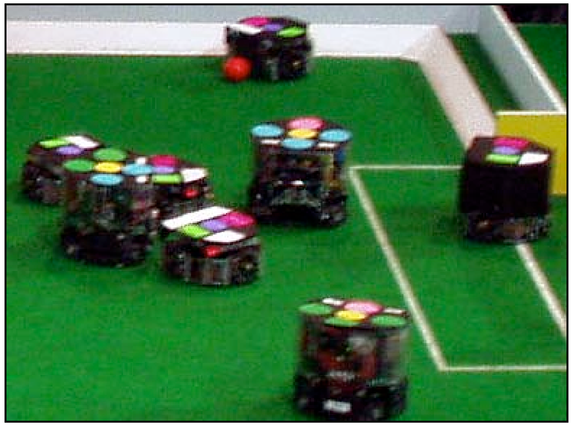
Toyota

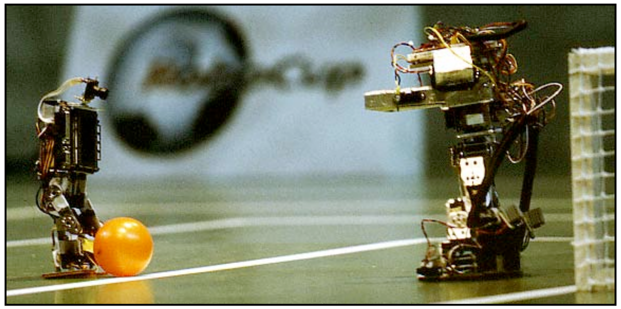
Soccer Leagues

Simulation



SmallSize





Sony Aibo

MidSize

Humanoid

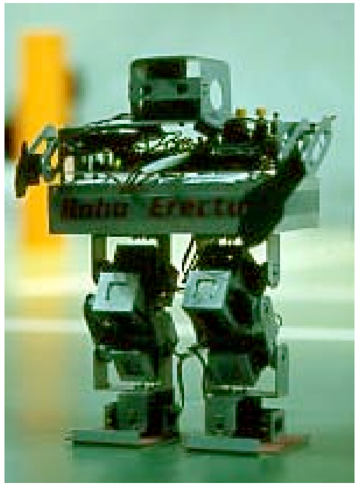
RoboCup Humanoid League

- Since 2002
- Step towards long-term goal:
  "By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champion team."
- So far, preliminary compe
  - Walking
  - Penalty kicks
  - Free performance
  - Technical challenges

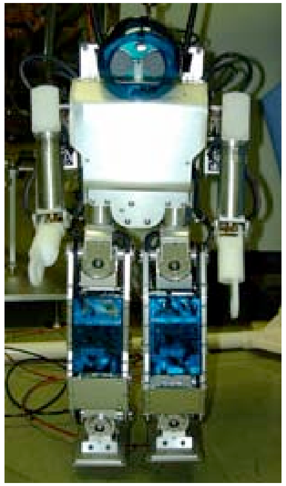
2002 Fukuoka

10 teams

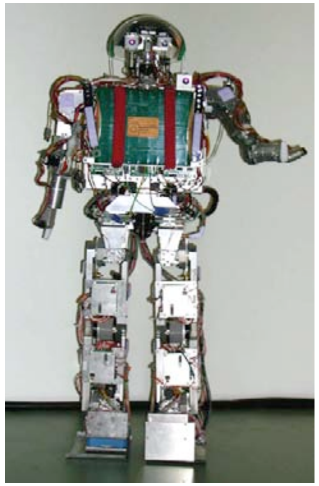
Footprints



Robo Erectus



Hoap-1



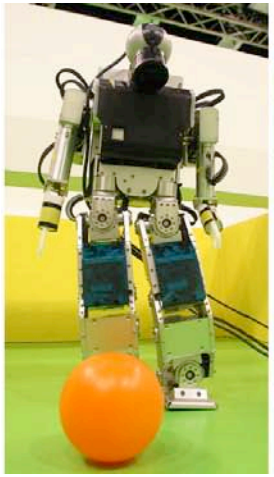
Nagara

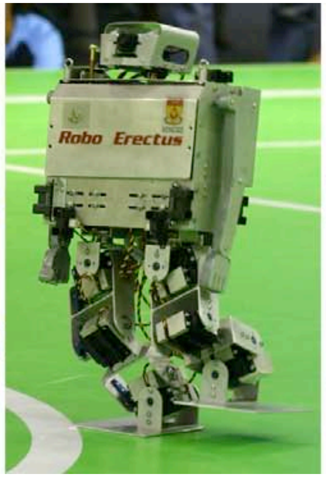
Priscilla

2003 Padova

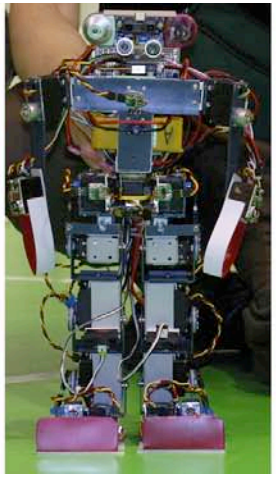
- 7 teams
- Honda Asimo prototype participated as HITS Firstep and won

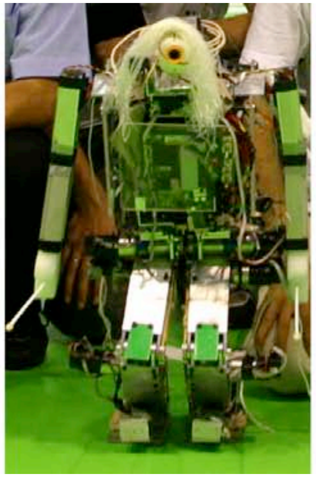

HITS Firstep

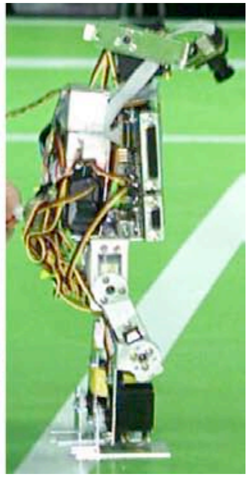

Senchans



Robo Erectus


Foot-Prints


Isaac

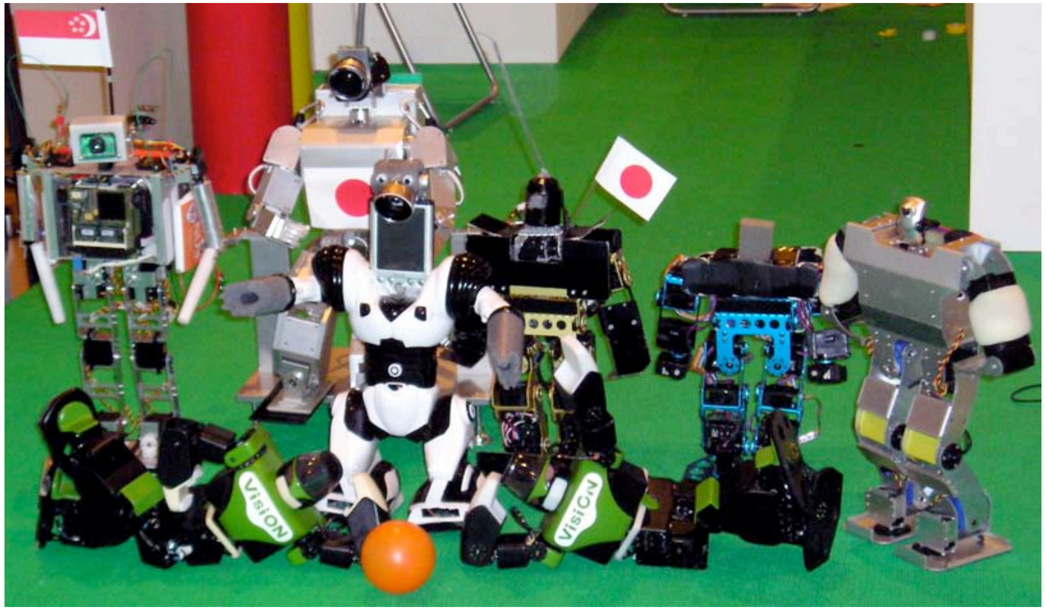

Tao-Pie-Pie

2004 Lisbon

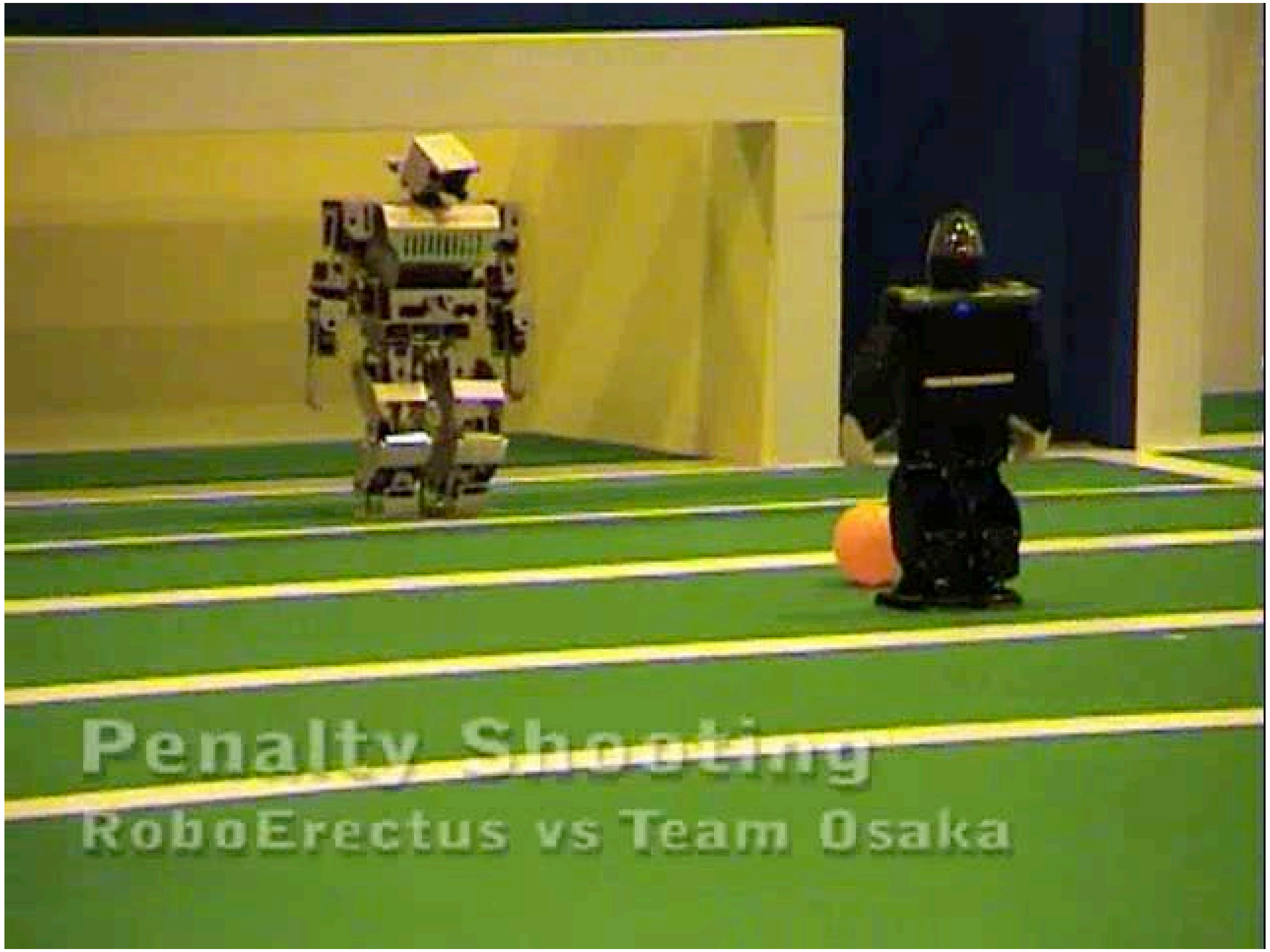
- 13 teams
- VisiON of team Osaka won

Alpha of team NimbRo

Rope, Senchans A, Senchans B, Persia, NimbRo RS, VisiON



RoboCup 2004 H40 Penalty Kick Final



Team NimbRo @ Lisbon

Norbert Mayer, Thorsten Kramer, Michael Schreiber, Sven Behnke, Sven Seuken

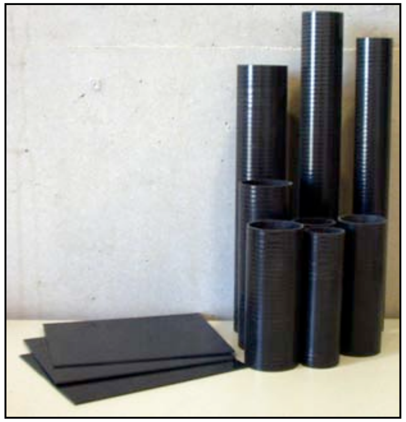
Alpha and RoboSapien

Jörg Stückler, Jürgen Müller, Tobias Langner

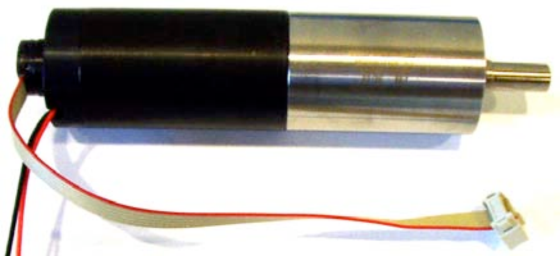
Alpha

- 21 DOFs
  - 6 per leg,
  - 3 per arm,
  - 3 in the trunk
  - Geared DC motors
- 155cm, ~30kg
- Dummy head and hands

Mechanics

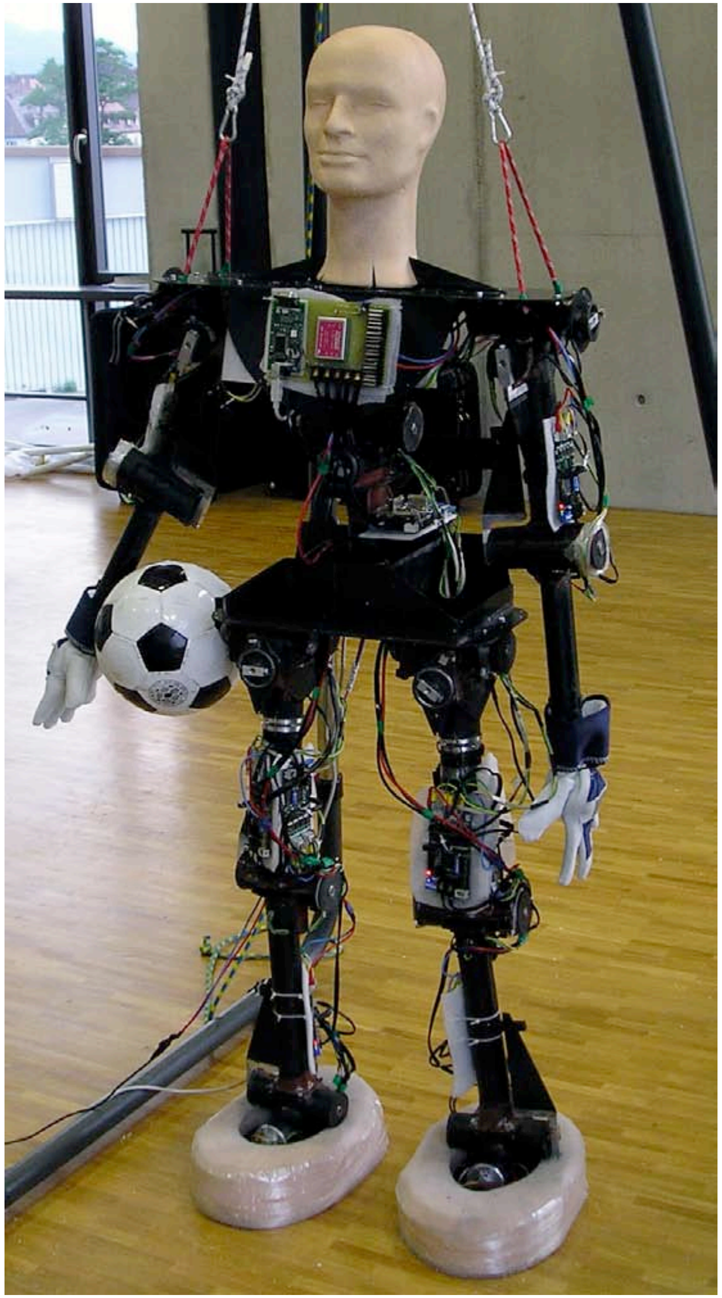


Carbon-composite material



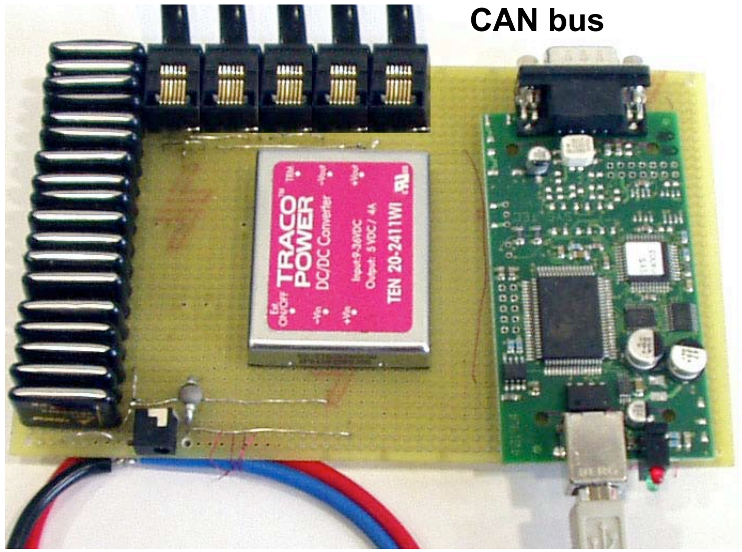
DC motor Faulhaber 3863, 3257
with 66:1 planetary gear
and magnetic encoder

2 DOF joint



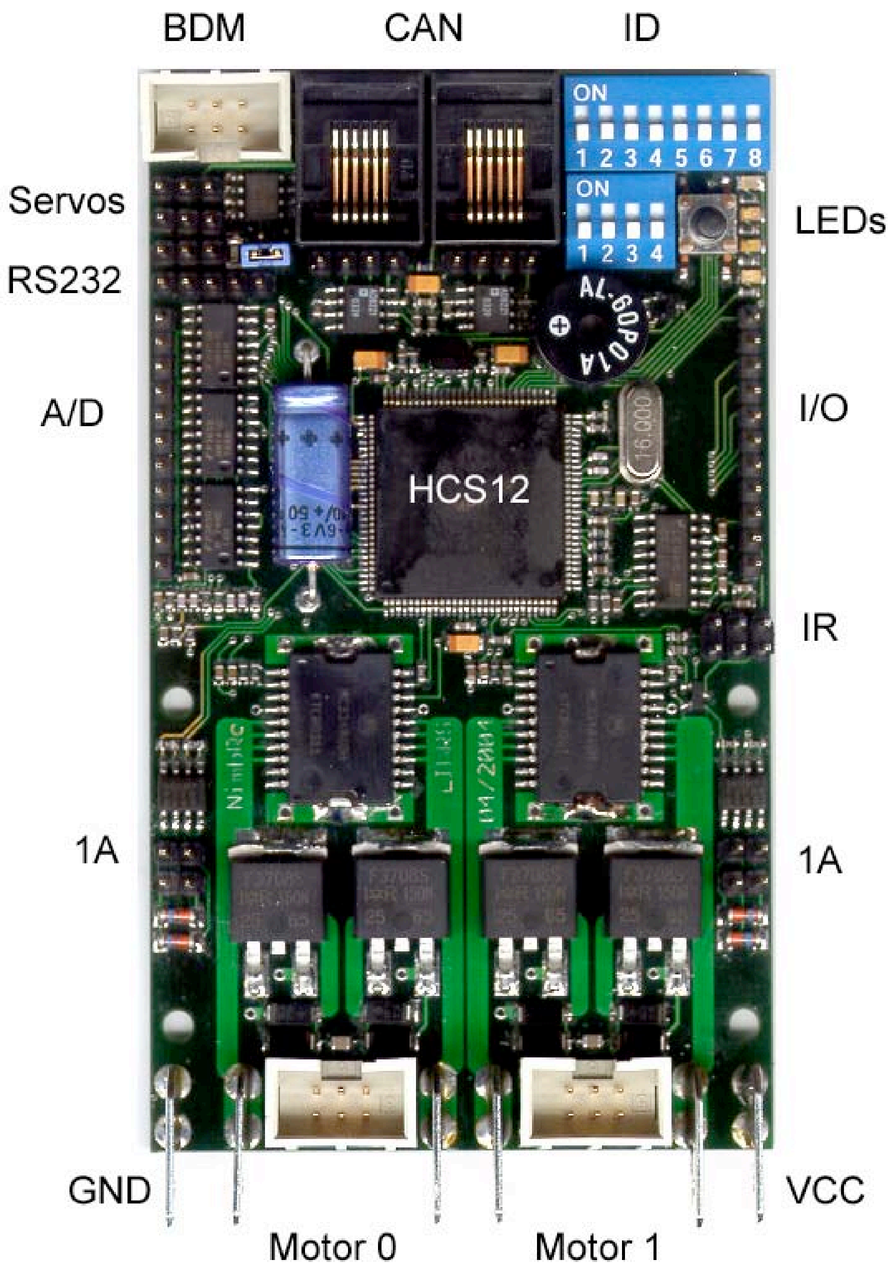
Electronics

- Subnotebook as main computer
  - 1.35kg, 1.7GHz Pentium-M
- 11 microcontroller boards
- CAN bus
- NiMH batteries
  - 12/24V
  - High current
- DC-DC-converter
  - buffered



Microcontroller board

- Motorola HCS12
  - 128K flash, 8K RAM
  - 8 x PWM, 16 x A/D
  - 2 x CAN controller
- 2 x motor driver MC33486
  - 35A max
  - 10A continuous
- 4 x 1A switches
- 2 x instrument amplifier AD8221
- CAN, RS232
- 3 x servo
- User interface
  - 4 x LED
  - DIP
  - Beeper



Microcontroller Tasks

- Motor control
  - Pulse accumulation, reading of potentiometers -> current position, speed
  - Outer loop controls position @ 60Hz
  - Inner loop controls speed @ 120Hz
  - Output: PWM, turning direction
- CAN communication
  - 60Hz
  - State to PC
  - Target position, parameters from PC
- Preprocessing of sensor readings
  - Robust filtering

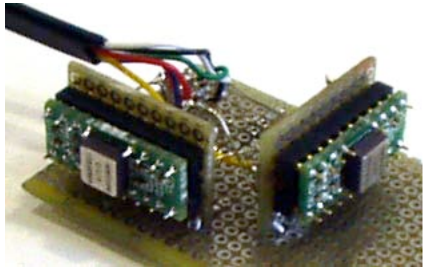
Sensors

- Cameras

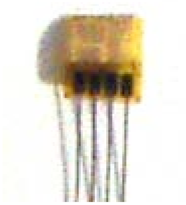
Apple iSight
uncompressed Firewire camera
with wide-angle converter

- Accerometers and gyros

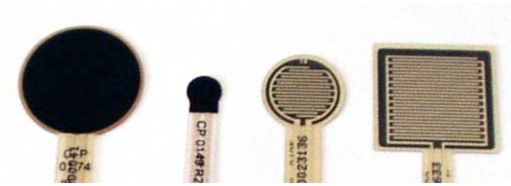
Accelerometer ADXL203
Gyroskope ADXRS150/300



- Force sensors



Strain gauge
BLH FAE4-6257J

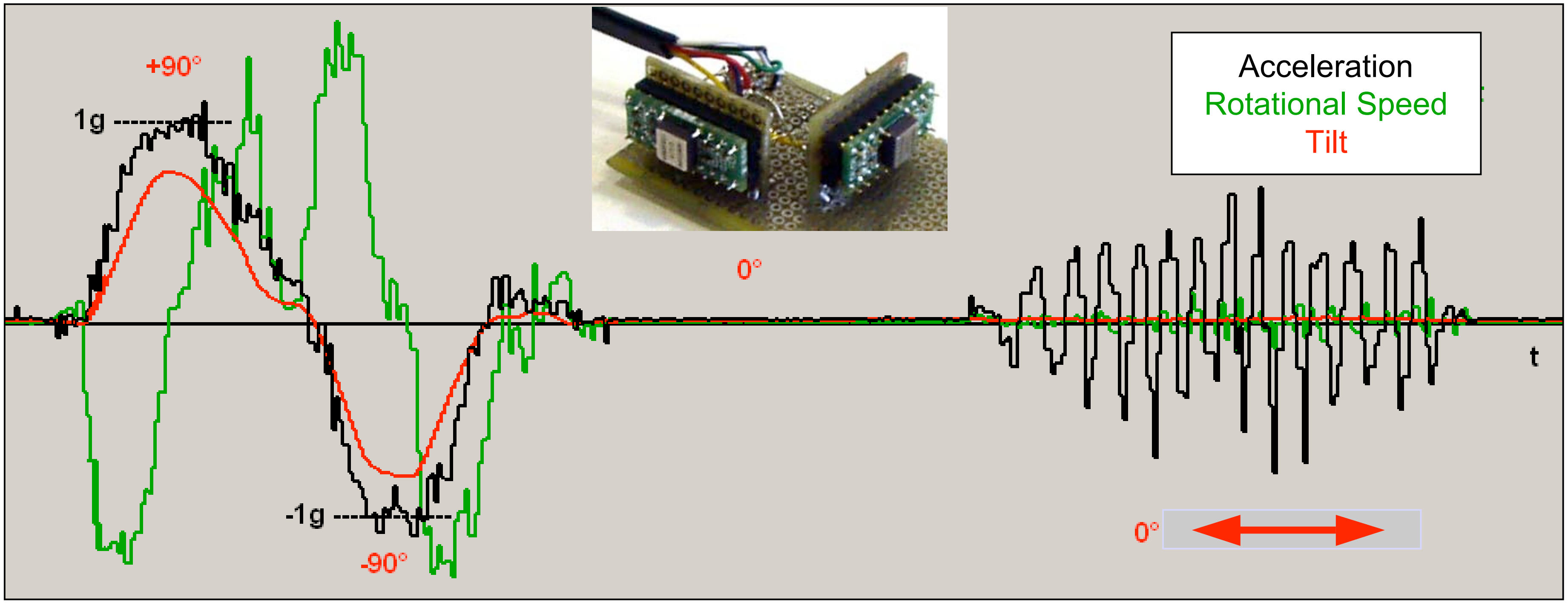


I.E.E. FSR

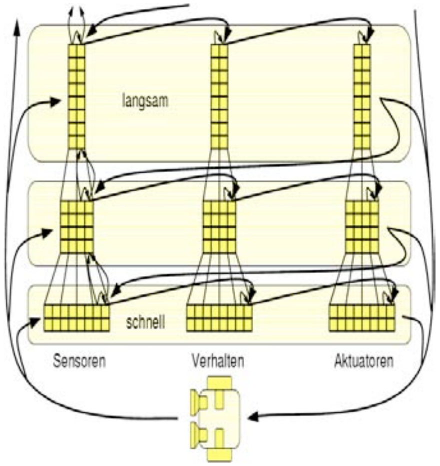
- Motor encoders
- Potentiometers

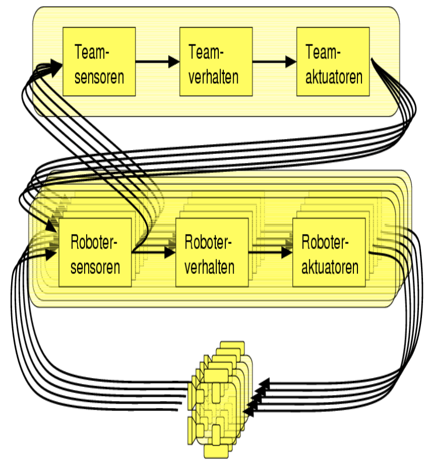
Attitude estimation

- Accelerometer cannot distinguish between gravity and other accelerations
- Gyro reports only rotational speed, need starting point for integration
- Offset must be calibrated, use longer-term accelerometer readings

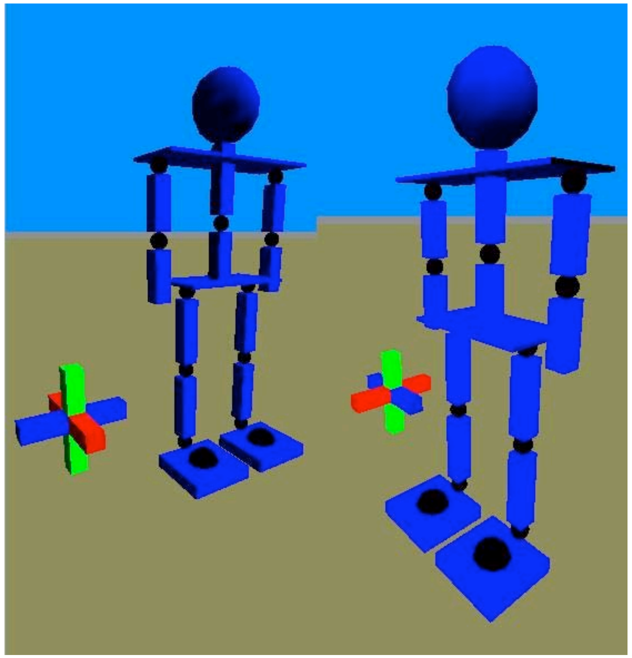


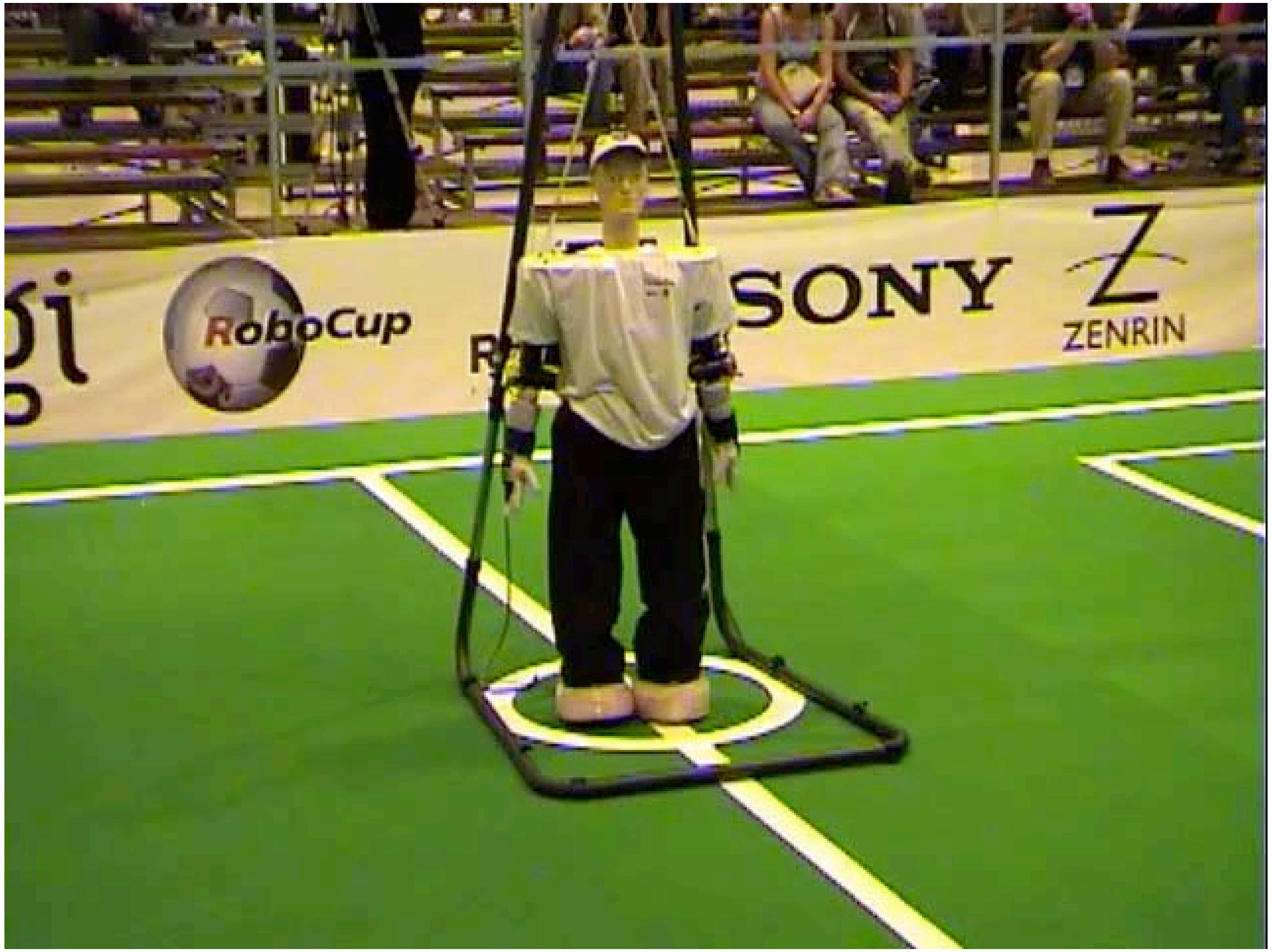
Framework for behavior control





- Developed at FU Berlin
- Supports hierarchy of reactive behaviors
  - Time hierarchy (60Hz, 30Hz, 15Hz, …)
  - Agent hierarchy (body-bodypart-joint)
  - Abstract interfaces
  - Complexity reduction trough interaction constraints
- Logging of all variables
- 3D visualization
- ODE simulation



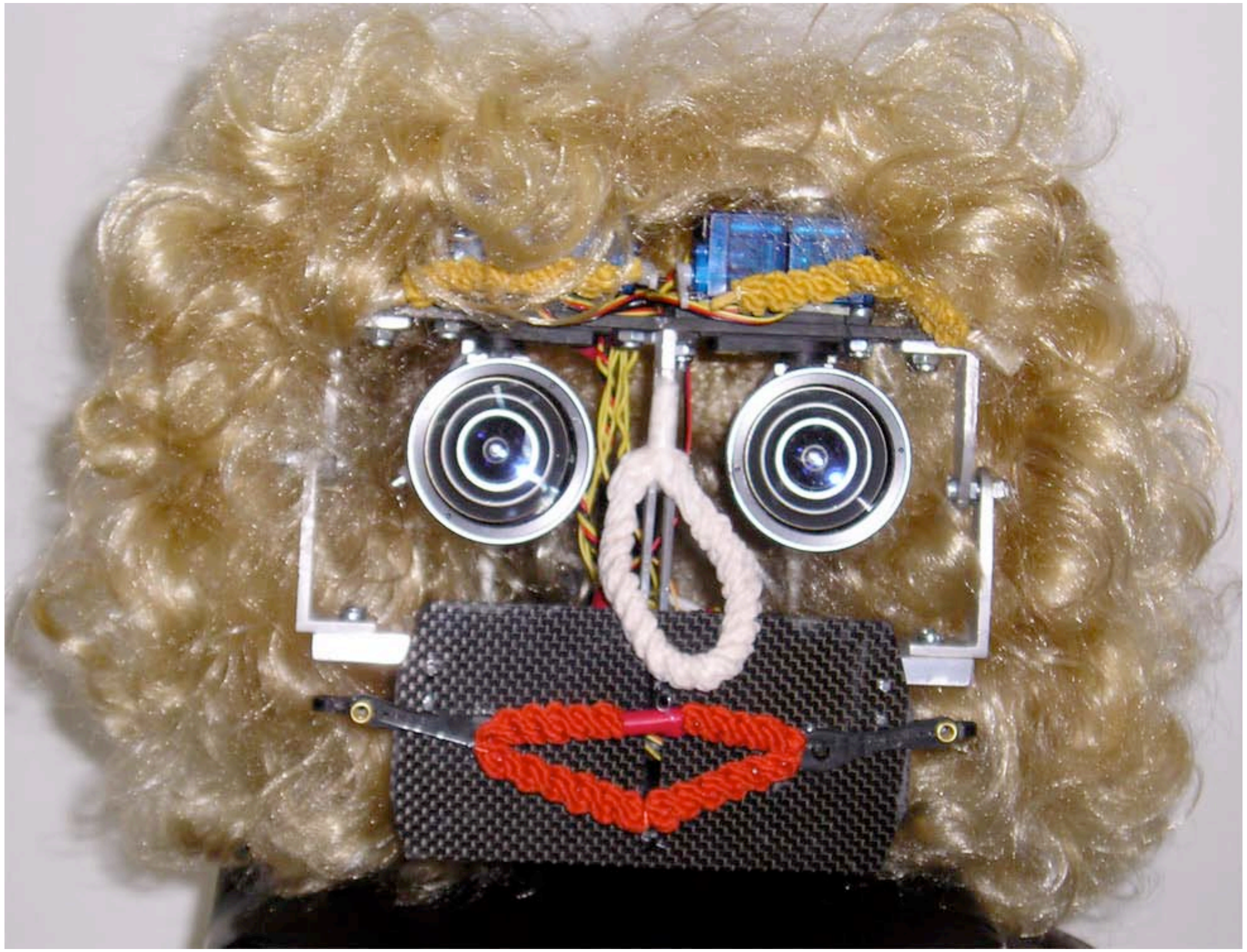


Third price @ RoboCup 2004 Freestyle Competition

Alpha's Head

16 DOFs:

- 3 eyes
- 3 neck
- 4 eye brows
- 6 mouth



Multimodal Dialog System

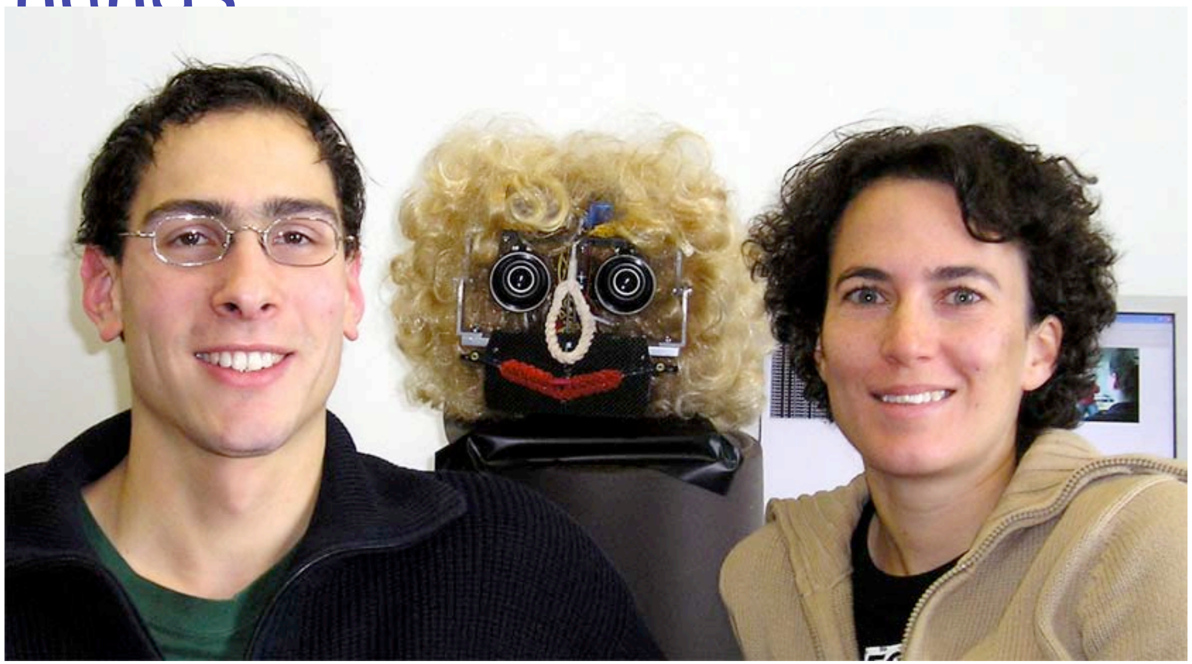
- Face localization and tracking (OpenCV)
- Maintain list of closest persons
- Robust speech recognition (Novotec)
- Dialog management (FSM)
- Speech synthesis (Txt2Pho, MBROLA)
- Gaze control (saccades, smooth pursuit)
- Head direction control
- Animated mouth while speaking



Conversation with Alpha's Head

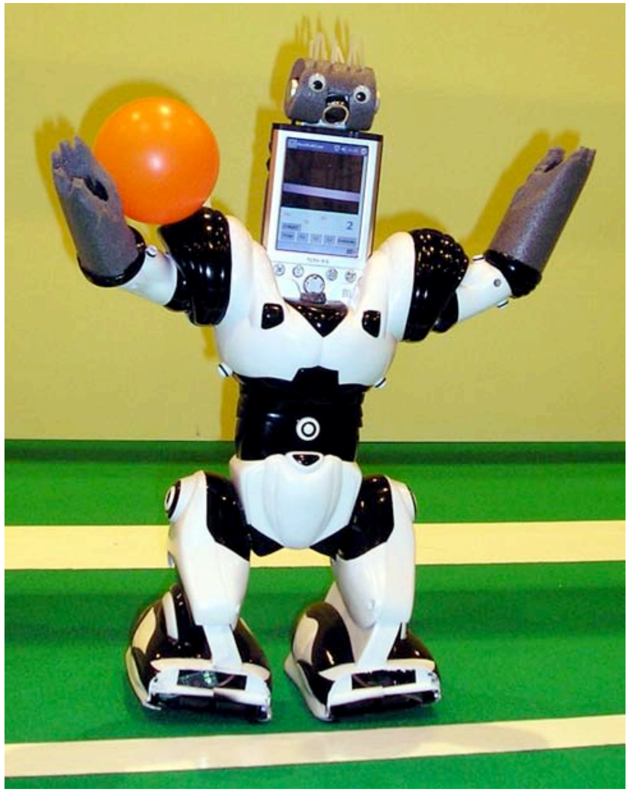
Outlook for Alpha

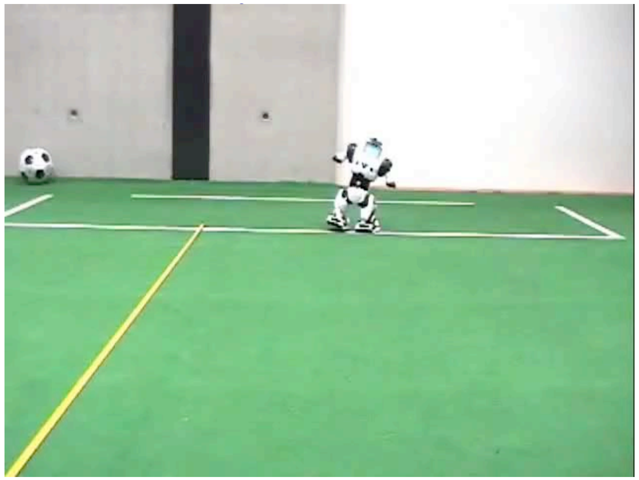
- Mimics, expression of emotions
- Integration of head and body
- Actuated hands
- Pointing gestures
- Use as museum guide

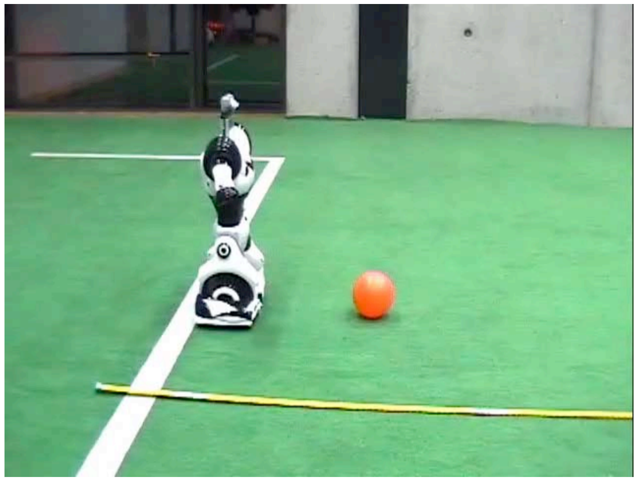


RoboSapien

- Toy robot, developed by M. Tilden, produced by WowWee
- 7 DOFs
- 3DOF Dynamic walking
- Augmented with Pocket

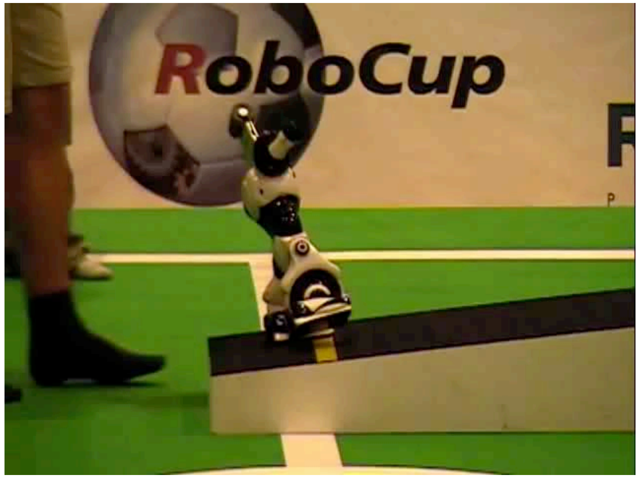


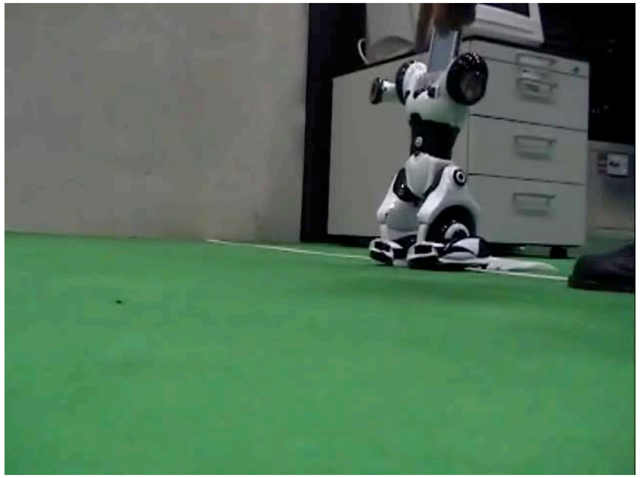




RoboSapien @ RoboCup 2004

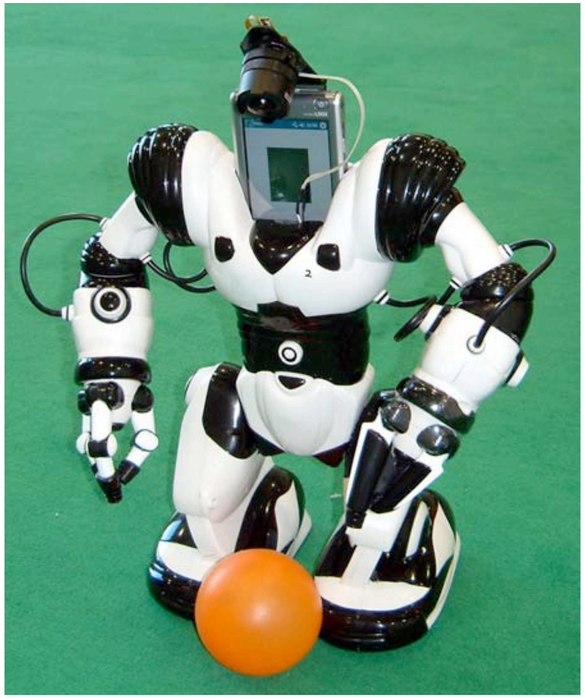
- Third place in RoboCup 2004 Technical Challenge (one of two teams able to walk over a ramp)
- Humanoid Walk in our lab
- API downloadable (got slash-dotted)

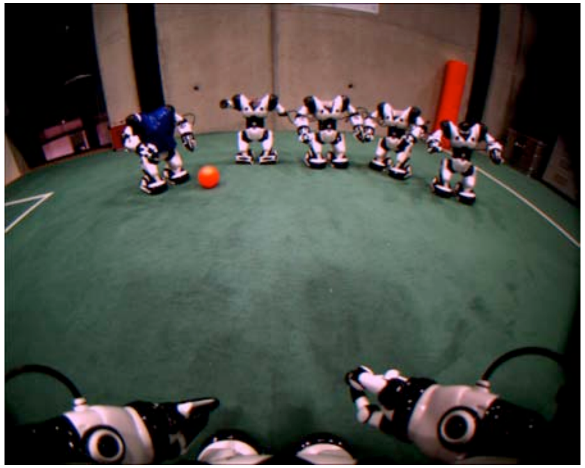




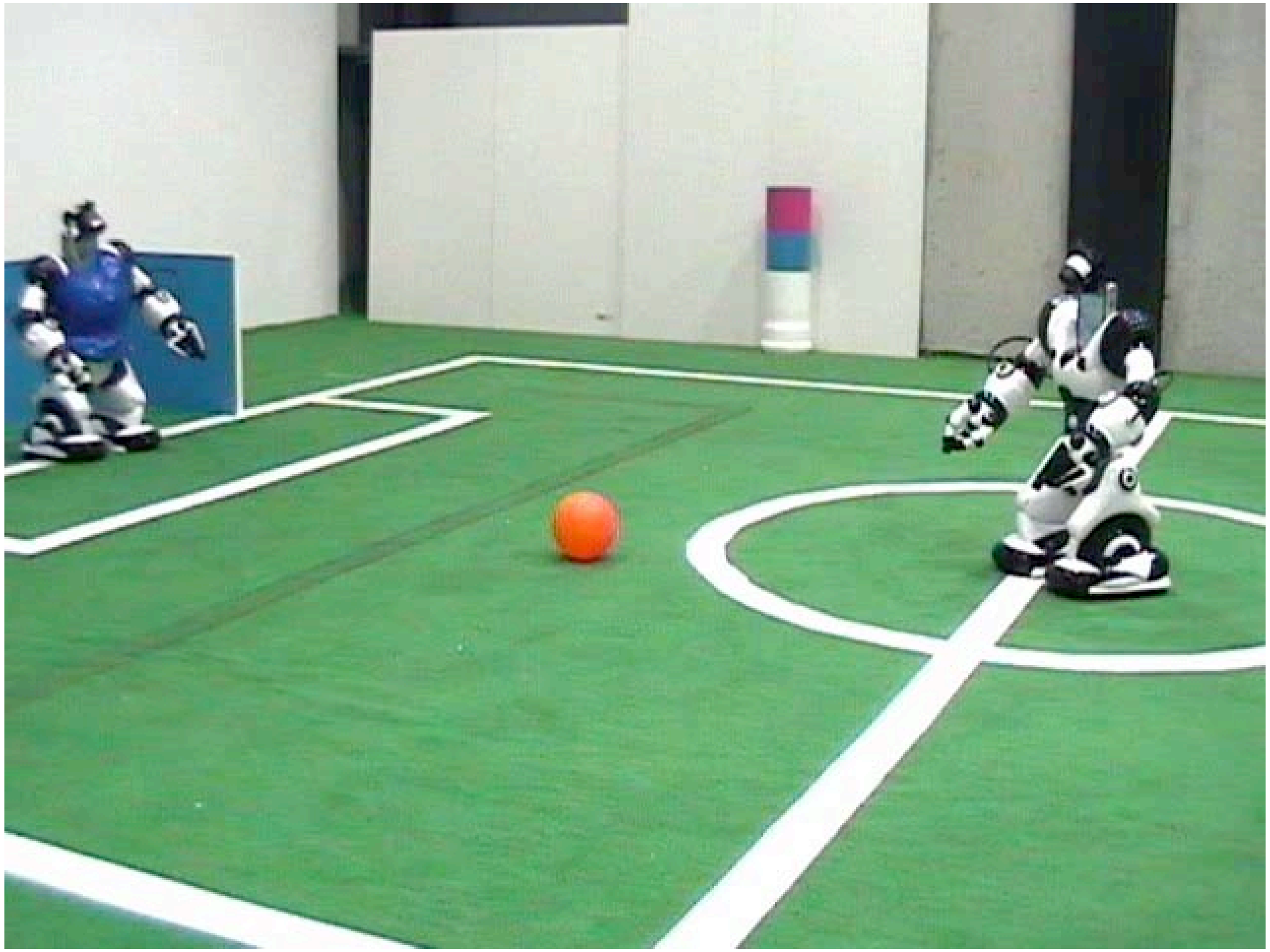
Soccer with RoboSapien

- New version with arms and wide-angle lens
- Want to show 4 vs. 4 demo game at German Open 2005 (with Brainstormers Osnabrück)
- Computer vision, behavior control, infrastructure



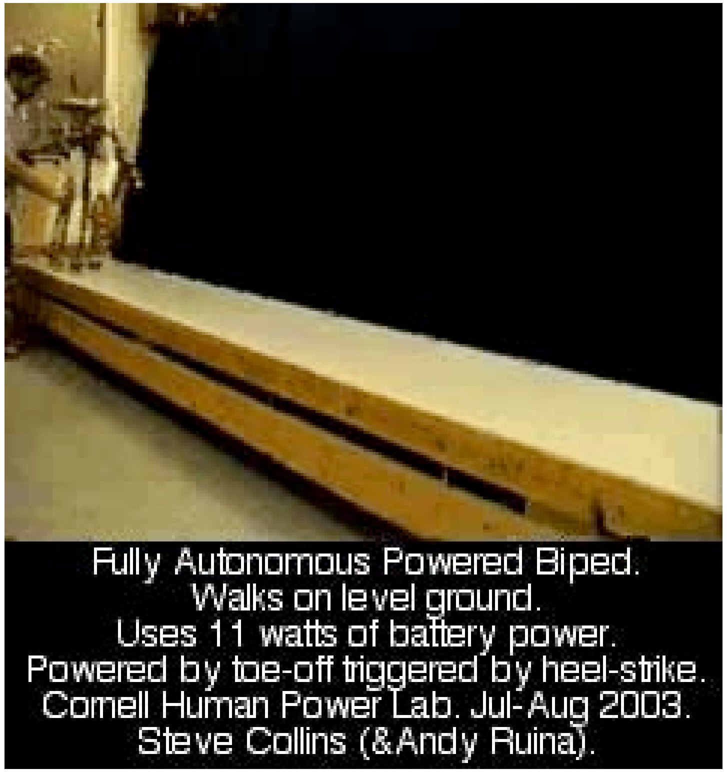


Field player and goalie



Dynamic Walking

- Starting from static stability
  - Zero-Moment-Point
  - Center of Pressure
- Starting from dynamic stability
  - Passive dynamic walking
    - Elegant
    - Energy efficient
    - Minimal actuation
  - Inverted pendulum
- Need booth modes

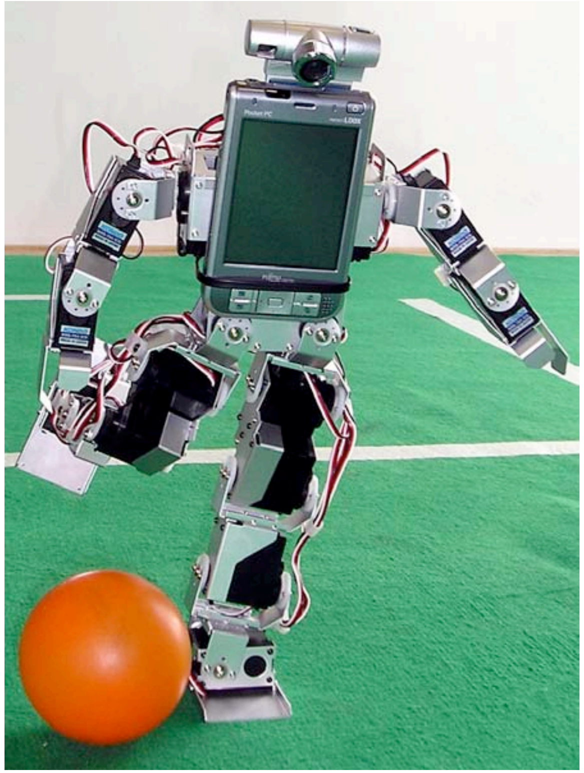


Kondo robot KHR-1

- Japanese construction kit
- 17 Servos
  - 5 per leg,
  - 3 per arm,
  - head
- 34cm, 1.2kg
- RS232 interface
- Motion control software
- NiCd battery

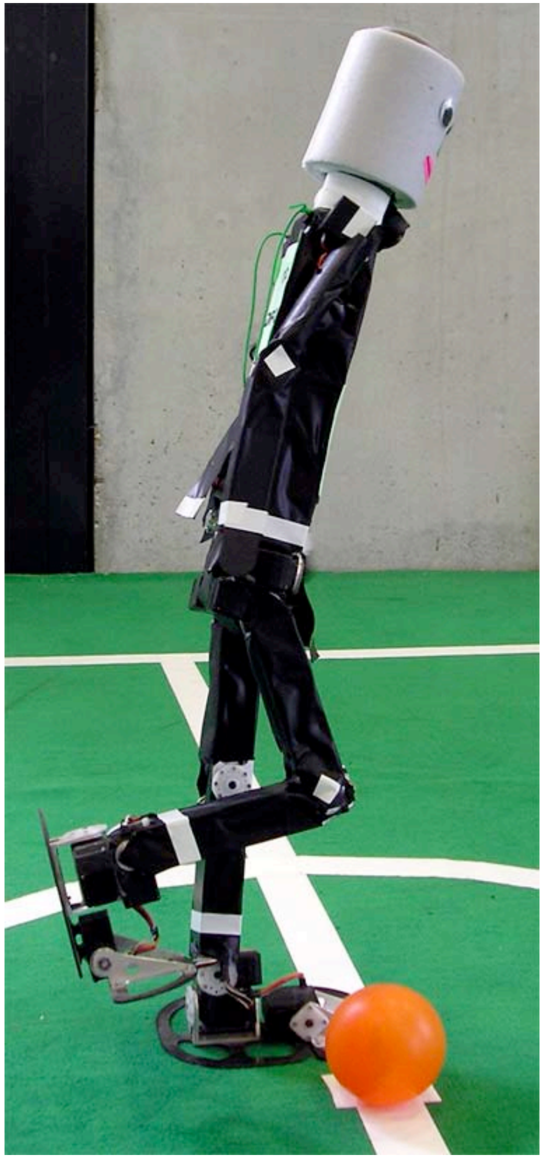
Augmented Kondo

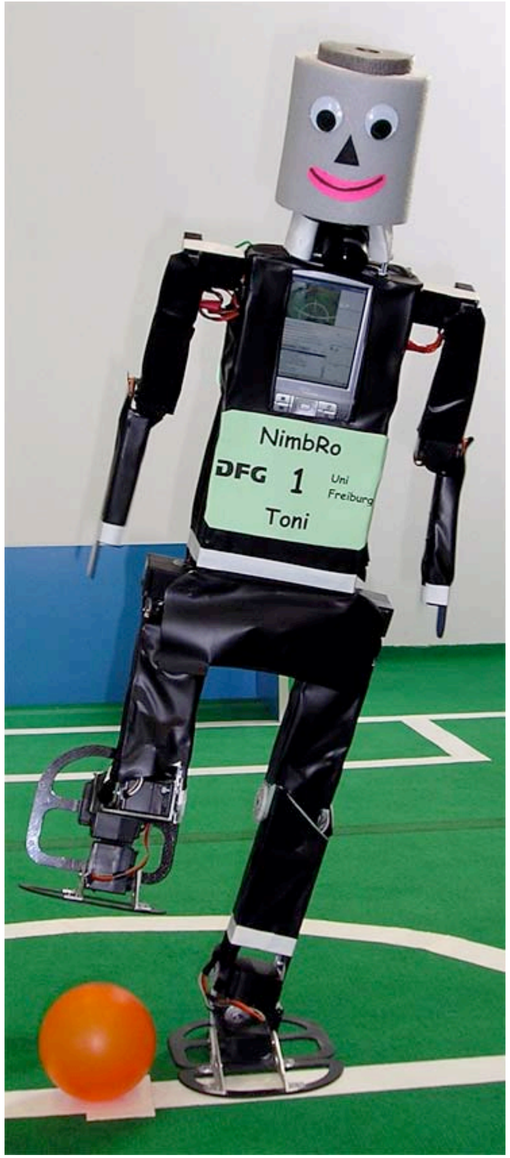
- Pocket PC + camera
- Behavior control @ 50Hz



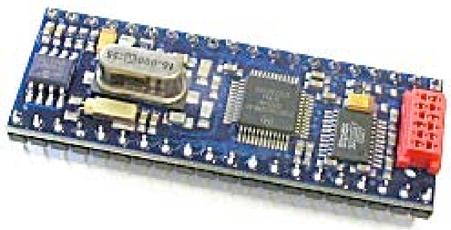
- Walking implemented
- Working on automatic gait optimization

Toni



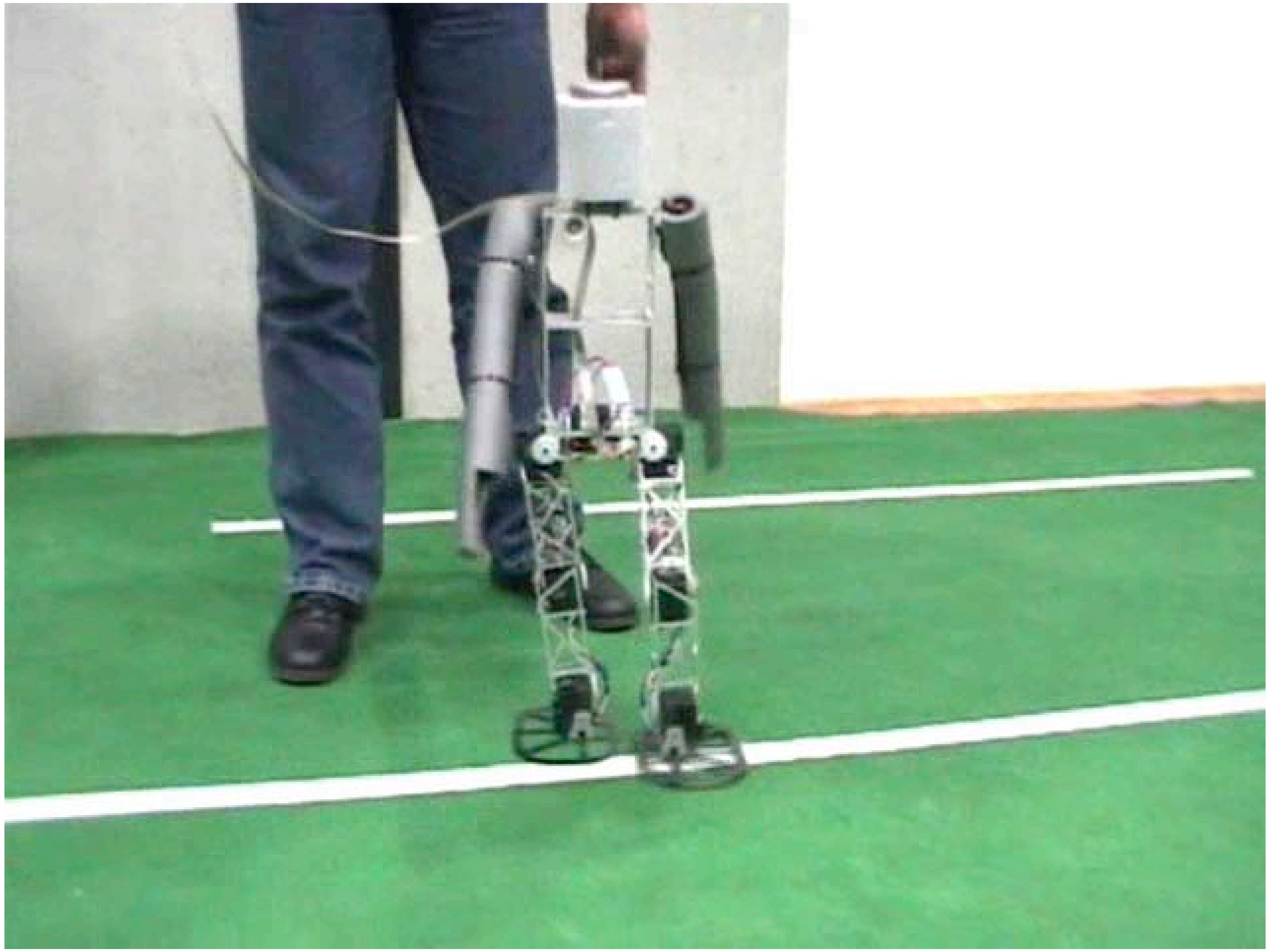


- 18 DOFs
  (6 per leg, 3 per arm)
- Driven by servos
- 74cm, 2,2kg
- Lightweight aluminum frame
- 3 Cl

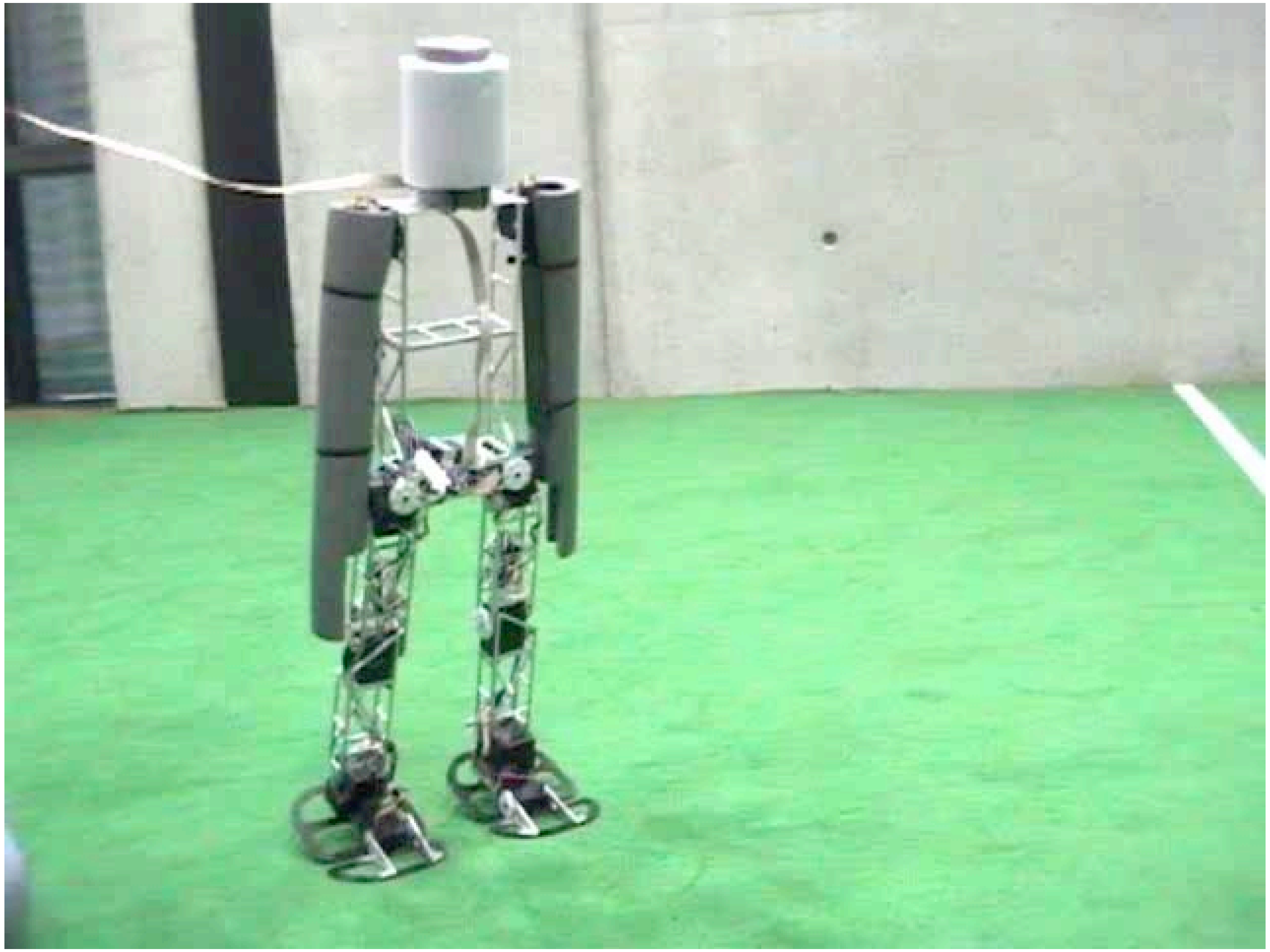


- CAN, RS232
- Pocket PC + camera
- 167Hz control
- Attitude sensors

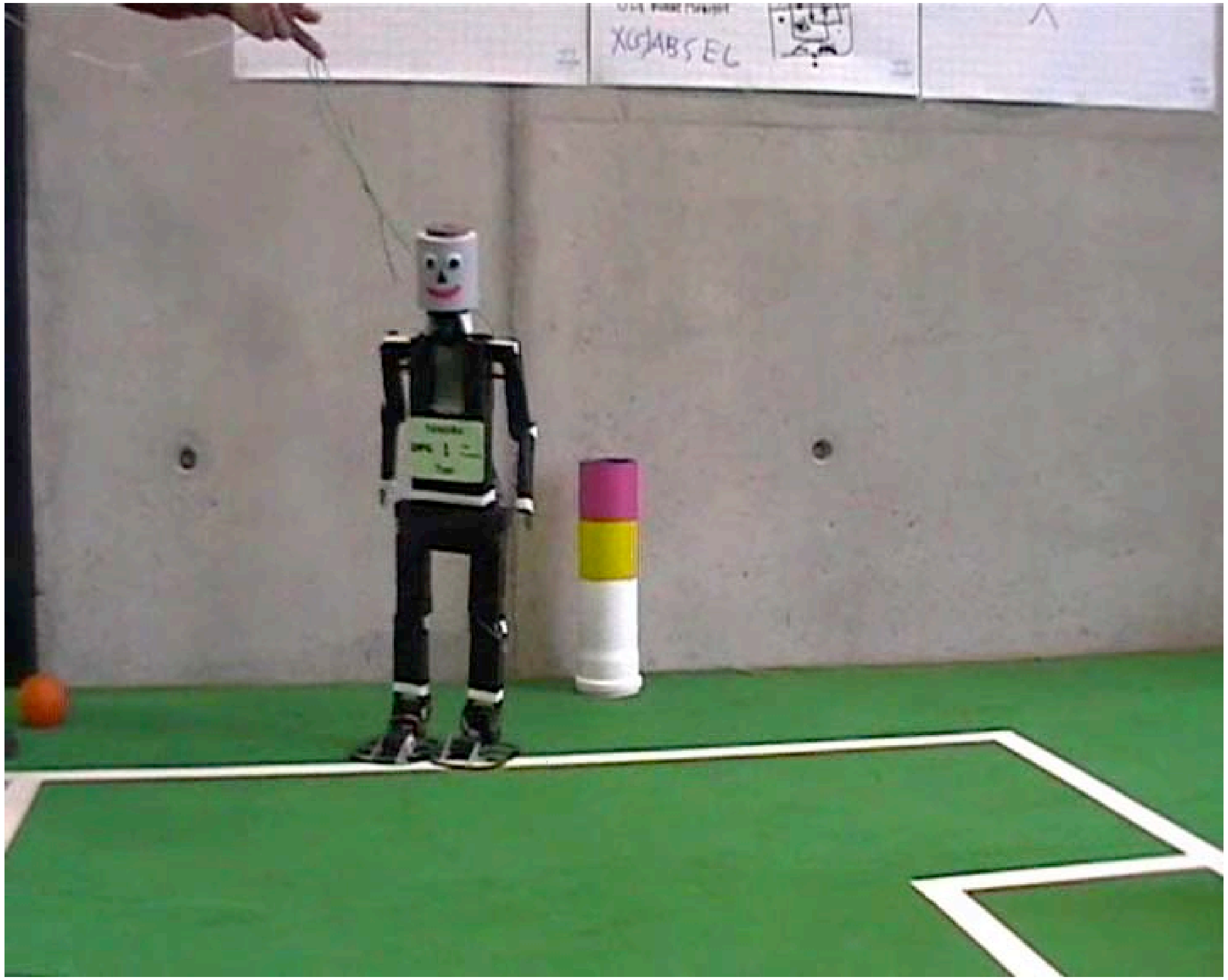
Walking with 16.5cm/s @ 2Hz



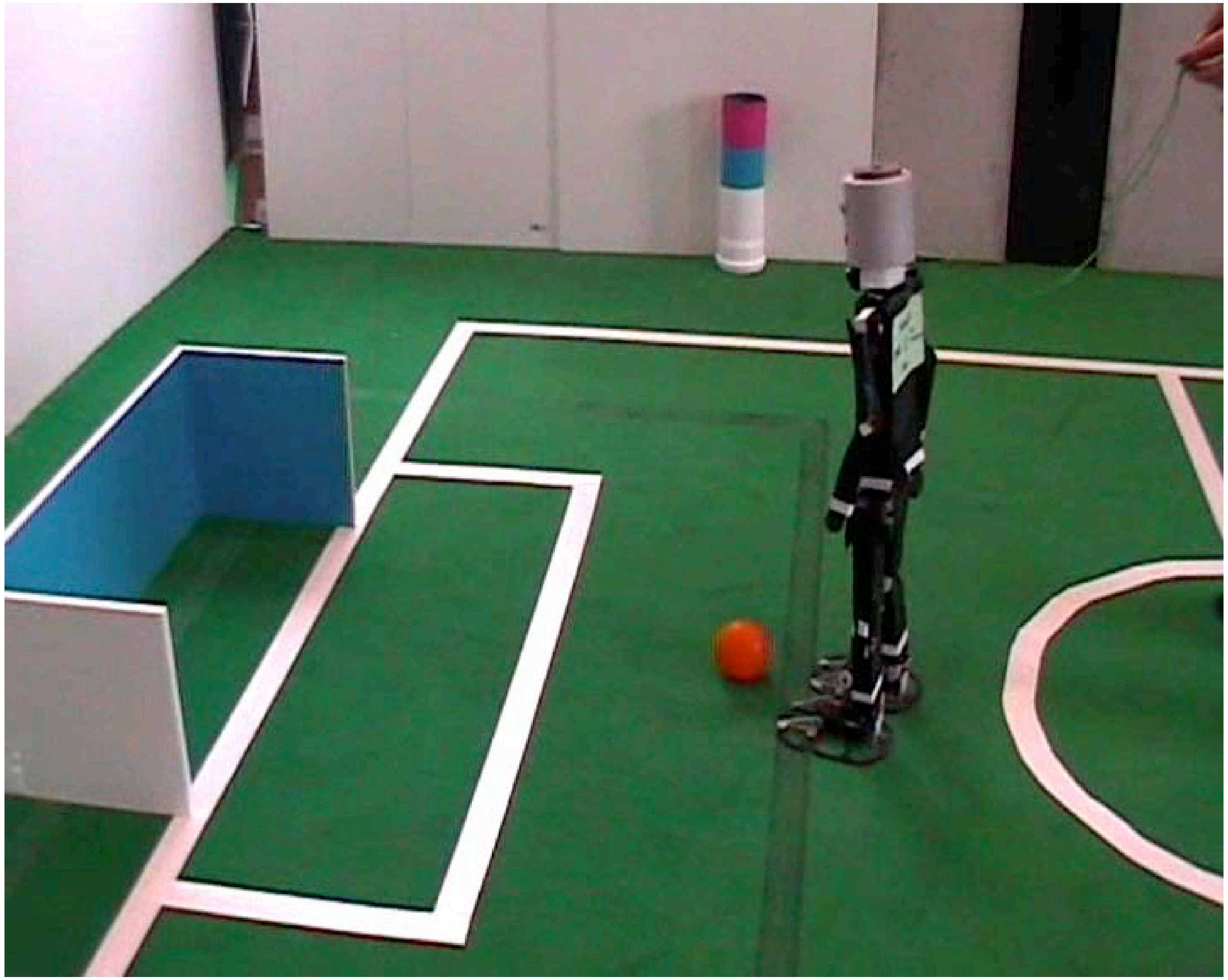
Toes Joint



Omnidirectional Walking



Autonomous Ball Play



Outlook for Toni

- Force sensors, compass
- Smaller and larger versions for KidSize (<60cm) and MidSize league (60…180cm)
- Soccer: Kicking, self localization, ball control,
  , …

RoboCup
2005
OSAKA

July 13^{th} – 19^{th},

Conclusions

- Complex integration task
- Weakest component determines performance
- Integrated system more than sum of parts
- Synergy effects:
  - Audio-visual speech recognition
  - Active perception
  - Perfect reconstruction of world not needed; percept must only be sufficient for behavior control

Challenges

- Artificial muscles
- Light-weight frames
- Soft covers
- Energy supply
- Efficient locomotion
- Robust control
- Managing complexity of high number of DOFs
- Multimodal perception
- Team coordination

NS-5 (I, Robot)

Vision: Personal Robots

Personal Robots Make the 21st Century More Fun

Corporate Executive Vice President, Sony Corporation
President, Intelligent Dynamics Research Institute
Chairman, Sony Computer Science Laboratories, Inc.
Founder, ROBODEX

Engineer Toshitada Doi

„In thirty years I think it [the personal robot industry] will be bigger than the personal computer industry. We need to do more research, however, into movement but also into intelligence.“

Team NimbRo

Staff:

- Dr. Maren Bennewitz,
- Jürgen Müller

Students:

- Felix Faber (Head control),
- Dominik Joho (Speech processing),
- Thorsten Kramer (Behavior control),
- Tobias Langner (Pocket PC),
- Julio Pastrana (Gait optimization),
- Michael Schreiber (Mechanics),
- Joachim Strach (Computer vision),
- Jörg Stückler (Simulation),
- Konstantin Welke (Behavior control),
- Rui Zhou (CAN flasher)

Other contributors:

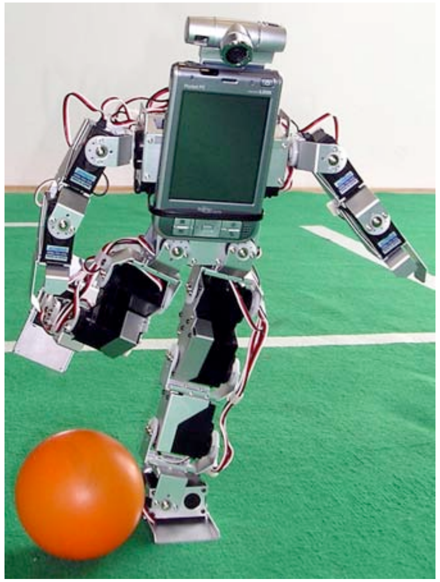
- Alexander Kleiner (Simulation)

Questions

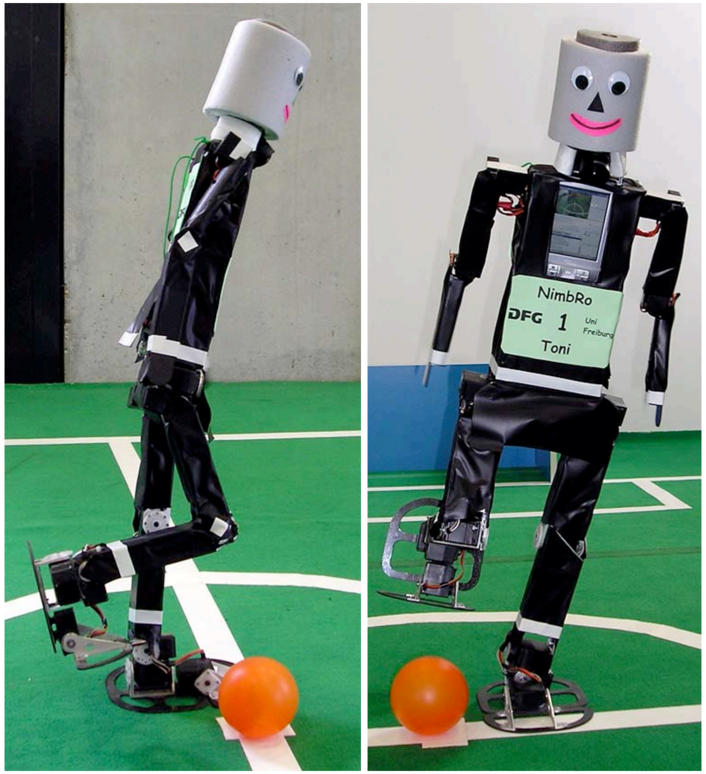
?

Demo in the hall.

RoboSapien



Kondo



Toni