ADAPT – UNIZH Future

Rolf Pfeifer, Gabriel Gomez, Martin Krafft,
Geoff Nitschke, NN
Artificial Intelligence Laboratory
Department of Information Technology
University of Zurich
Switzerland

Goals for ADAPT -- the UNIZH perspective

- developmentally bootstrap a process of high-level cognition using the synthetic methodology
- steps toward a theory of intentionality and sense of presence
- develop an experimental platform
- investigate role of
  - morphology
  - sensory-motor coordination
  - social interaction
  - scaffolding
- interaction with psychology

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Experimental platform co-development LIRA Lab - UNIZH

- complex sensory and motor systems
- bendable high-density touch sensors
- artificial skin
- artificial muscles (pneumatic actuators, series-elastic actuators?)
- soft, deformable materials
- flexible morphology

M. Inaba, University of Tokyo
“Kenta” (tendon boy)

Principle of “ecological balance”

balance / task distribution between

- morphology
- materials
- neuronal processing (nervous system)
- environment (scaffolding)

Basic competences LIRA Lab (present)

- foveation
- reaching
- poking
- grasping
- orienting reactions

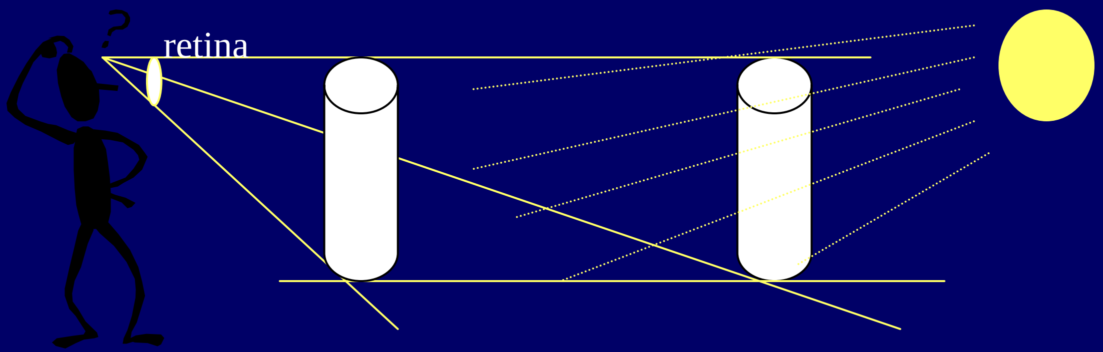
through learning (see presentation LIRA Lab)

additional competences -->

Categorization in the real world

Hard problem in real world:

- continuously changing sensory stimulation
- sensory stimulation varies greatly depending on distance, orientation and lighting conditions



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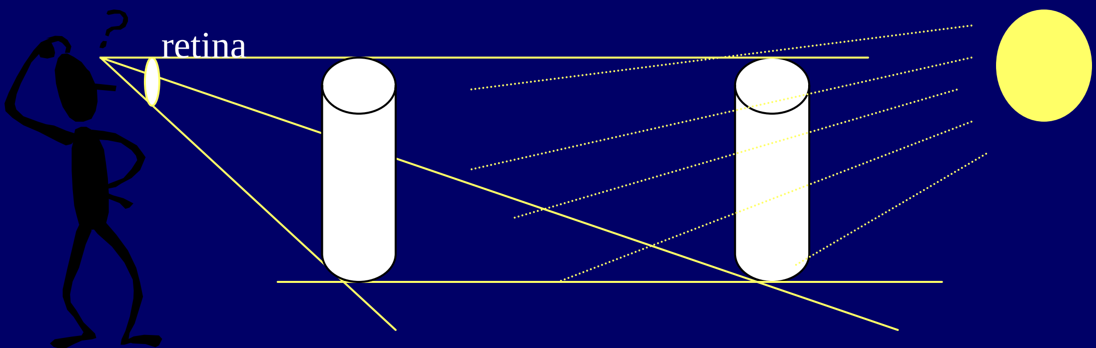
Idea 1:
sensory-motor coordination



Sensory-motor coordination:

- serves to structure sensory input
- provides correlations within and between different sensory channels (e.g. poking experiments)

--> enables learning and concept formation

The principle of sensory-motor coordination

intelligent behavior: sensory-motor coordination/ coupling

leads to:

- structuring of sensory stimulation
- generation of correlations in sensory data (“good data”)

examples:

- foveation
- reaching, poking, grasping
- categorization, perception

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Bootstrapping „high-level cognition" (grand goal)

→ sensory-motor coordination

→ cross-modal associations

→ basic categorization behavior

→ gradual decoupling from sensory-motor level

→ same neural structures involved (mirror neurons)

→ new types of mechanisms?

→ *mechanisms / models / value systems*

Issues

- developmental scenarios / experimental setups
- models and mechanisms
- freezing / freeing degrees of freedom
- changing resolution / precision
- value systems
  - motivators
  - contingencies
  - novelty
  - ability to predict sensory stimulation
  - explicit/implicit value
- interplay sensory-motor development and social interaction / scaffolding

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Theory of intentionality

(work package 2)

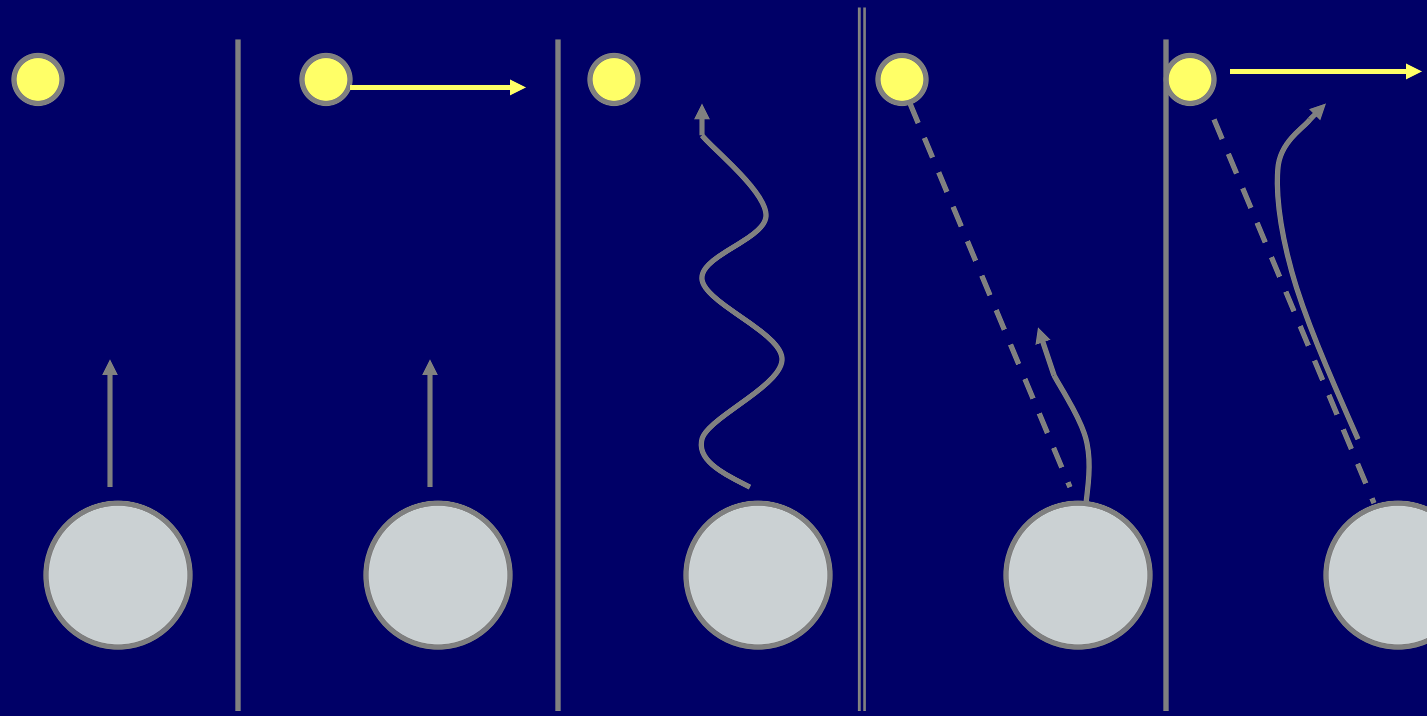
- „design principles“ (examples: ecological balance, sensory-motor coordination, value principle, „cheap design“, redundancy, etc.)
- „body schema“ / „body self-image“

„Body schema“ / „Body self-image“

- „finger print“ of agent-environment interaction

Experiments – Idea

comparing not sensory-motor coordinated behavior with sensory-motor coordinated behavior



not sensory-motor coordinated sensory-motor coordinated

„Body schema“ / „Body self-image“

- „finger print“ of agent-environment interaction
- transfer experiments to more complex experimental platform
- explore effect of morphologies and materials (artificial muscles, sensor positioning, etc.)

Social interaction / scaffolding

- interplay sensory-motor development and social interaction / scaffolding

Sense of presence

- “tuning into” robot experiences
- cooperation with other PRESENCE projects?

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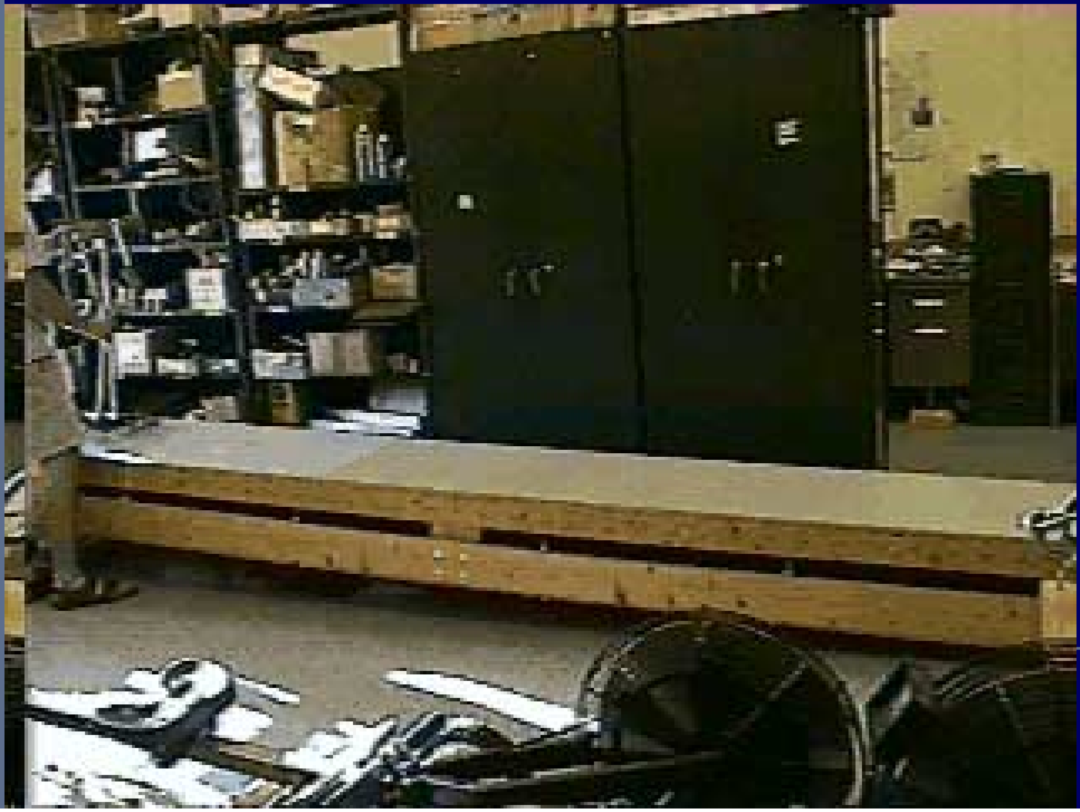
Interaction with psychology

- engineering
- synthetic experiments -- psychological experiments (Giorgio)
- mutual transfer (mutual, NOT one-way!)

“Passive Dynamic Walker” – the brainless robot

walking without control

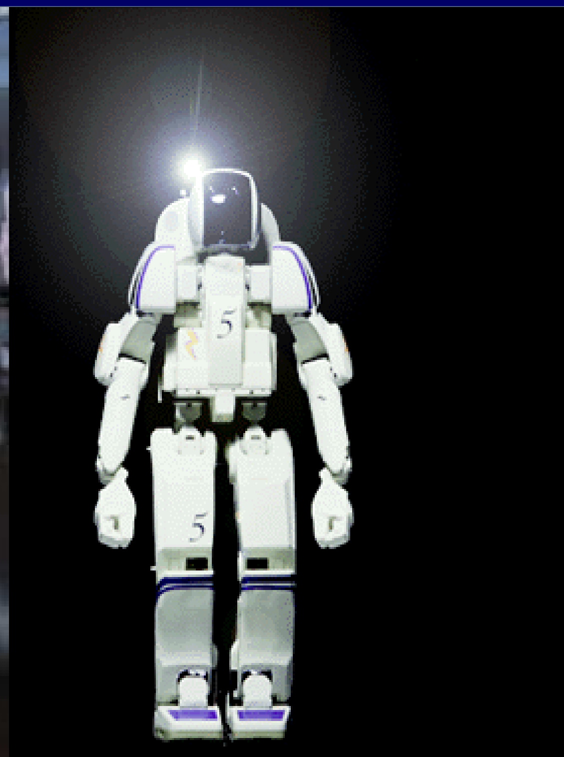
design and construction
Steve Collins, Cornell University



morphology:
- wide feet
- elastic heels
- counterswing of the arms
- properties of the feet

dynamically stable
statically unstable

Asimo (Honda) and H-7 (Univ. of Tokyo)

Asimo

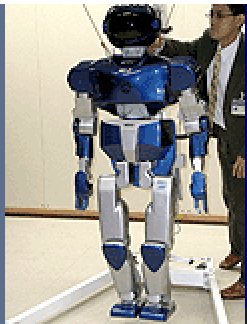
H-7
design and construction
S. Kagami, Univ. of Tokyo

Conclusions from walking study

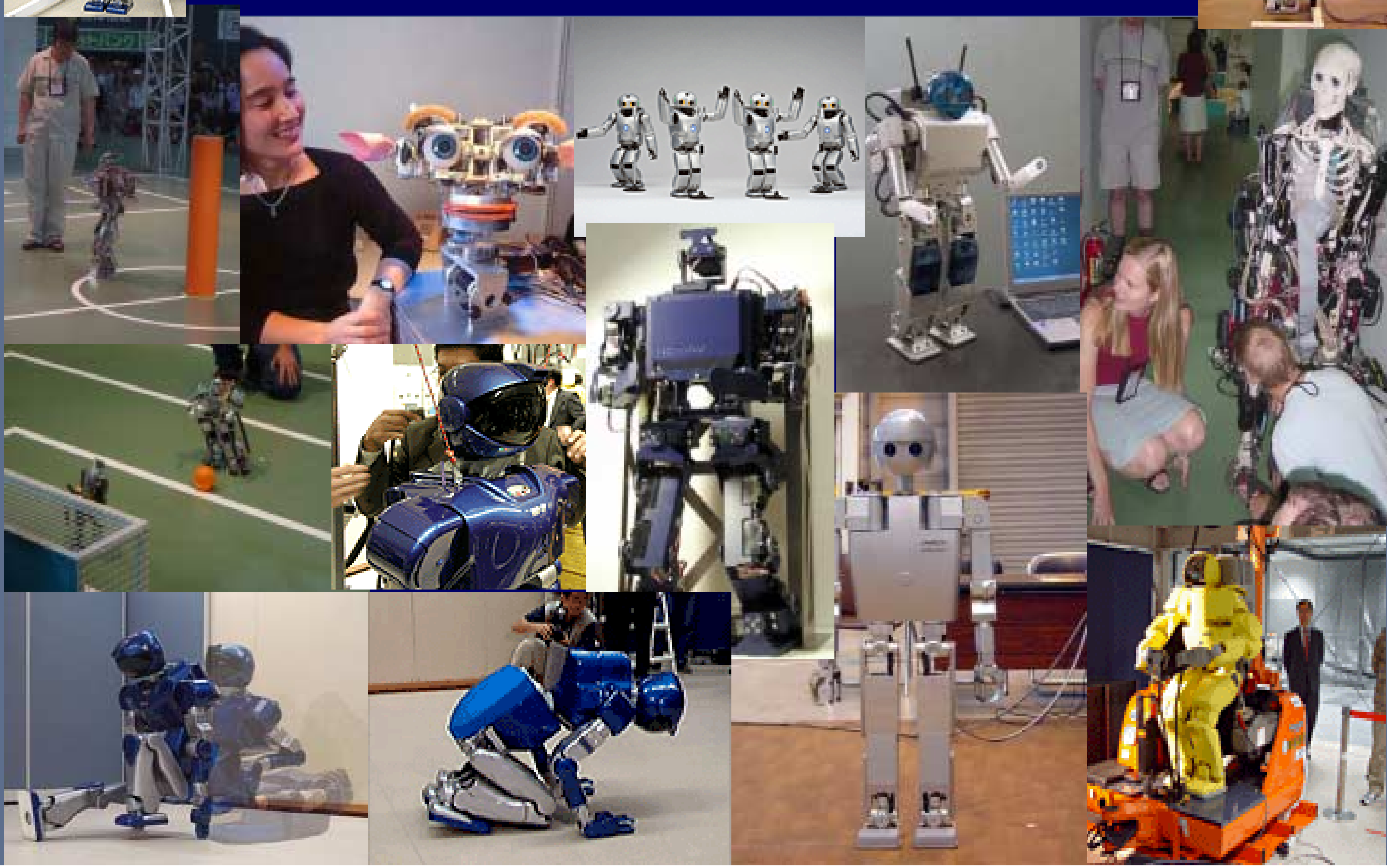
appropriate morphology and materials
exploitation of dynamics / physics
→ minimal control effort
→ energy-efficient walking
→ natural walking

and vice versa:

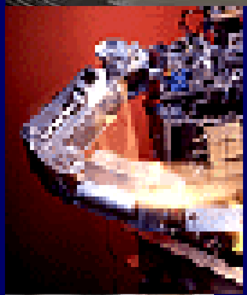
- hard materials
  no exploitation of dynamics
  → large effort for control



Humanoid robot epidemic



Control from materials



traditional robot arms:
- hard materials
- electrical motors

human hand-arm-shoulder system:
- elasticity
- stiffness
- damping

Properties of the muscle-tendon system

- grasping an object
- winding a spring
  → energy expenditure
- release
  → turning back without control
- exploited by the brain

"good control"
- decentralized -- little effort of the brain required
- "free" – exploitation of physical properties

Control from materials

- spring-like behavior
- stiffness and elasticity
- damping properties

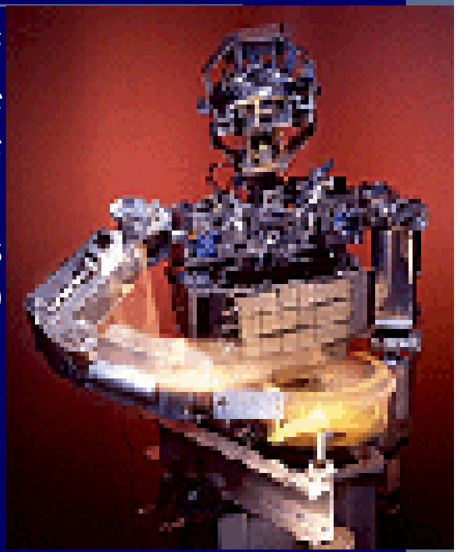
("computational properties" of materials)

robots with artificial muscles
→ exploitation of the dynamics of the (artificial) muscle-tendon system

Robots with artificial muscles

The service robot ISAC
pneumatic actuators
by Alan Peters
Vanderbilt University

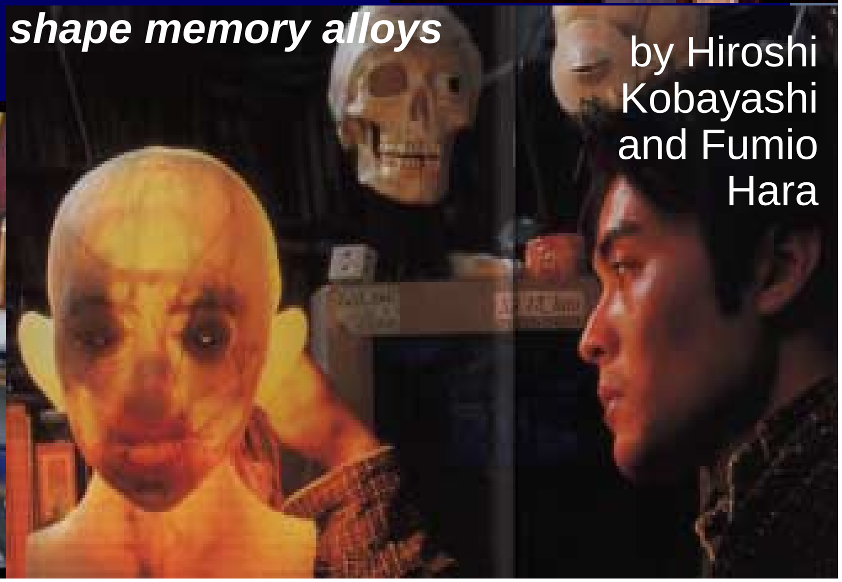
COG
series elastic actuators
by
Rodney Brooks
MIT AI Lab



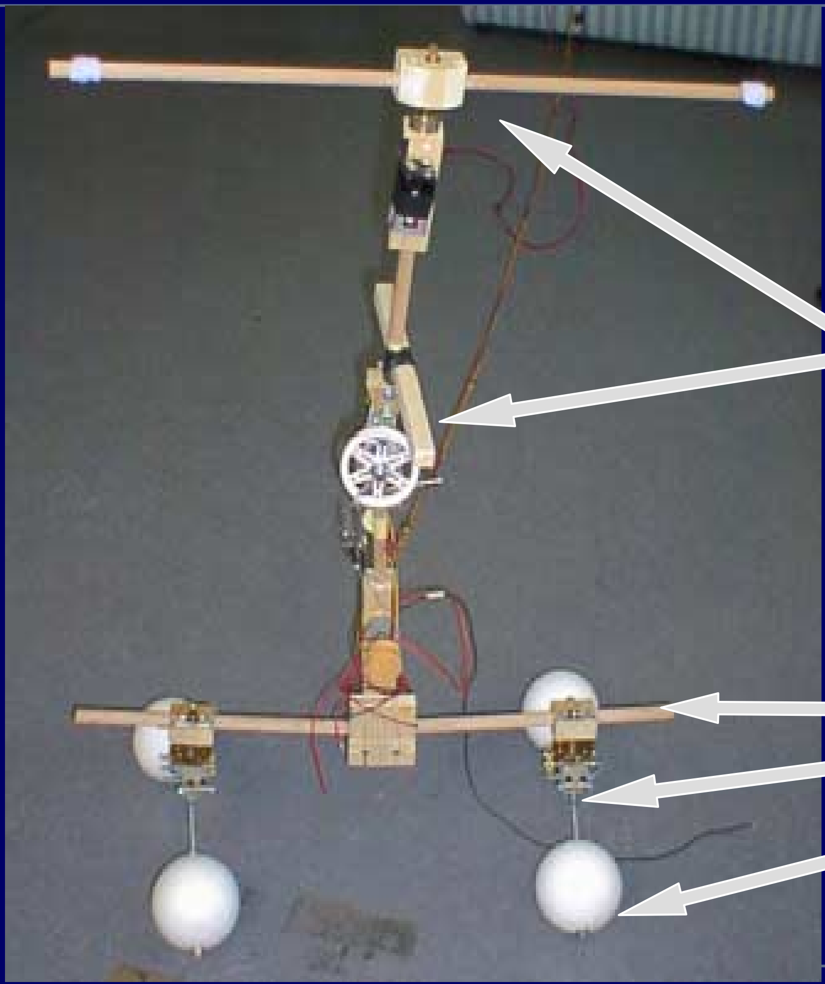
artificial hand
pneumatic actuators
by Lee and Shimoyama
University of Tokyo

Humanoid robot
pneumatic actuators
by Rudolf Bannasch, TU Berlin

The Face Robot
shape memory alloys
by Hiroshi Kobayashi and Fumio Hara



The dancing robot “Stumpy”



virtually “brainless” (simple control)
two motors

joints

elastic materials

surface properties

Design and construction:
Raja Dravid, Fumiya Iida, Max Lungarella, Chandana Paul

The dancing robot “Stumpy”

“Stumpy”: Summary

- Exploitation of dynamics
  - spring-like properties
  - natural elasticity and damping of materials
  - surface properties of the feet
- many behaviors with two joints
- self-stabilization

good control through morphology and materials

Principle of “ecological balance”

balance / task distribution between

- morphology
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- neuronal processing (nervous system)
- environment (scaffolding)

Interest of locomotion and orientation for cognitive robotics

- grounding of cognition in sensory-motor patterns
- “body schema”
- spatial abilities essential
- body as basis for metaphors (Lakoff, Johnson)

Contents

- Introductory comments
- Zurich AI Lab research overview
- The synthetic methodology
- Embodiment – illustrations
- A hard problem in cognitive science: perception in the real world
- The evolution of intelligence: morphogenesis
- The „Zen of robot programming“

Categorization in the real world: fundamental to cognition

categorization:

- ability to make distinctions in real world
- fundamental to any intelligent system
- closely intertwined with perception

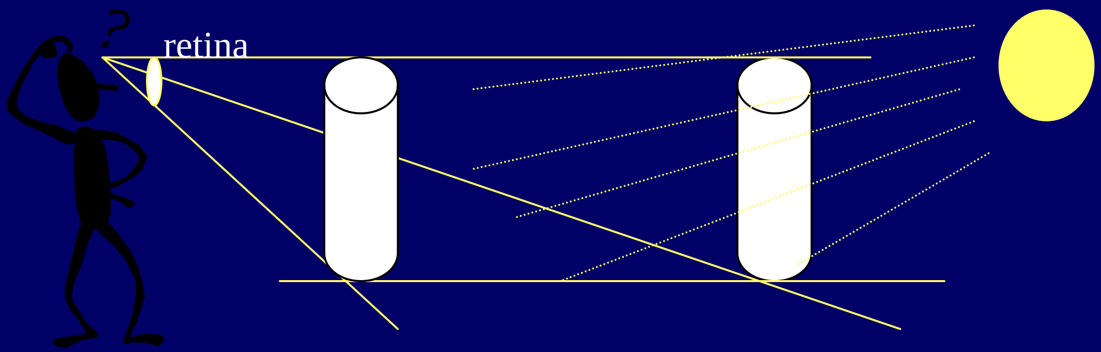
careful!

- frame-of-reference (behavior vs. internal representation)

Perception in the real world

Hard problem in real world:

- continuously changing sensory stimulation
- sensory stimulation varies greatly depending on distance, orientation and lighting conditions



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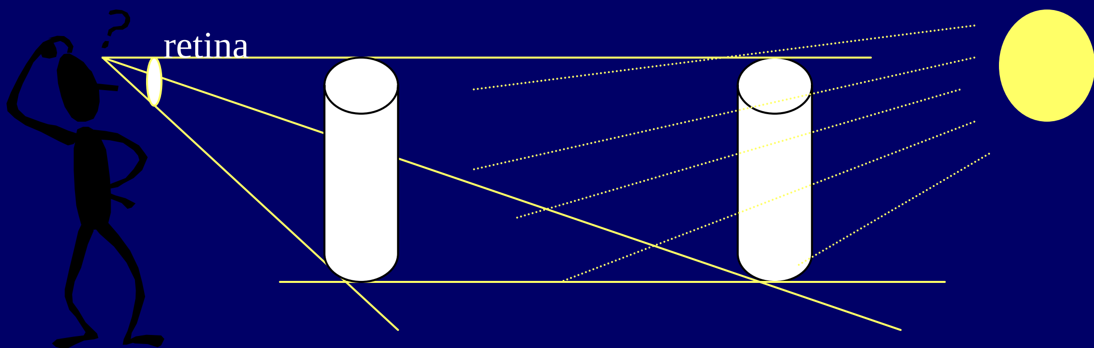

The principle of sensory-motor coordination

intelligent behavior: sensory-motor coordination/ coupling

leads to:

- structuring of sensory stimulation
- generation of correlations in sensory data (“good data”)

examples:

- foveation
- reaching, grasping
- perception, categorization

inspiration
— John Dewey, 1896 (!)
— Edelman and co-workers
— developmental studies; Thelen and Smith

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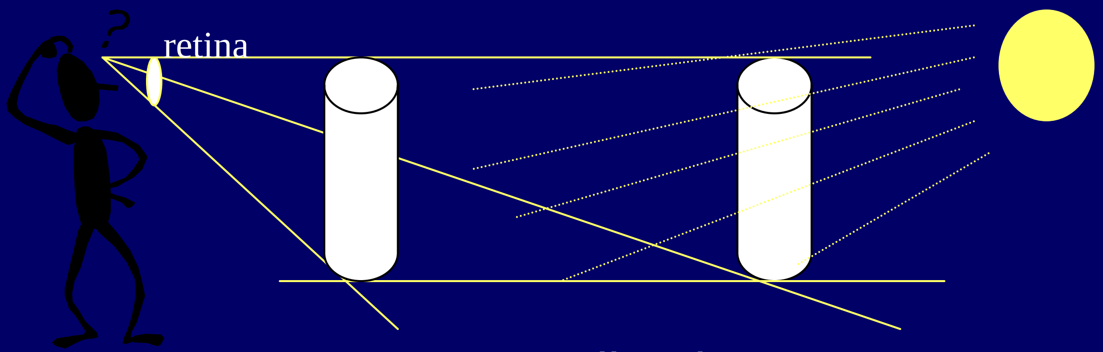

Sensory-motor coordination:

- serves to structure sensory input
- provides correlations in different sensory channels

--> enables learning and concept formation

Categorization as sensory-motor coordination

“We begin not with a sensory stimulus, but with a *sensory-motor coordination* […] In a certain sense it is the movement which is primary, and the sensation which is secondary, the movement of the body, head, and eye muscles determining the quality of what is experienced. In other words, the real beginning is with the act of seeing; it is looking, and not a sensation of light“.

(John Dewey, 1896)

Complexity reduction through sensory-motor coordination

Complexity reduction through sensory-motor coordination

it can be shown: sensory-motor coordination leads to

- dimensionality reduction (sensory data)
- induction of correlations in different sensory channels

$\rightarrow$ *information theoretic reason for sensory-motor coordination*

$\rightarrow$ *basis for learning*

(experiments by Max Lungarella, Gabriel Gomez, and Rene te Boekhorst)

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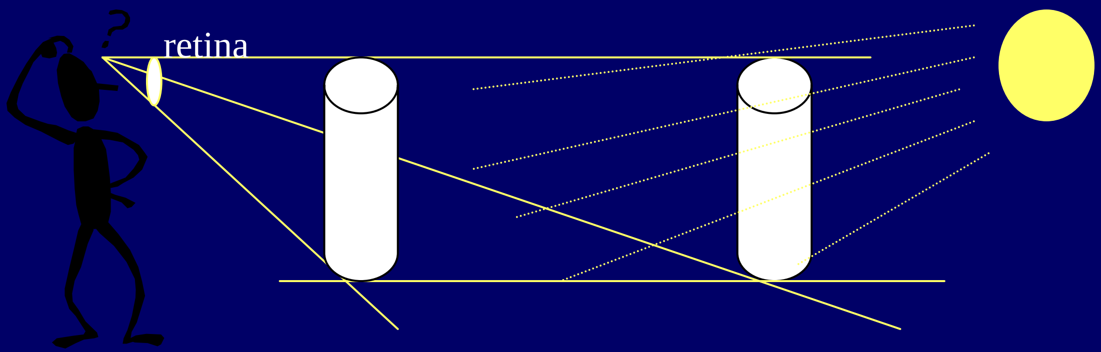


Idea 1:
sensory-motor coordination

Idea 2:
development

„Developmental robotics“

- robot interacting with the environment over extended periods of time → individual history
- advantage of robots: record internal and sensory-motor states → analyze time series
- goals:
  - learning categorization/perception
  - „body schema“
  - basis for metaphors
  - „sense of presence“

→ *robots as cognitive tools*

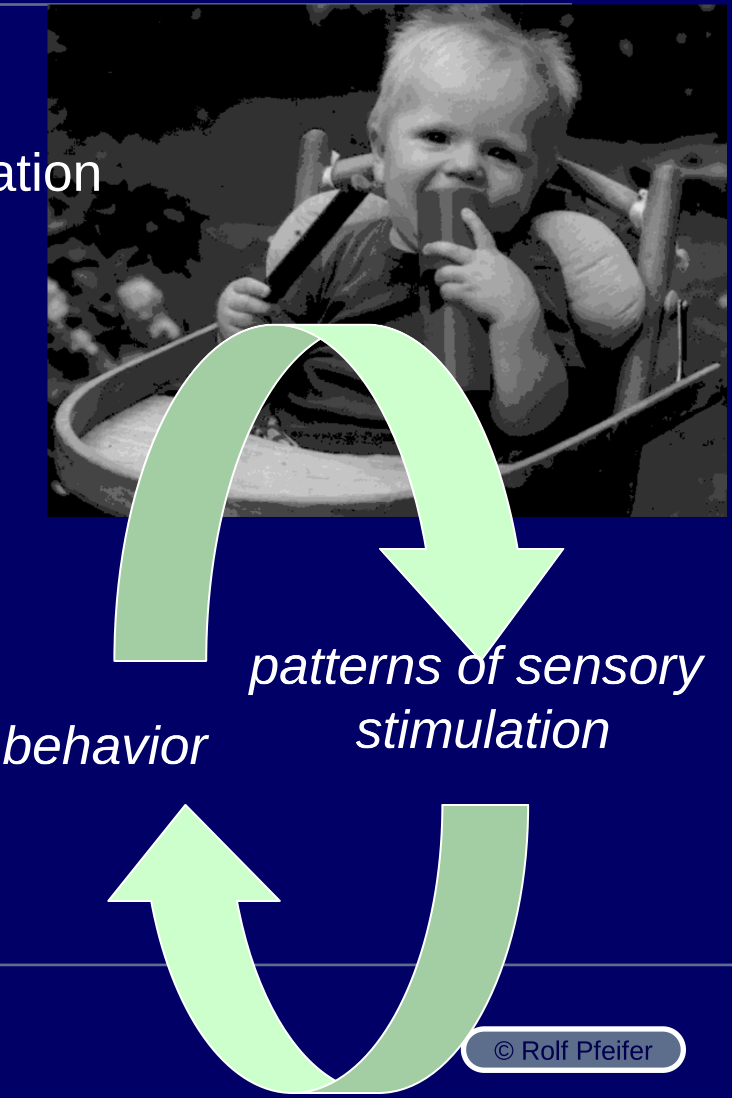
Facilitation through morphology and materials

- constraining movements
  - generating rich sensory stimulation
  - inducing correlations

$\rightarrow$ enables cross-modal associations

example:

random neural stimulation



Bootstrapping „high-level cognition“

→ sensory-motor coordination

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→ gradual decoupling from sensory-motor level

→ same neural structures involved (mirror neurons)

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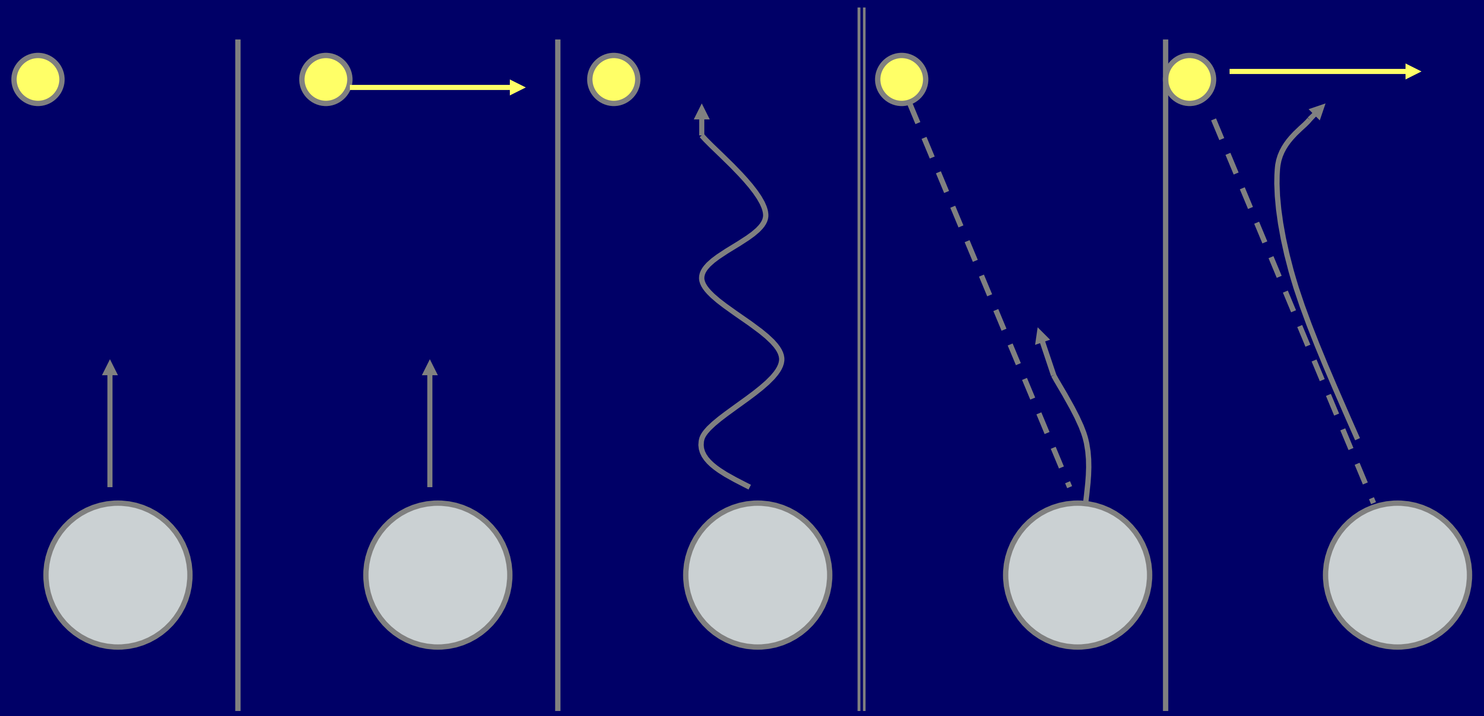

not sensory-motor coordinated sensory-motor coordinated

Technological requirements

- complex sensory and motor systems
- bendable high-density touch sensors
- artificial muscles
- soft materials

„Developmental robotics“: Research directions

- sensory-motor coordination (foveation, visual tracking, grasping) (Brooks, Sandini, Metta, Schaal, Pfeifer)
- social interaction and communication (Breazeal, Kuniyoshi, Steels)
- learning by imitation (Kuniyoshi, Schaal, Dautenhahn, Berthouze, Gaussier, Nadel, Sandini, Metta)
- reinforcement learning (Asada)

also: robots learning by imitating humans (Schaal, Metta)

„Developmental robotics“: Activities

- EDEC-workshop: Emergence and Development of Embodied Cognition
- DECO-workshop: Development of Embodied Cognition
- Epigenetic robotics workshop
- Cognitive robotics workshop (AAAI) (careful!)

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Artificial evolution and morphogenesis

not only “life as it is”

but “life as it could be” (Chris Langton)

Implication of embodiment:

Co-evolution of morphology and neural control

exploring “ecological balanced”

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The “Zen of robot programming”

- relax, the real world is there
- it’s your friend, not your enemy — exploit
- not everything needs to be controlled — physics is for free

Rodney Brooks, MIT Artificial Intelligence Laboratory

Summary

- cognitive robotics — robots as cognitive tools
- embodiment — implications: ecological balance
- categorization and perception: sensory-motor coordination and developmental robotics

Recruiting: PhD students for AI Laboratory

- “developmental robotics”

talk to me afterwards!

Comparison

Felix, Regula and Exuperantius

the three saints of the city of Zurich

Grossmünster

Legend??

→ *"passive dynamic walkers"*