Lecture 8

Theory of intelligence: Design principles for intelligent systems and Intelligence revisited: Achievements and challenges

13 January 2004

Participating sites

	time
• Japan: Tokyo	17.15 - 19.15
• China: Beijing	16.15 - 18.15
• Saudia Arabia: Jiddah	11.15 - 13.15 (new partner)
• Poland: Warsaw	09.15 - 11.15
• Poland: Lodz	09.15 - 11.15
• Germany: Munich	09.15 - 11.15
• Switzerland: Zurich	09.15 - 11.15

University of Jiddah, Saudia Arabia

Moderator: Dr. Fatmah Baothman

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• Germany: Munich	09.15 - 11.15
• Switzerland: Zurich	09.15 - 11.15

Today's program

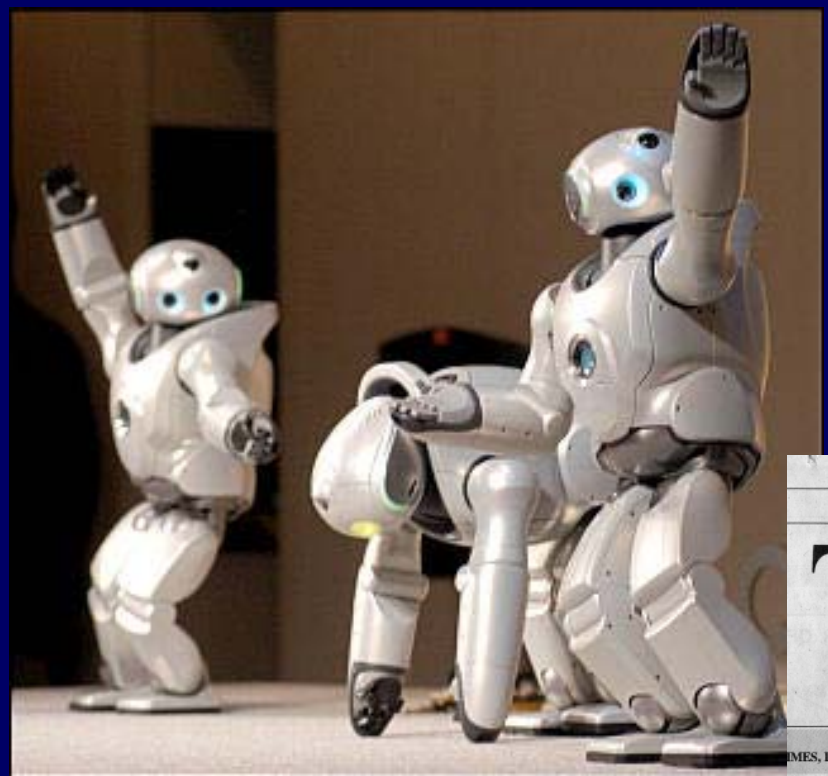
1. Statement from Warsaw on "Evolution as a tool for automated design".
2. "Theory of intelligence: What should it look like?"
   Presentation by Peter Horn
   Resulting from discussions of Dr. Marc Dekamps, Prof. Ernst Poeppel and their students in Munich
3. (a) Design principles for intelligent systems
   (b) Intelligence revisited: Achievements and challenges
4. The latest from China
   Presentation by Prof. Hong-bin Zha, Beijing University: "Latest robotics from Beijing"

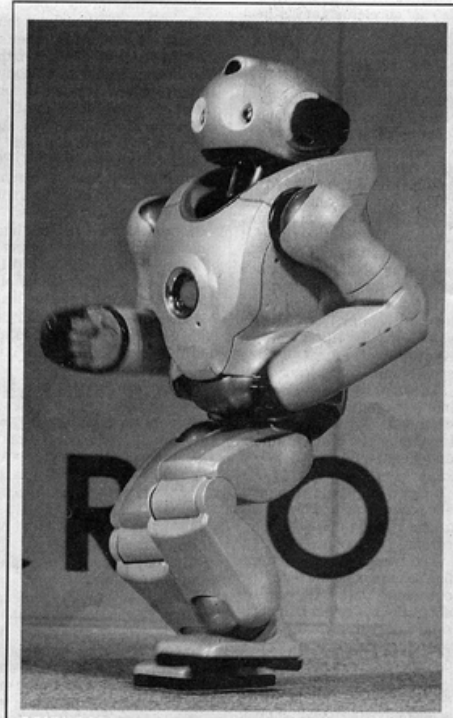
The latest from China

Prof. Hong-bin Zha
Center of Information Science
Peking University, China
“Latest robotics from Beijing”

Qurio (Sony)

the latest small humanoid from Sony





SONY CORP.'S Qrio humanoid robot jogs during an unveiling ceremony Thursday in Tokyo. REUTERS PHOTO

Sony's Qrio robot learns how to jog

The Associated Press

Sony Corp.'s child-size walking robot already knows a few hip dance steps and can kick a miniature soccer ball.

Now, it can jog — a new trick developers say is ingenious because it requires the machine to jump off the ground, even for a fraction of a second.

The new skills of the humanoid, developed by the electronics and entertainment giant's robot unit, which also makes Aibo, a doglike robot, was demonstrated to reporters at a Tokyo hall Thursday.

When an upgrade of the 58-cm-tall robot was introduced last year, Sony executive Toshitada Doi had said it might go

ALL THE NEWS WITHOUT FEAR OR FAVOR

The Japan Times

IMES, LTD., 2003

Friday, 19 Dec. 2003

4T

Mars Rover: “Spirit” and “Opportunity”

A FULL-SCALE COPY of Spirit and Opportunity, the twin robot explorers currentl
Mars, rolls over a rock at a mockup of the Martian surface in a parking lot be
Propulsion Laboratory in Pasadena, Calif., in November. AP PHOTO

Developed by
Jet Propulsion Laboratory
Pasadena, Calif.

http://marsrovers.
jpl.nasa.gov/home/index.html

ALL THE NEWS WITHOUT FEAR OR FAVOR

The Japan Times

IMES, LTD., 2003

Tuesday, 23 Dec. 2003

4TH

Asimo making "mochi"

(Japanese rice cakes)

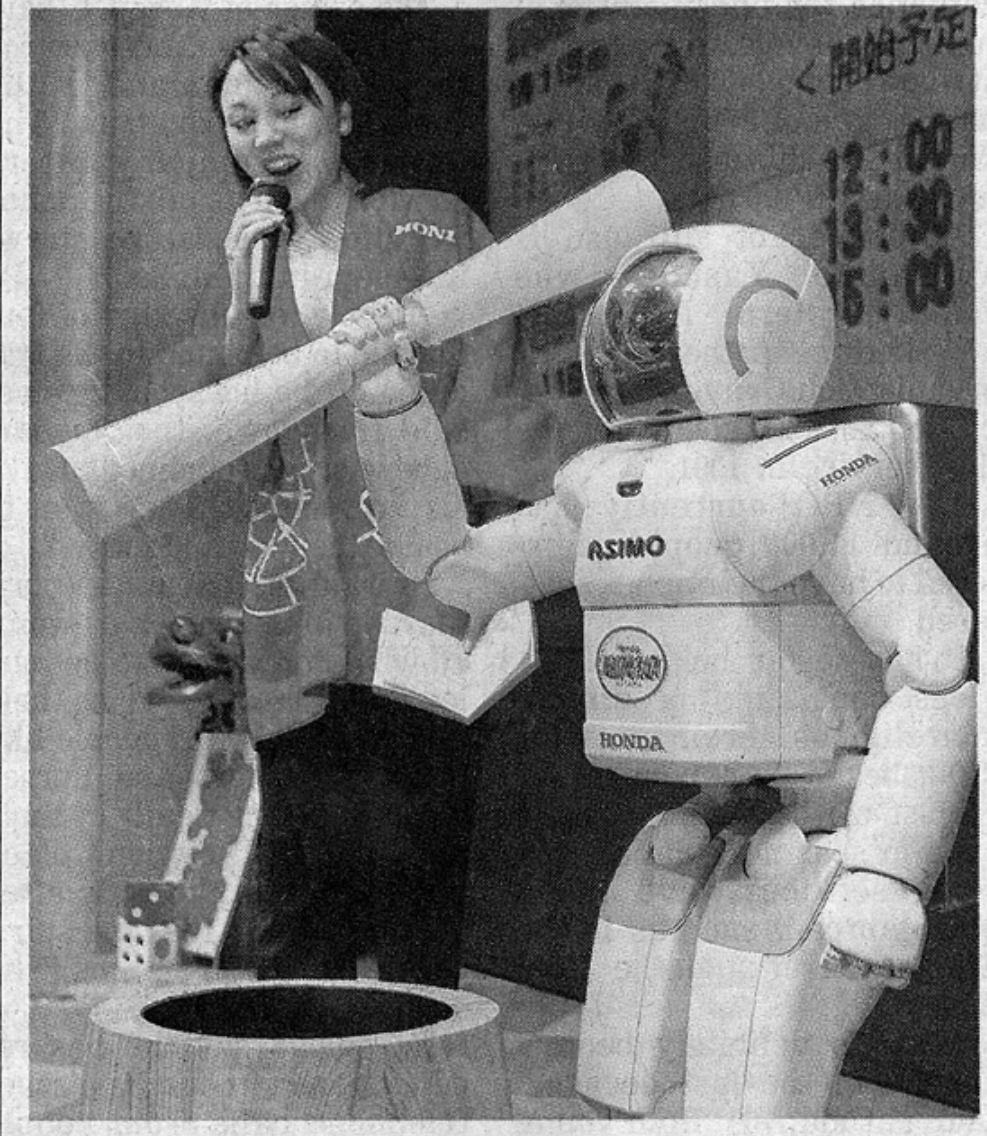
ALL THE NEWS WITHOUT FEAR OR FAV

The Japan Tim

Tuesday, 12 Jan. 200

MES, LTD., 2003

MECHANIZED 'MOCHI'

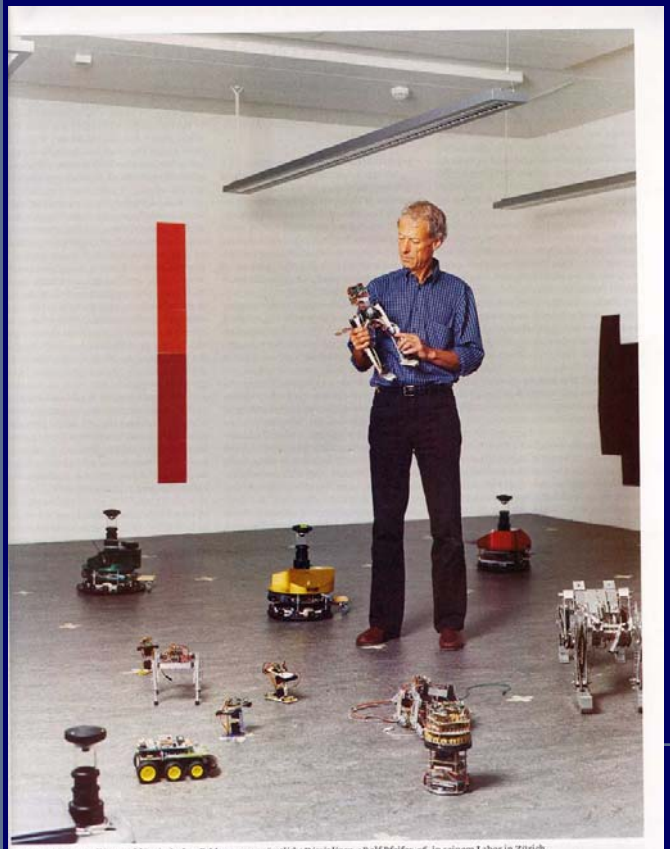


HONDA MOTOR CO.'s humanoid robot Asimo pounds steamed rice to make "mochi" at the company's headquarters in Tokyo on Sunday. Honda employees made the rice cakes to celebrate the new year and gave them to customers in the showroom. AFP-JIJI PHOTO

“Brainless intelligence” (German: “Kopflose Intelligenz”)

from Swiss weekly

“Die Weltwoche”



«Die Künstliche Intelligenz schlägt in Sachen Fehlprognosen sämtliche Disziplinen»: Rolf Pfeifer, 56, in seinem Labor in Zürich.

Kopflose Intelligenz

Seine Roboter sind Basteleien, seine Konzepte der Natur abgeschaut. Rolf Pfeifer ist einer der kreativsten Forscher der modernen Robotik. Jetzt präsentiert er eine Weltpremiere: eine Vorlesung, die von Tokio aus rund um den Globus übertragen wird. *Von Mathias Plüss und Vera Hartmann (Bild)*

Die Szene gleicht einer Götzenhuldigung. Scheinwerfer gleissen, die Musik wird lauter, der Moderator triumphiert – und dann betritt Er die Bühne: Asimo, der neue Star der Roboterzunft, ein Ausbund japanischer Ingenieurskunst, von Kopf bis Fuss mit Hightech voll gestopft. Gebaut haben ihn die besten Techniker des Autoherstellers Honda, und hier, auf der Bühne der Technischen Universität Darmstadt, wird er zum ersten Mal dem europäischen Publikum präsentiert.

Asimo sieht aus wie ein Kind in einem weissen Raumanzug; 1,20 Meter gross, 52 Kilogramm schwer und 1,6 Stundenkilometer schnell. Das ist nicht besonders viel, aber Asimo bewegt sich auf Beinen und nicht auf Rädern, und einem Roboter das Gehen beizubringen, ist unendlich viel schwerer als das Rollen. Doch bieten die Beine entscheidende Vorteile: Asimo kann enge Kurven machen, seitwärts gehen, Treppen steigen; auf der Bühne wagt er sogar ein erstes Tänzchen.

Nur einer stört das Ritual: Rolf Pfeifer, 56, Professor für Computerwissenschaften und Direktor des Labors für Künstliche Intelligenz an der Universität Zürich. Gewiss, auch er lobt in seinem Gastvortrag in Darmstadt die technische Raffinesse des Roboters. Doch wenn er Asimo «viel Gehirn» attestiert, hat das schon einen ironischen Unterton.

Vollends zum Advocatus Diaboli macht sich Pfeifer mit Filmeinspielungen über Billigroboter, über seinen Tanzroboter Stumpy etwa. Der besteht nur aus einer Art Oberkörper aus Eichenholz, zwei Styroporkugeln als Füsse und ein paar Batterien – das pure Gegenteil des hochgerüsteten Asimo. Trotzdem kann Stumpy hopsen und hüpfen, tänzeln und schwänzeln, vibrieren und rotieren; ein grosses Bewegungsrepertoire, das sich unmittelbar aus der Konstruktion des Roboters ergibt.

«Eines will ich klarstellen: Asimo ist absolute, einsame Spitzentechnologie», sagt Rolf Pfeifer, als ich ihn ein paar Wochen später auf seinen Darmstädter Vortrag anspreche. «Da ist alles optimiert bis zum Letzten. Aber aus meiner Sicht ist Asimo auch der Endpunkt einer bestimmten Entwicklung. Jetzt braucht es neue Ideen.»

Wir befinden uns im Labor für Künstliche Intelligenz an der Universität Zürich – einem Ort, wo neue Ideen brodeln. In einem Mordstempo führt uns Pfeifer herum; er steht kurz vor der Abreise nach Japan, wo er ein Forschungssemester an der Universität Tokio verbringen will, die Zeit ist knapp.

Alles ist ziemlich klein hier, die Roboter reichen einem kaum bis zu den Knien, das meiste sieht eher nach Bastelei aus als nach Wissenschaft. Und doch hat sich das Zürcher Labor in den vergangenen Jahren zu einem der Zentren der so genannten Neuen Künstlichen Intelligenz gemausert und Pfeifer mit ihm zu einem Guru der Alternativrobotik. Dem Fortschritt der herkömmlichen Robotik, der oft genug nur auf der stetig wachsenden Leistungsfähigkeit der Elektronik beruht, stellt er seine eigenen, oft verblüffend einfachen Ideen entgegen – energieeffiziente und elegante Konzepte, meist der Natur abgeschaut.

Pfeifer ist ein Querdenker, der damit kokettiert, er habe noch vor vierzehn Jahren «nicht gewusst, was ein Roboter ist», habe sich bis heute geweigert, sich die Theorie systematisch anzueignen – und w… welt anerkannt, ja … Lehrbuch der Neuen… geschrieben und hat… prägt: «Cheap Desig… um nur die beiden w…

Der Mensch ist ein…

Den Begriff «… durchaus wörtlich n… wand für Asimo pu… Geld in die Million… Version des Tanzro… paar Franken und zw… sign bedeutet aber n… sich um ein raffinier… Lebewesen sind so … Energie- und Steuer… nimum reduziert.

Unsere Beine si… Bewegung beim V… neunzig Prozent aus… letzten Schritt, ist a… ert», sagt Pfeifer. «… konstruktion.» Das… sätze. Doch Pfeifer… Analyse, seine Devis… Nachbauen». So ha… metallhund Puppy … Fortbewegungsapp… ist. Federn an den Be… le von Oberschenkel… flexible Rückgrat s… zität. Kleine Elektro…

an, der Rest ist reine Mechanik. Keine Sinnesorgane melden die Positionen der Beine, keine Zentralinstanz steuert die Bewegung. Und Puppy, muss man sich vorstellen, kann rennen, ja sogar galoppieren – allein durch die Genialität der Konstruktion.

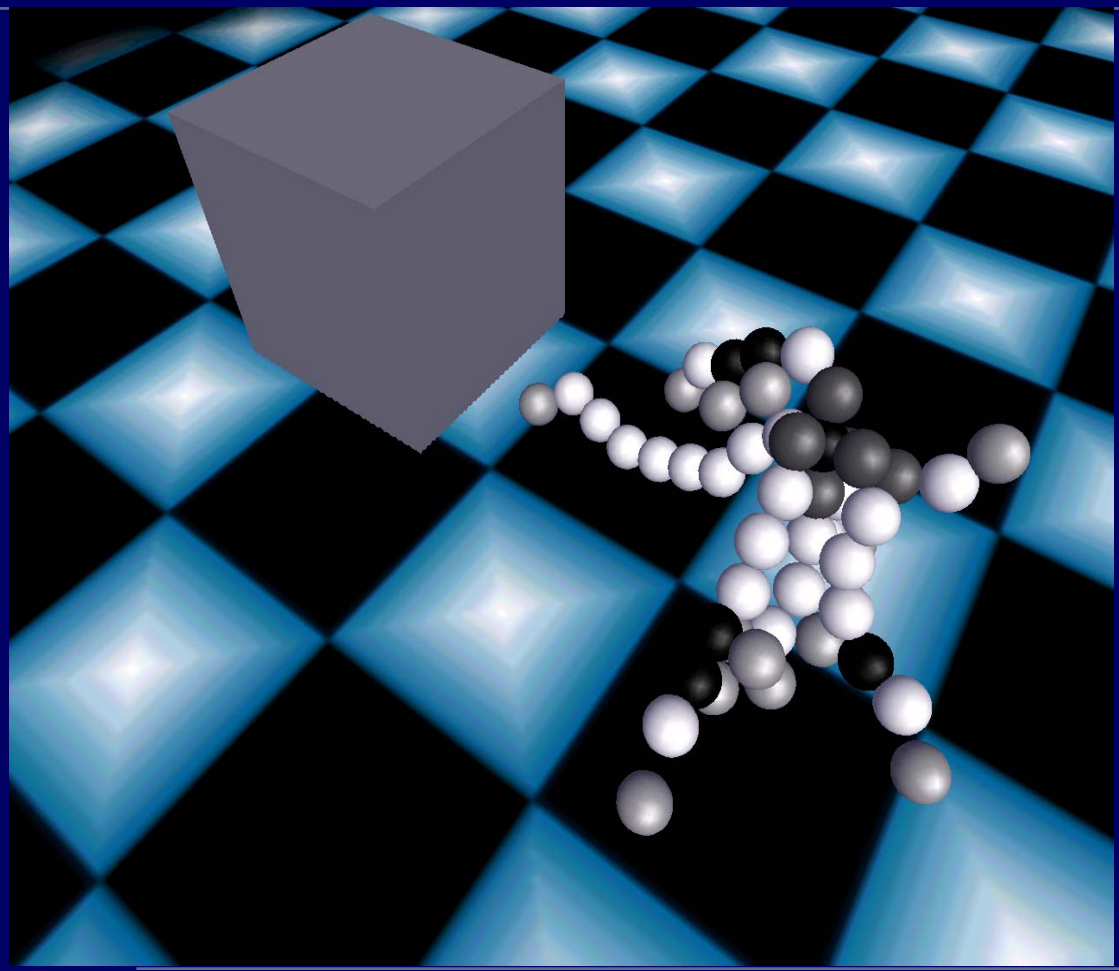
Der Unterschied ist augenfällig: Puppys Galopp wirkt sehr natürlich – Asimo geht langsam und ungelenk, wie ein Roboter eben. «Das liegt daran, dass die herkömmliche Robotik viel zu sehr auf die Steuerung fokussiert», sagt Pfeifer. «Darum sieht der Gang so unnatürlich aus.» Puppys ungesteuerte Bewegungen seien näher am natürlichen Vorbild: «Das Gehirn eines Hundes wäre gar nie in der Lage, das alles zu steuern.»

Denken ist etwas anderes als Rechnen

Ich frage Rolf Pfeifer, was ein hirnloser, galoppierender Hund mit Intelligenz zu tun …

Final comment on "The emergence of intelligence: Artificial evolution and morphogenesis"

Evolution of a “Block Pusher”



artificial evolution and morphogenesis

based on models of genetic regulatory networks

Design and programming: Josh Bongard

Limitations of the model

- fitness function rather than survival
  --> survival as the only criterion for selection (e.g. Jeffrey Ventrella)
- simulation rather than real world
  --> “connect” to real world (e.g. Adrian Thompson)
- no interaction with the environment during ontogenetic development
  --> developmental plasticity (e.g. Josh Bongard)

How far can we get? Where will we go???

Automated Design

- Warsaw:
  Special Assignment: “Artificial Evolution as a tool for Automated Design”

  (5 min presentation)

switch to Warsaw

This concludes chapter 8

- please read complete chapter (including artificial life part)

more information on this topic at:
http://www.ifi.unizh.ch/ailab/teaching/AL03/

Design principles for "…" systems

chapter 10: overview

chapters 11-14: details

Artificial Intelligence

goals

not only “life as it is” but “life as it could be”
(Chris Langton)

understanding biological systems

principles of intelligent systems

useful artifacts applications



abstract

theory



Special assigment: Munich

- “Theory of intelligence: What should it look like?”

  Presentation by Peter Horn
  Resulting from discussions of Dr. Marc de Kamps, Prof. Ernst Poeppel and their students in Munich

switch to Munich

Design principles of intelligent systems Overview

Design procedure / „meta principles“

- synthetic methodology
- time perspectives
- emergence
- diversity/compliance
- frame-of-reference

Agent design

- three constituents
- complete agent principle
- „cheap design“
- „ecological balance“
- redundancy principle
- parallel, loosely coupled processes
- sensory-motor coordination
- value principle

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Time scales for understanding and design

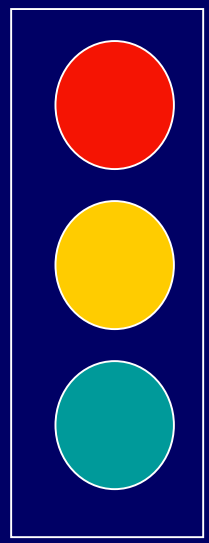
state-oriented	--	the “here and now”
learning and development	--	the ontogenetic perspective
evolutionary	--	the phylogenetic perspective

Time frames illustration: Traffic lights

Why stop at traffic light?

SHORT TERM

specific visual stimlus, the red light → apply brakes



LONG TERM (PHYLOGENETIC)

historical process whereby traffic lights came to be used

LEARNING AND DEVELOPMENT (ONTOGENETIC)

rule learned from school, TV, experience

FUNCTIONAL EXPLANATION

drivers who do not stop → reduced fitness

Time scales for understanding and design

state-oriented	--	the “here and now”
learning and development	--	the ontogenetic perspective
evolutionary	--	the phylogenetic perspective

emergence

comprehensive explanation of behavior: all three required

Time scales for understanding and design

state-oriented	--	the “here and now”
“hand design”		
learning and		
development	--	the ontogenetic perspective
initial conditions		
learning/dev. procs.		
evolutionary	--	the phylogenetic perspective
evolutionary algs.		
morphogenesis		

for engineering: level of designer commitments

Time scales for understanding and design

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emergence: more powerful explanation

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Case study: Walking

illustrating

- principle of “cheap design”
- principle of “ecological balance”

Video

Goal: natural walking

Miriam

"Passive Dynamic Walker" – the brainless robot

Video

SCollinsWalker

"walking without control"

Design and construction:
Ruina/Wisse/Collins, Cornell University

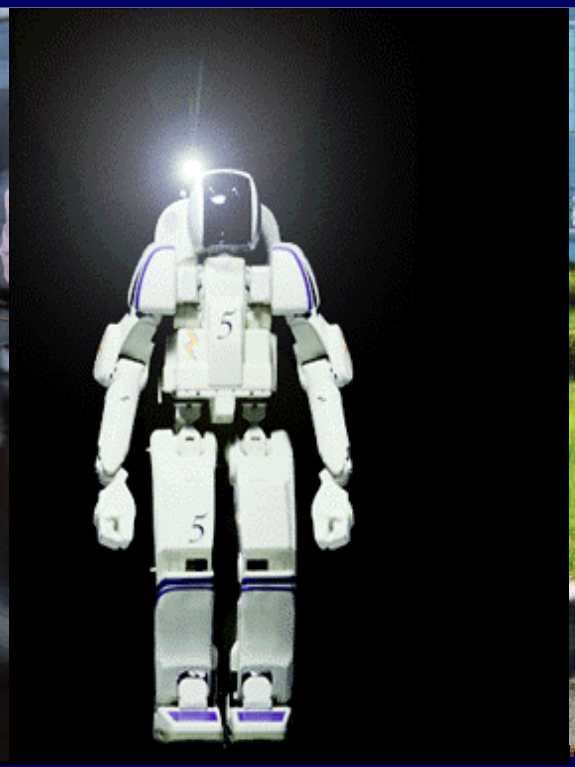
Morphology:
- wide feet
- elastic heels
- counterswing of the arms
- surface of feet

dynamically stable
statically unstable

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

Video

HONDA Asimo

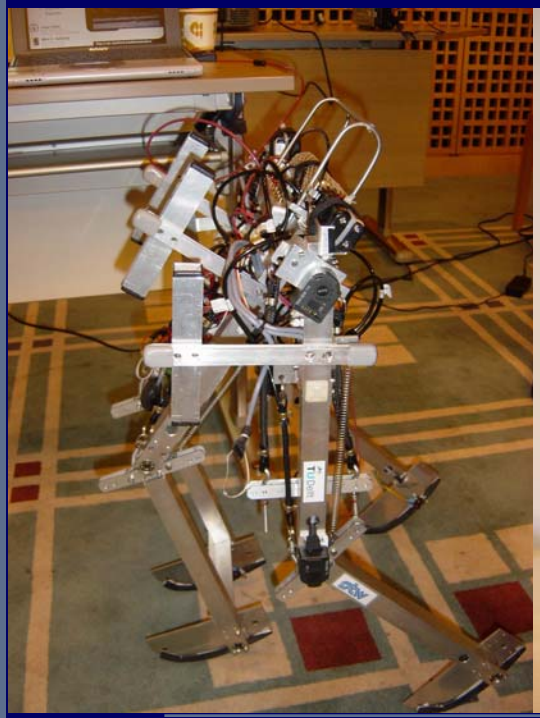


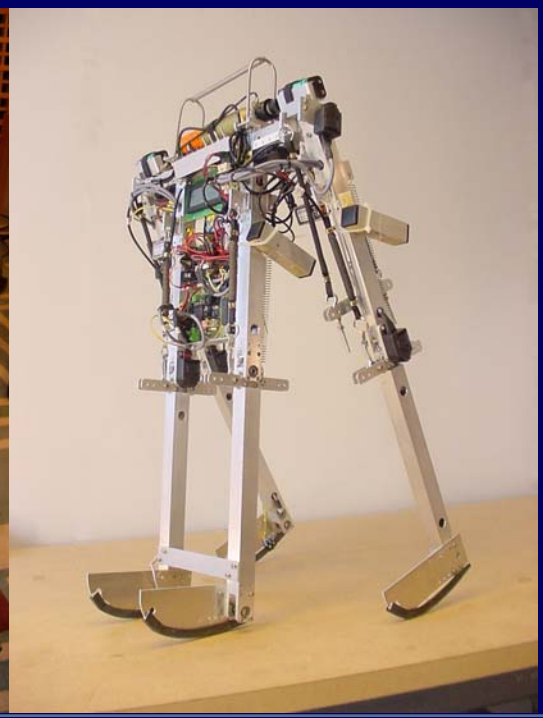
Asimo

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

“Almost Passive Dynamic Walker” – MIKE

Design and construction: Martijn Wisse
Delft University, The Netherlands





Morphology
Materials
pneumatic actuators
(artificial muscles)
minimal actuation
passive dynamics

walking almost without control

“Almost Passive Dynamic Walker” – MIKE

Design and construction:
Martijn Wisse, Delft University
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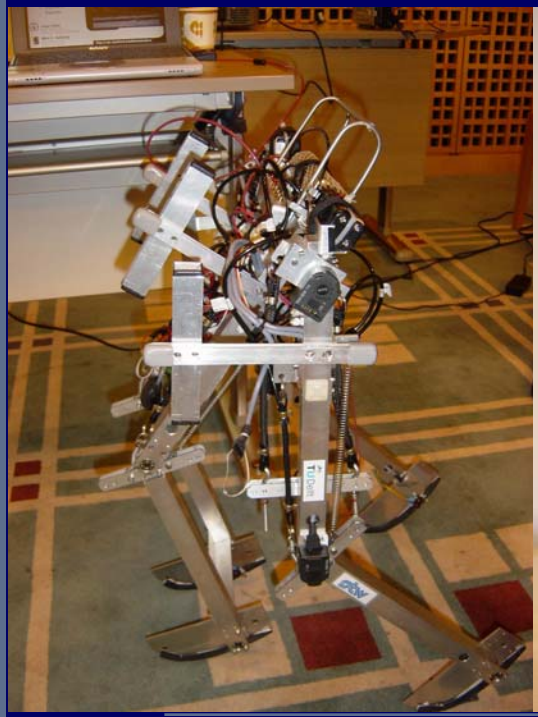
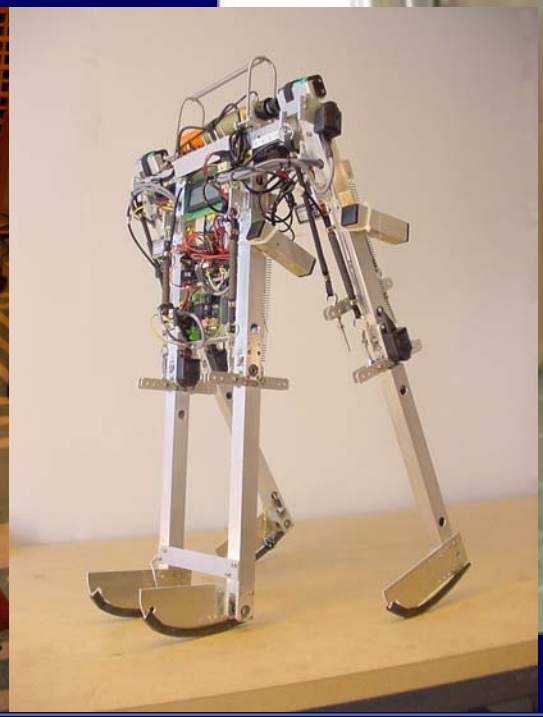




Morphology
Materials
pneumatic actuators
(artificial muscles)
minimal actuation
passive dynamics

walking almost without control

Conclusions

- appropriate embodiment („ecological balance“)
  - morphology
  - materials
  - exploitation of dynamics in interaction with environment

  → minimal effort for control

  → energy-efficient walking

  → natural walking

Felix, Regula and Exuperantius

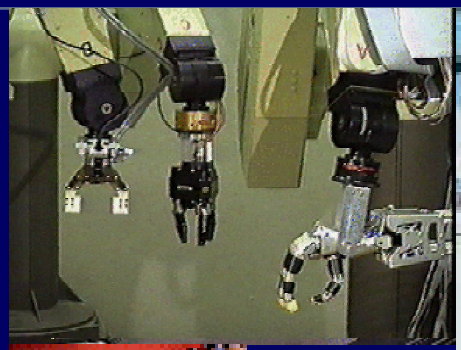
the three saints of the city of Zürich

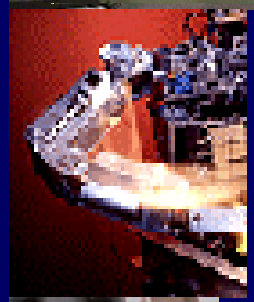
Grossmünster in Zürich

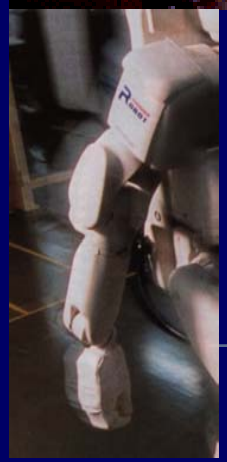
legend??

→ *“passive dynamic walkers”*

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
- rapid

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

“Cheap design” and “ecological balance”

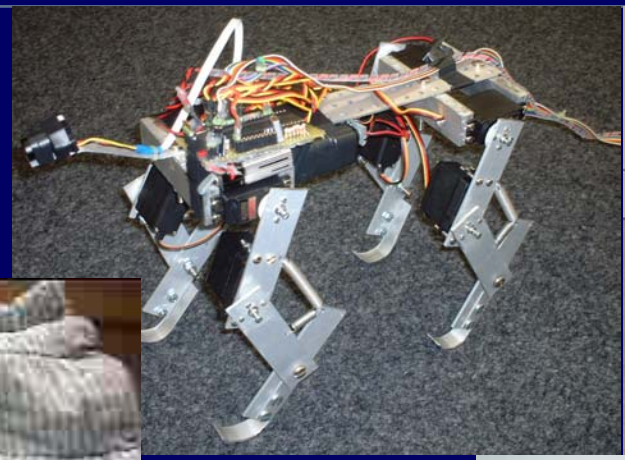
another illustration: The quadruped “puppy”

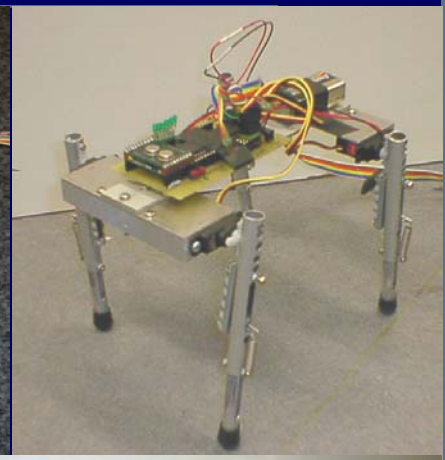
The quadruped “puppy”

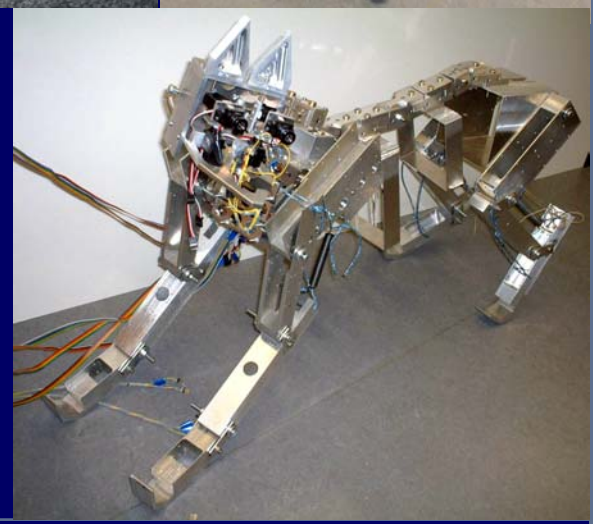
Video

puppy

rapid locomotion
in biological systems





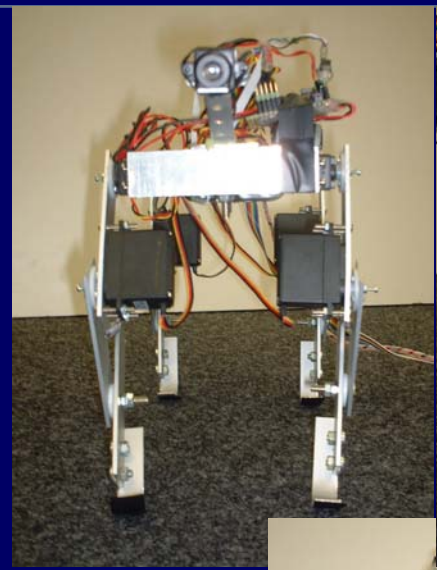


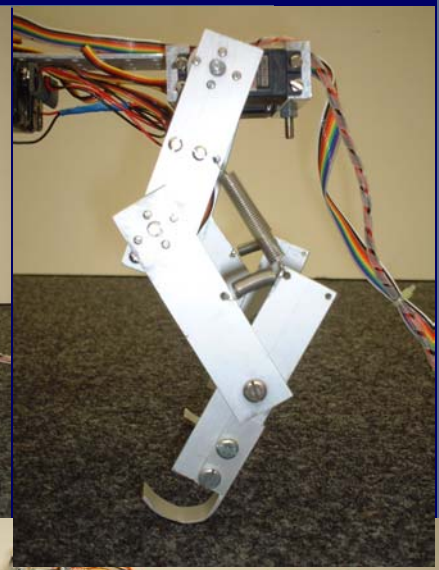
Design and construction:
Fumiya Iida

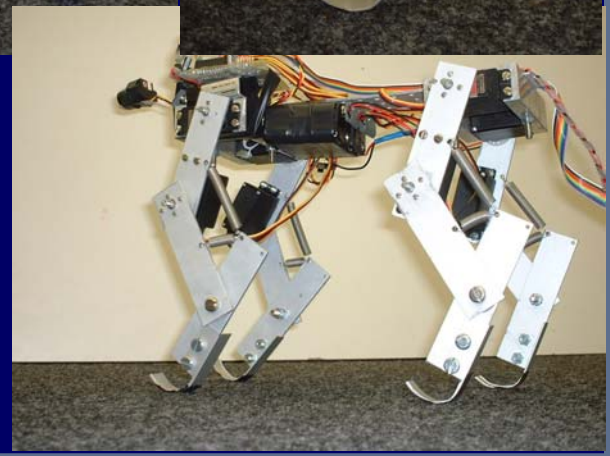
Video

The quadruped “puppy” *puppy, slow motion*

slow motion

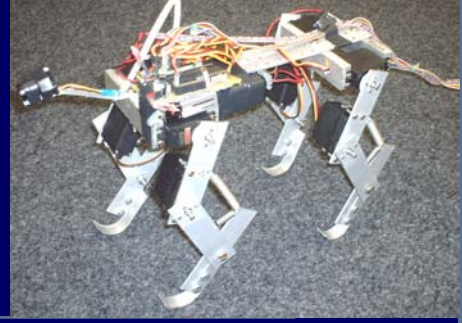


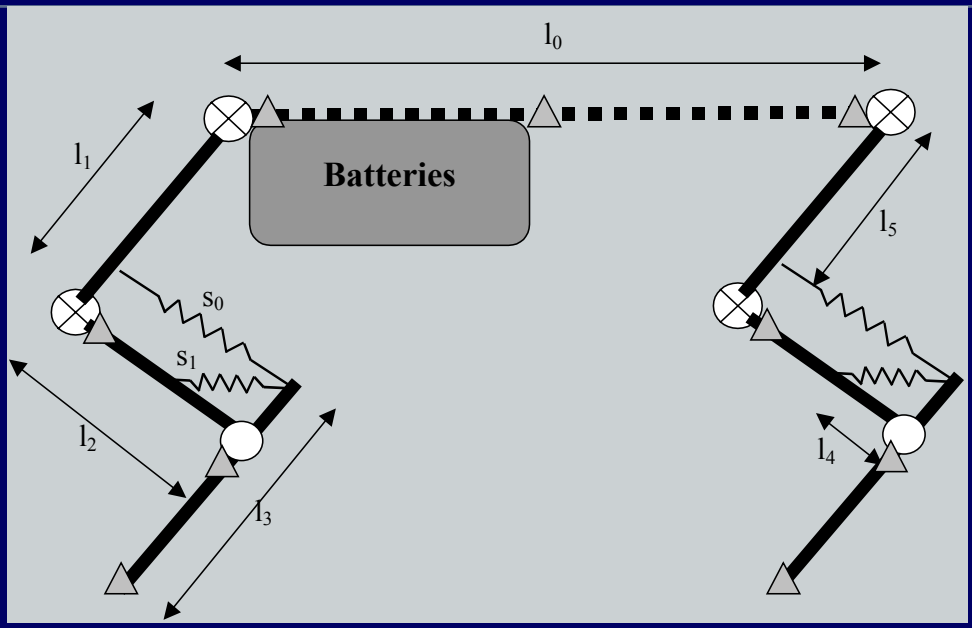


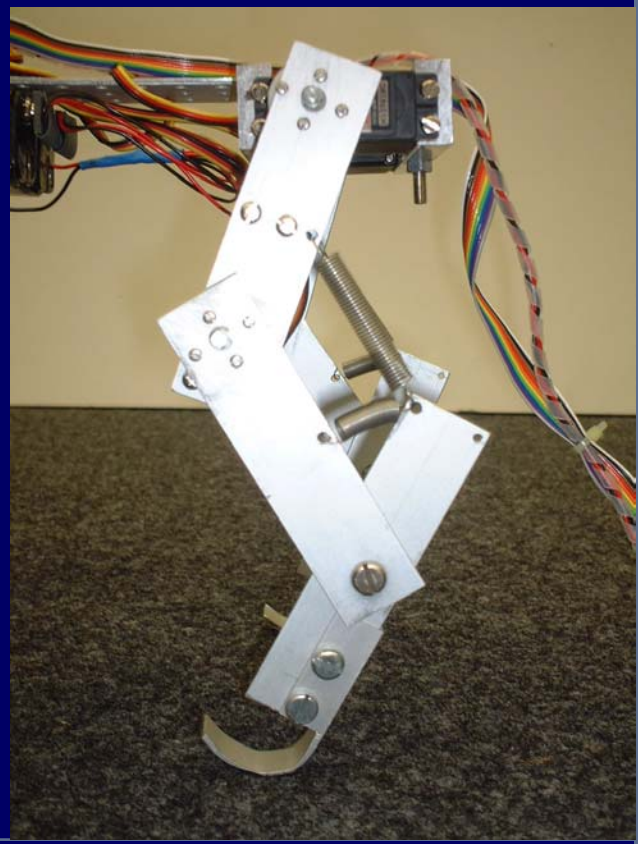


Design and construction:
Fumiya Iida

The quadruped “puppy”





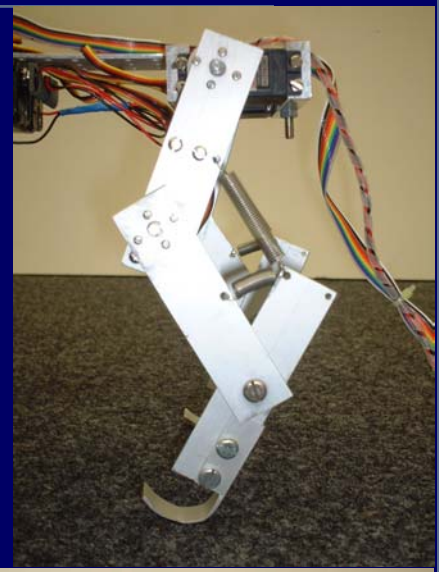


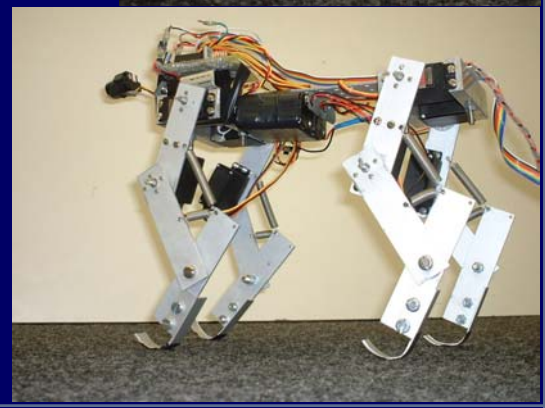
- circles: passive joints
- circles with cross: joints with servo-motors
- fat lines: solid limbs
- dashed line: elastic plate
- triangles: positions of LEDs for visual tracking

The quadruped “puppy”: summary

- simple control (!)
- springlike materials
- flexible spine
- exploitation of dynamics of actuators and of interaction with environment
- self-stabilization

“cheap design” and “ecological balance”



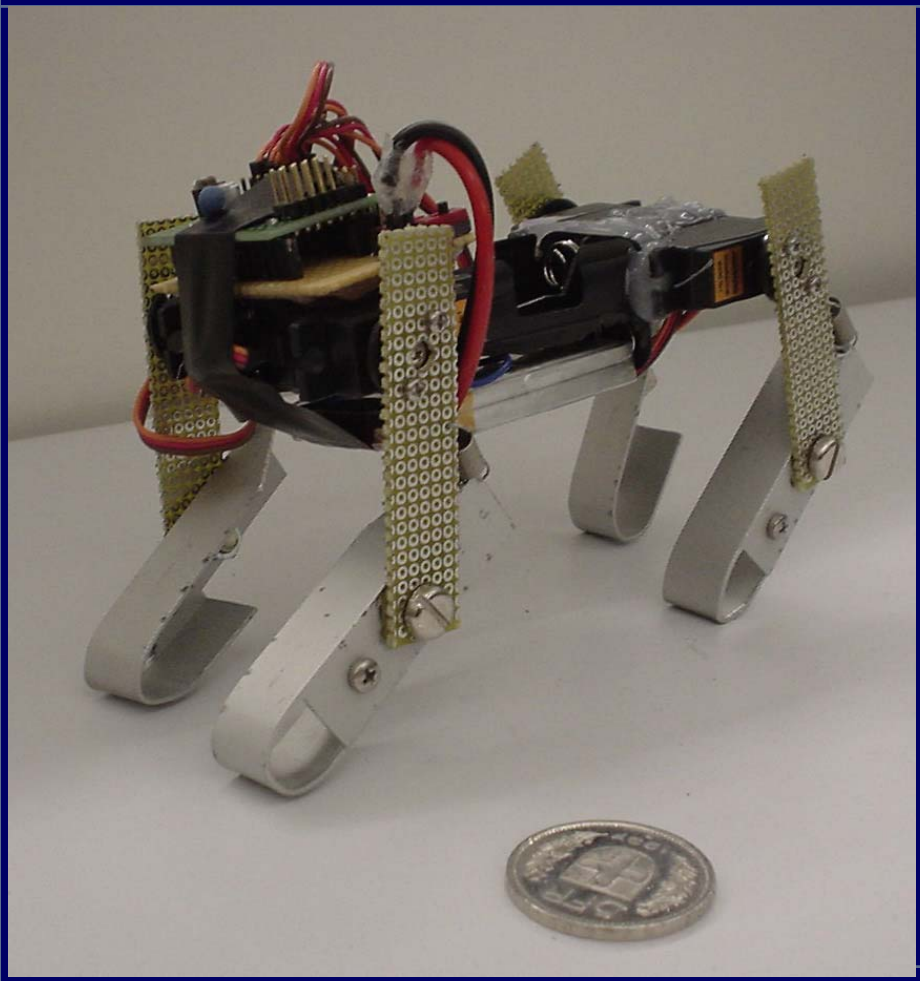


Design and construction:
Fumiya Iida

Video

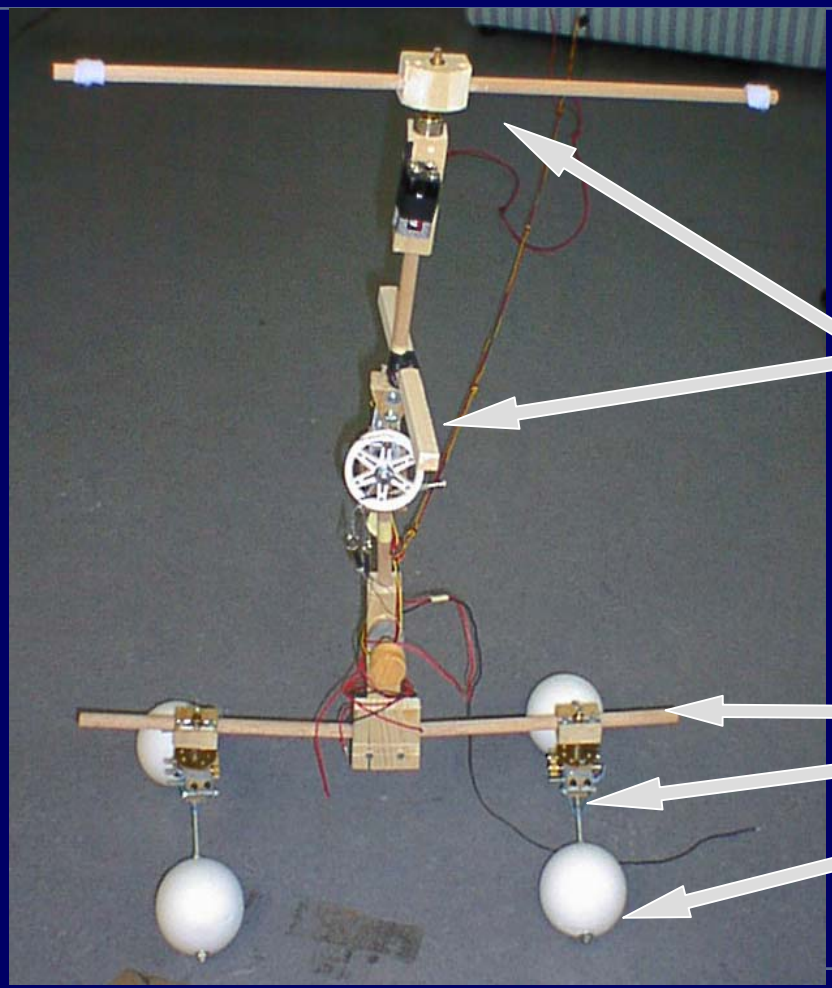
The “mini dog” by Fumiya Iida

“mini dog”



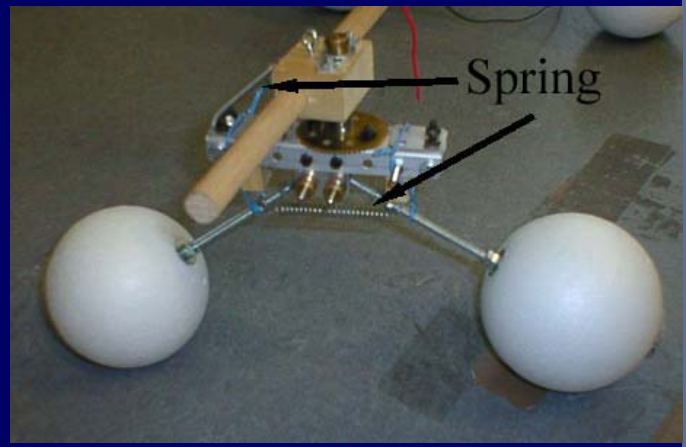
Artificial Intelligence Laboratory
Dept. of Information Technology
University of Zurich

Recall: 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”: many behaviors with only two joints

Video

Stumpy

The principle of “cheap design”

intelligent agents: “cheap”

- exploitation of ecological niche
- parsimonious (Occam’s razor) (but see “redundancy principle”)
- exploitation of specific physical properties of itneraction with real world

Principle of “ecological balance”

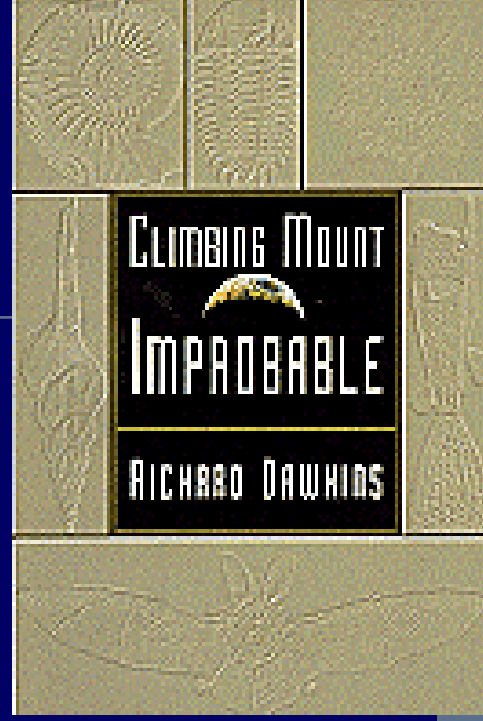
balance / task distribution between

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

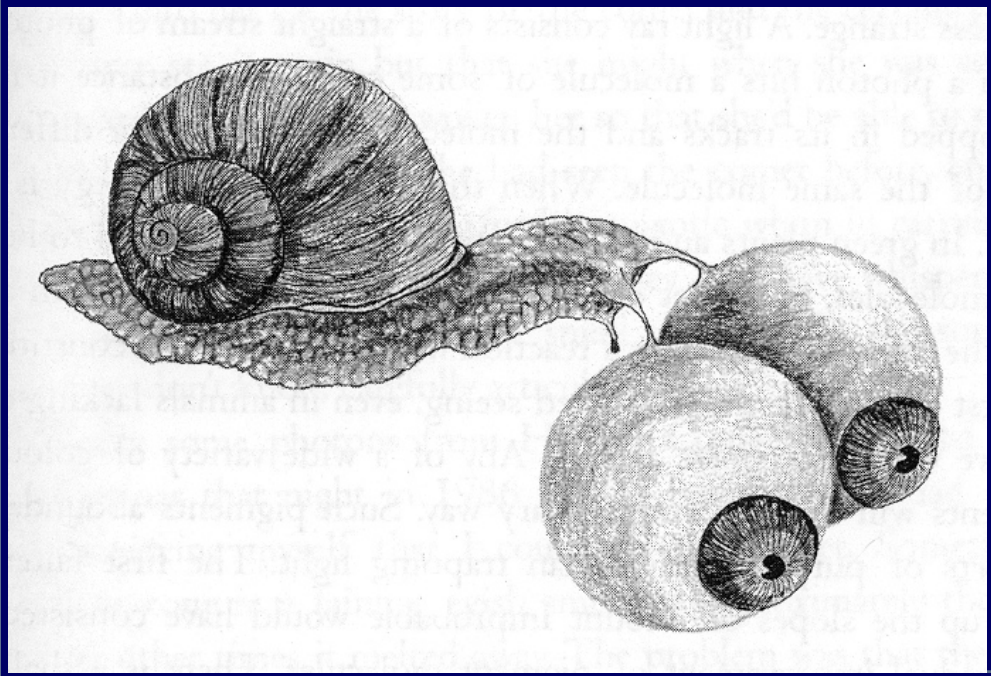
balance in complexity

- given task environment
- match in complexity of sensory, motor, and neural system

Snail with giant eyes (Richard Dawkins)

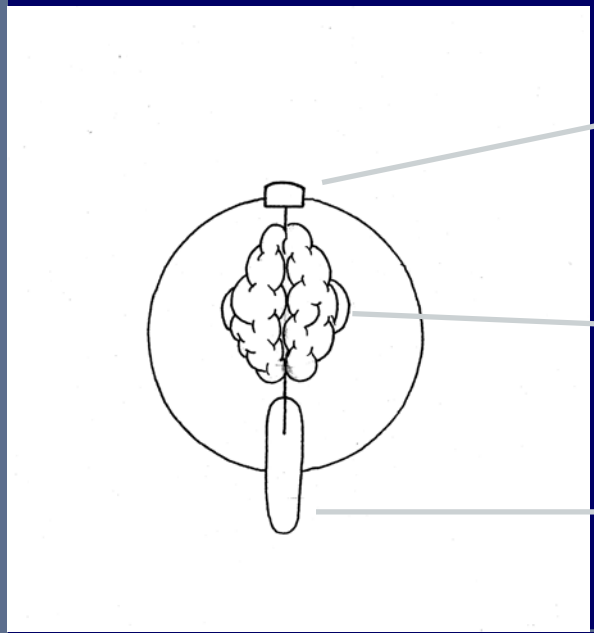


ecologically unbalanced system



Braitenberg Vehicle 1 with large brain

ecologically unbalanced system



sensor for one quality (e.g. temperature, light)

very large brain

one motor

Design principles of intelligent systems Overview

Design procedure / „meta principles“

- synthetic methodology
- time perspectives
- emergence
- diversity/compliance
- frame-of-reference

Agent design

- three constituents
- complete agent principle
- „cheap design“
- „ecological balance“
- redundancy principle
- parallel, loosely coupled processes
- sensory-motor coordination
- value principle

The redundancy principle

- redundancy prerequisite for adaptive behavior
- partial overlap of functionality in different subsystems
- sensory systems: different physical processes with “information overlap”

chapter 13: The principles of cheap design, redundancy, and ecological balance

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Generation of sensory stimulation through interaction with environment

- multiple modalities
- constraints from morphology and materials
- generation of correlations through physical process
- basis for cross-modal associations

–> „good“ raw material for neural processing

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

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)

(for documentation)

The principle of sensory-motor coordination

- self-structuring of sensory data through interaction with environment

*physical process — **not** „computational“*

prerequisite for learning

The principle of sensory-motor coordination

- self-structuring of sensory data through interaction with environment

*physical process — **not** „computational“*

prerequisite for learning

“developmental robotics”

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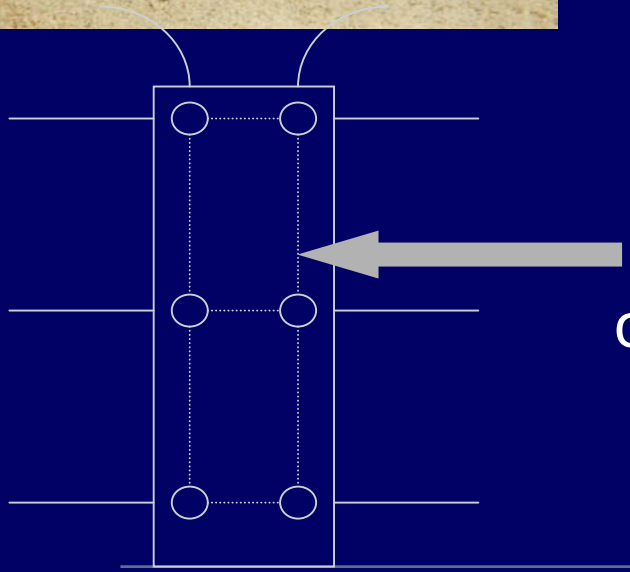
The principle of parallel, loosely coupled processes

(intelligent) behavior emergent from

- agent-environment interaction
- large number of parallel, loosely coupled processes
- asynchronous
- coordinated through agent's
  - sensory-motor system
  - neural system
  - interaction with environment

Locomotion of insects



Holk Cruse

- no central control
- only local neuronal communication
- global communication through environment

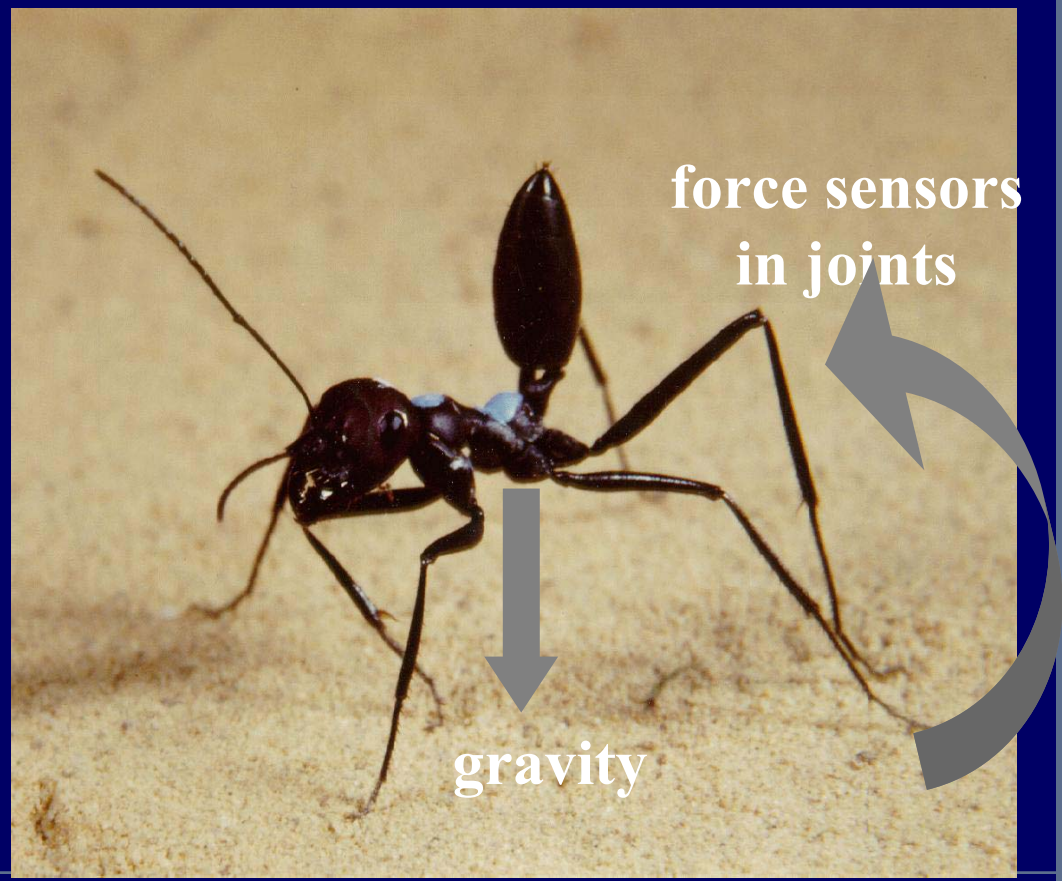
neuronal connections

Global communication through environment

- exploitation of interaction with environment

→ simpler neuronal connections

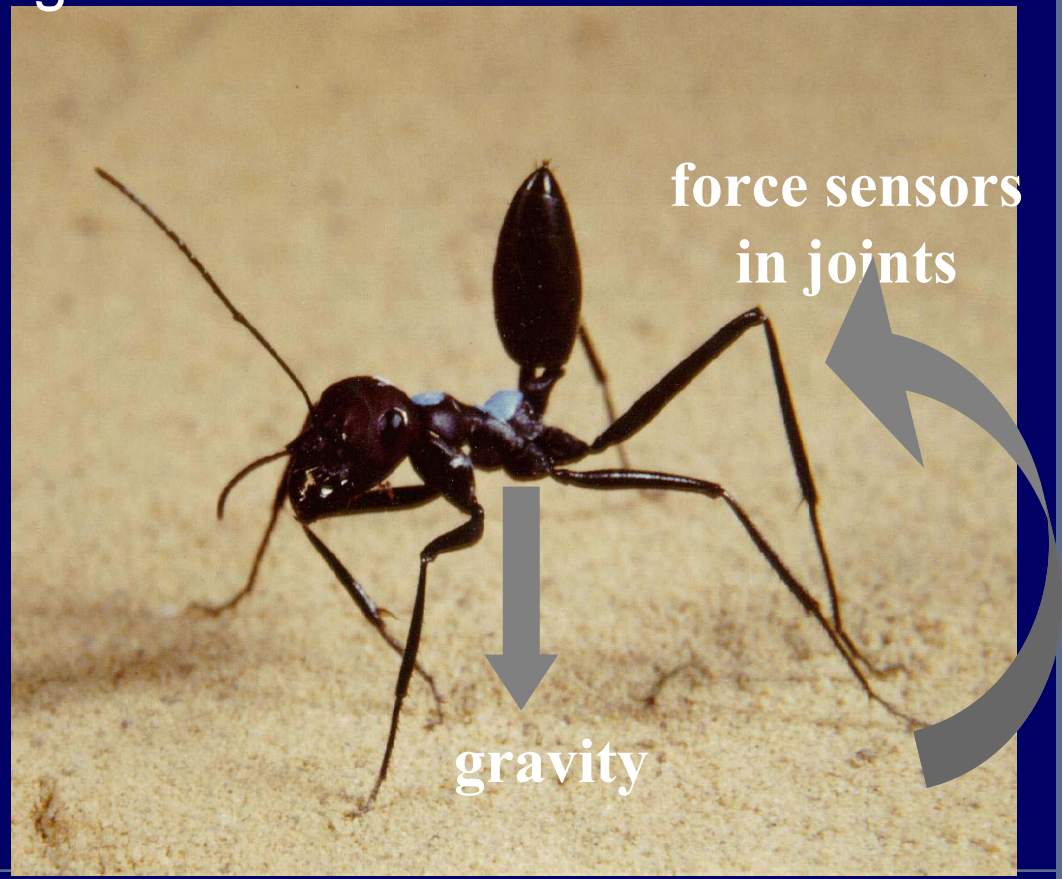
→ “cheap design”



Principle of parallel, loosely coupled processes

Intelligent behavior emergent from

- large number of
  - asynchronous
  - parallel
  - autonomous
  - loosely coupled
- as agent interacts with environment



Principle of parallel, loosely coupled processes

Intelligent behavior emergent from

- large number of
  - asynchronous
  - parallel
  - autonomous
  - loosely coupled
- as agent interacts with environment

scalability to higher levels?? (recall: Kirsh-Brooks debate)

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The “value principle”

- about motivation
- evaluation of actions
- frame-of-reference: explicit and implicit values
- recent theorizing: information theoretic
  (organism tries to mainting “flow of information”)

chapter 14: The value principle

Challenges

see

- “Future trends sessions”
- Summary statement provided by
  - Yasuo Kuniyoshi
  - Rolf Pfeifer
  - Britta Glatzeder

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The latest from China

Now:

Prof. Hong-bin Zha
Center of Information Science
Peking University, China
“Latest robotics from Beijing”

switch to Beijing

Thank you for your kind attention!

CU all next week
20 January 2004 in the

GLOBAL VIRTUAL LECTURE HALL

stay tuned for
“Future trends 1 and 2”

Future trends 1 (1)
20 January 2004

meet the leading researchers in the field

Moderation:

Yasuo Kuniyoshi, University of Tokyo

Contributions by:

Friedrich Pfeiffer, Technical University of Munich
"Control of walking"

Hirochika Inoue, University of Tokyo
"Intelligent humanoids and the future of robots in human society"

Isao Shimoyama, University of Tokyo
"Micro/nano technology for robots and the future in a ubiquitous robotics"

Future trends 1 (2)
20 January 2004

meet the leading researchers in the field

Witold Kosinski, Polish-Japanese Institute of Information Technology, Warsaw
"Overview of the research activities of the Polish-Japanese Institute"

Adam Borkowski, Institute of Fundamental Technological Research, Warsaw
"Omnidirectional camera for controlling a modile robot"

Albrecht Schmidt, Ludwig Maximilian-University, Munich
(title to be announced)

Future Trends 2 (1)
27 January 2004

meet the leading researchers in the field

Moderation:

Yasuo Kuniyoshi, University of Tokyo

Shigeru Hirose, Tokyo Institute of Technology
"Morphology and functionality of robotic mechanisms and truly useful applications in the real world"

Yoshihiko Nakamura, University of Tokyo
"Modeling human body and mind by dynamics and the future of the new approach to intelligence"

Future Trends 2 (2)
27 January 2004

meet the leading researchers in the field

Minoru Asada, Osaka University
"Cognitive developmental robotics"

Yasuo Kuniyoshi, Rolf Pfeifer, and guests
"Conclusions of the lecture series"