Lecture 5

Building Brains and Bodies:
Embedded Artificial Neural Networks

The “walking chair”

Developed by Atsuo Takanishi, Waseda University, Tokyo

and tmsuk, Kitakyushu

Two-legged walking chair a world first from Japan

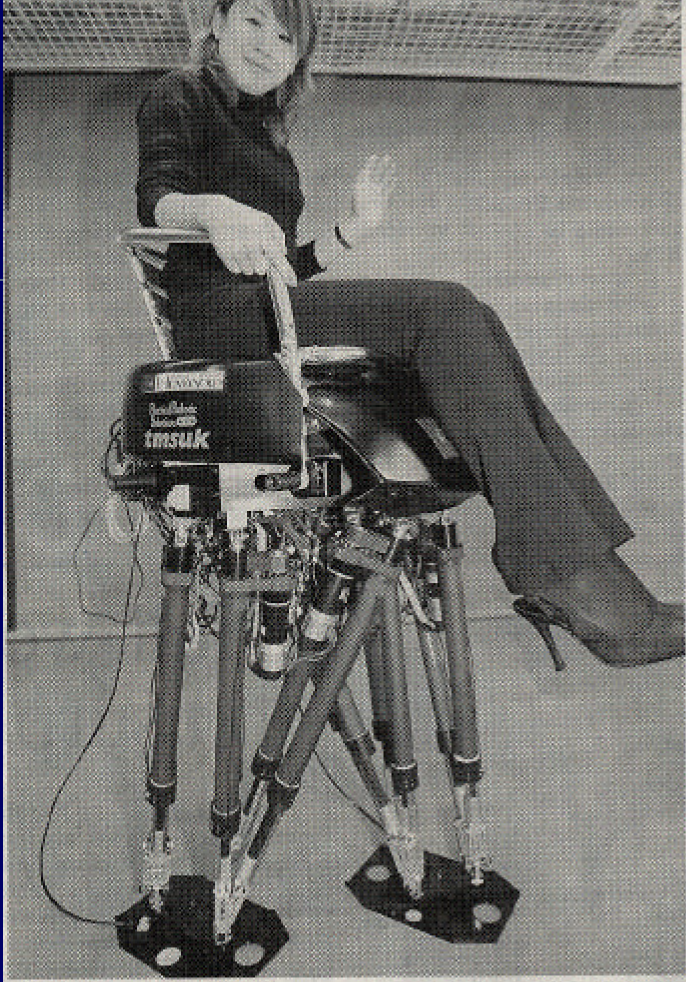
AFP-Jiji

Japanese researchers have unveiled the world’s first “two-legged walking chair” capable of carrying a person.

The battery-powered prototype, WL-16, is basically an aluminum chair mounted on two sets of telescopic poles bolted to flat plate “feet.” It can move forward, backward and sideways while carrying a person weighing up to 60 kg, and can adjust its posture if

It took two years to develop in a joint project involving the science and engineering department of Tokyo’s Waseda University and robot-maker tmsuk, based in Kit

“I believe this bip which I prefer to c legged walking cha than a wheelchair, tually enable (disal ple to go up and dow said Atsuo Takanis fessor in Waseda’s



YOSHIKO SAKAMOTO, an employee of robotics venture tmsuk, shows off the WL-16 prototype walking chair in Tokyo. AFP-JIJI PHOTO

ALL THE NEWS WITHOUT FEAR OR FAVOR

The Japan Times

Wednesday, 26 Nov. 2003

The “grand scheme”

Artificial Intelligence

higher level intelligence

goals

not only "life as it is" but "life as it could be"

--> synthetic methodology

understanding biological systems

principles of intelligent systems

useful artifacts applications



abstract theory



General idea

"bottom-up":

many examples --> extract principles

"Swiss robots" --> principle of "cheap design"

"Fungus Eaters" --> complete agent principle

Braitenberg vehicles --> principle of "cheap design"

Braitenberg 1 with large brain --> principle of "ecological balance"

DAC (today - see later) --> "redundancy principle"

Subsumption architecture (today - see later)

--> principle of "parallel loosely coupled processes"

Design principles of intelligent systems Overview

Design procedure / „meta principles“

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

Agent design

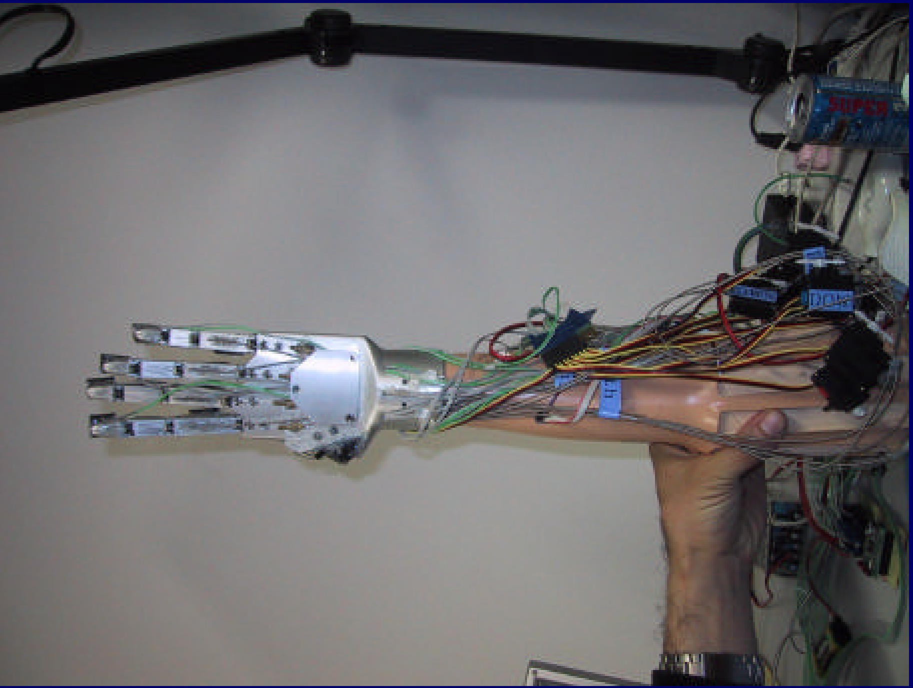
- three constituents
- complete agent principle
- „cheap design“
- redundancy principle
- „ecological balance“
- parallel, loosely coupled processes
- sensory-motor coordination
- value principle

Today’s topics

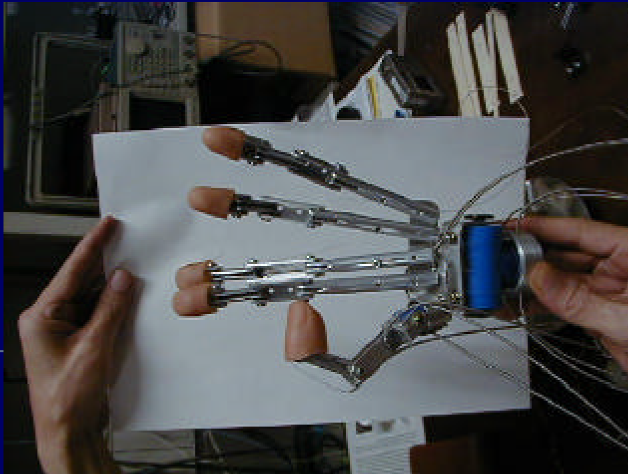
- Case study: Heider and Simmel
- “action selection” and segmentation of behavior (Zurich students)
- Building brains and bodies: embedded artificial neural networks
- The “behavior-based” approach
- “The latest from Japan”

The latest from Japan

Prof. Hiroshi Yokoi
Complex Systems Laboratory
Hokkaido University



frequent visitor to
AI Laboratory
Dept. of Information Technology
University of Zurich



“Action selection” and segmentation of behavior

switch to Zurich

Case study: Heider and Simmel

Video

Heider and Simmel

Movie by F. Heider, and M. Simmel, 1944

Please observe carefully!

Case study: Heider and Simmel

Switch to Beijing

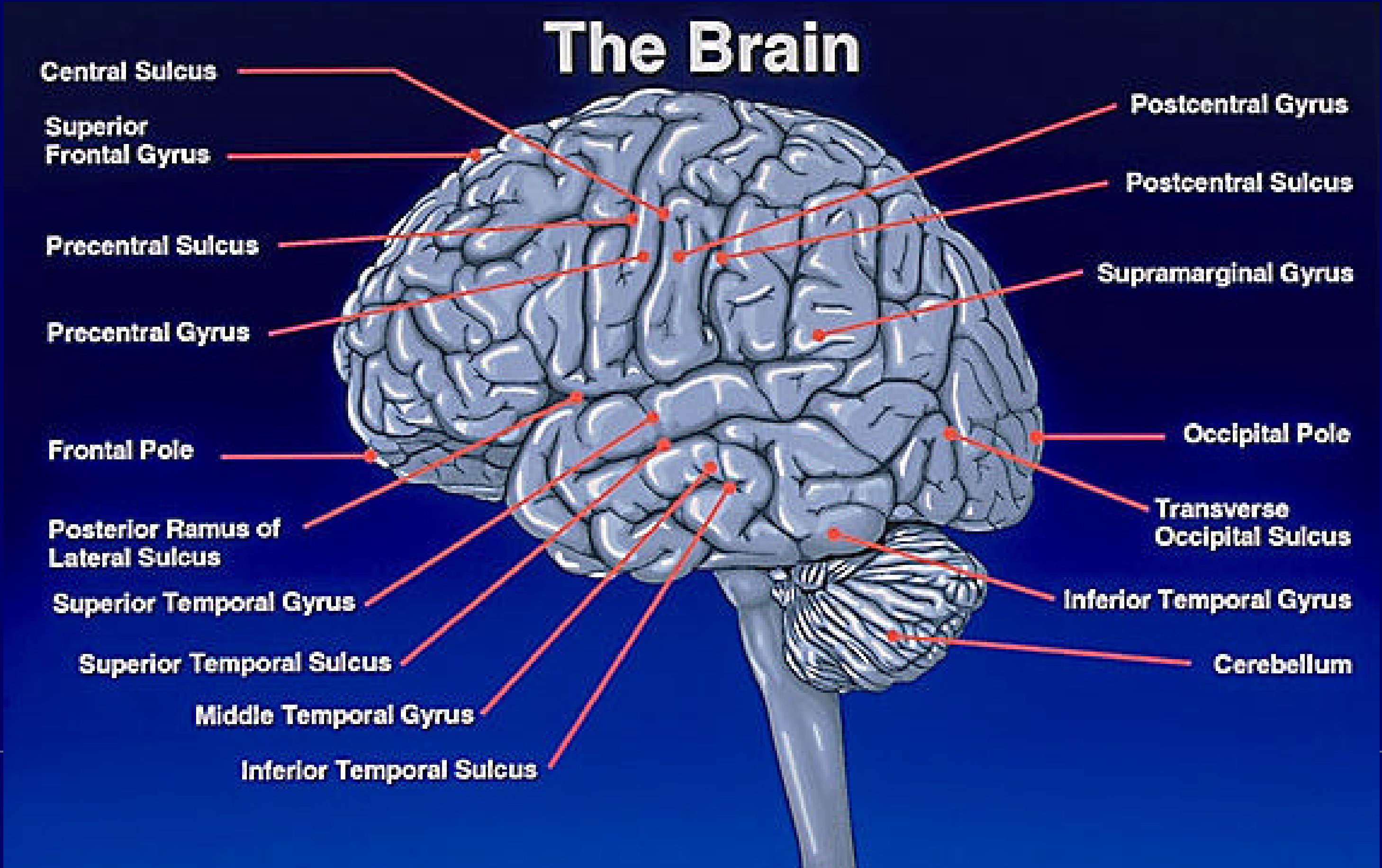
Case study: Heider and Simmel

"Anthropomorphization, the incurable disease."

David McFarland, Ethologist, Oxford University

Building Brains and Bodies: Embedded Artificial Neural Networks

Drawing inspiration from nature

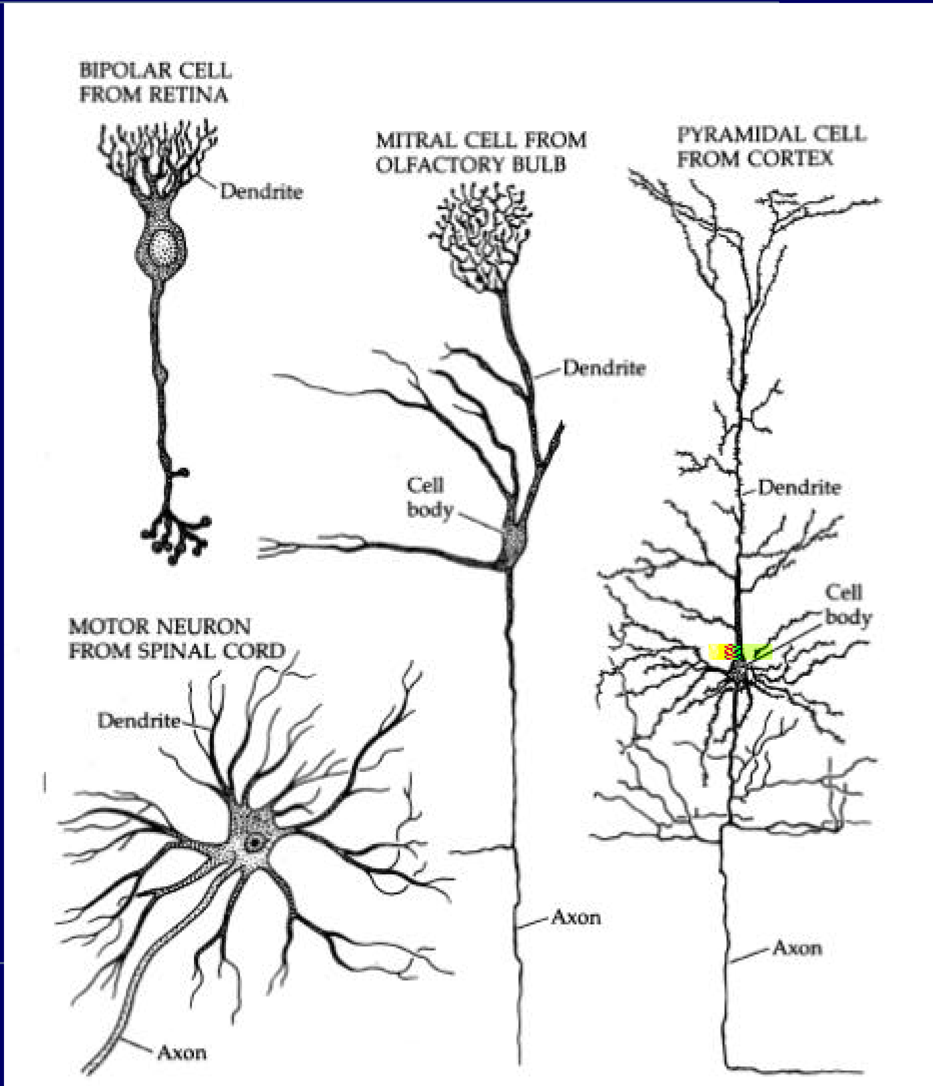


Brain vs. Computer

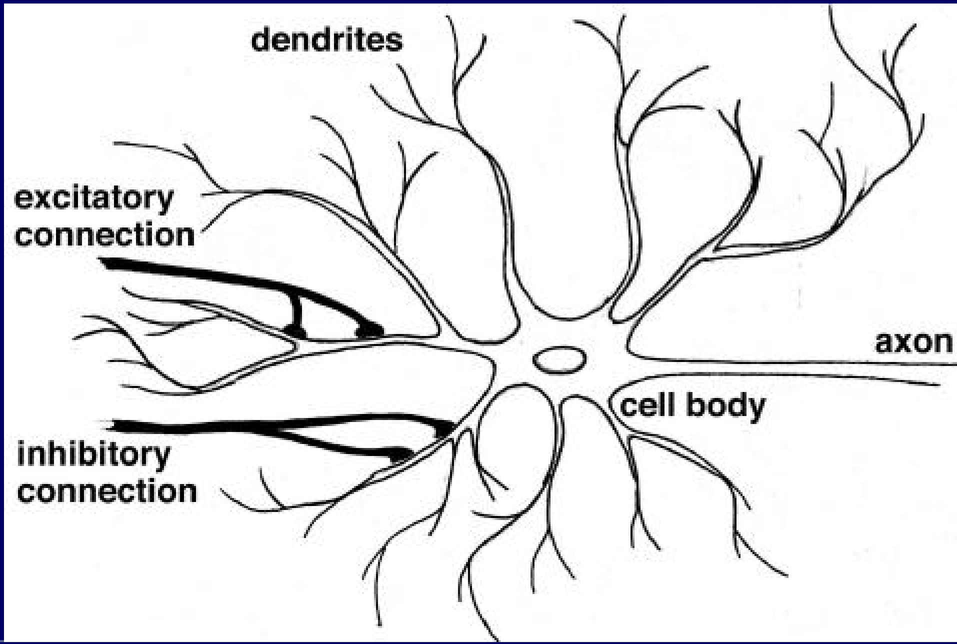
ideas: Warsaw
Munich

Brain vs. Computer

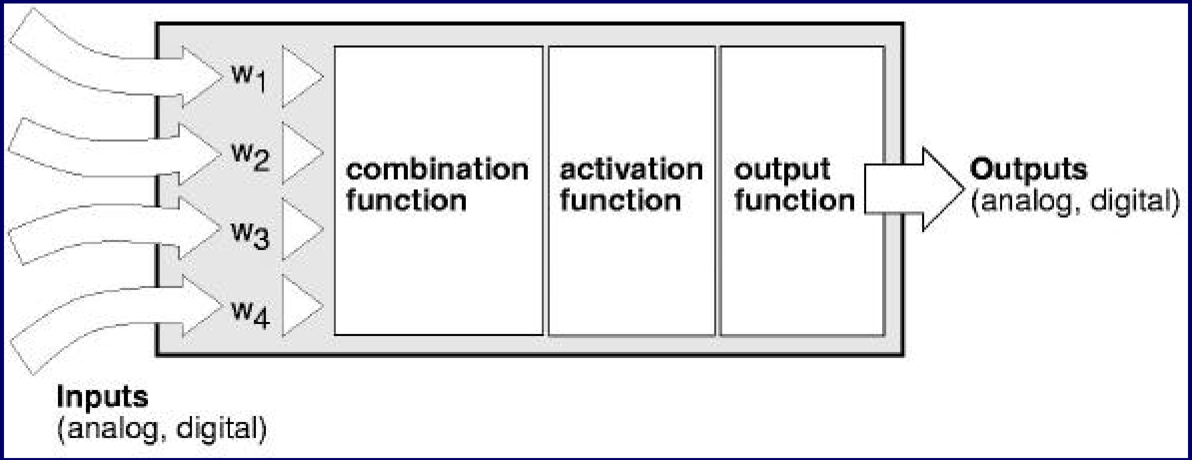
Different Types of Neurons



Modeling a neuron - neural networks



Artificial Neuron

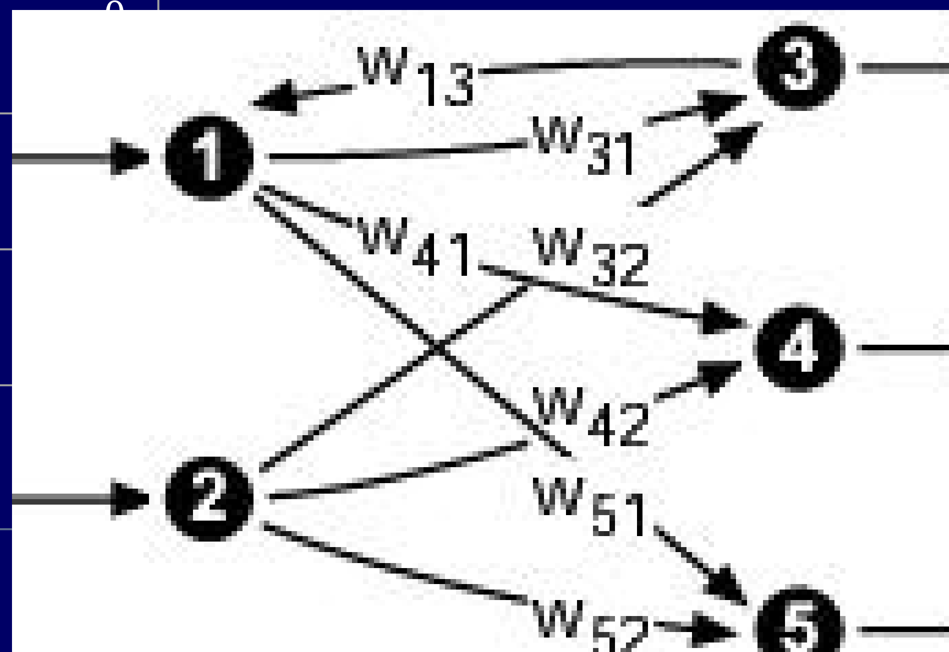


Artificial Neural Network: Representations

	node 1	*node 2*	*node 3*	*node 4*	*node 5*
node 1	0	0	0.8	0	0
node 2	0	0	0	0	0
node 3	0.7	0.4	0	0	0
node 4	1.0	-0.5	0	0	[illegible]
node 5	0.6	0.9	0	0	[illegible]

Matrix

Graph



Embedded Artificial Neural Networks
DAC – Distributed Adaptive Control

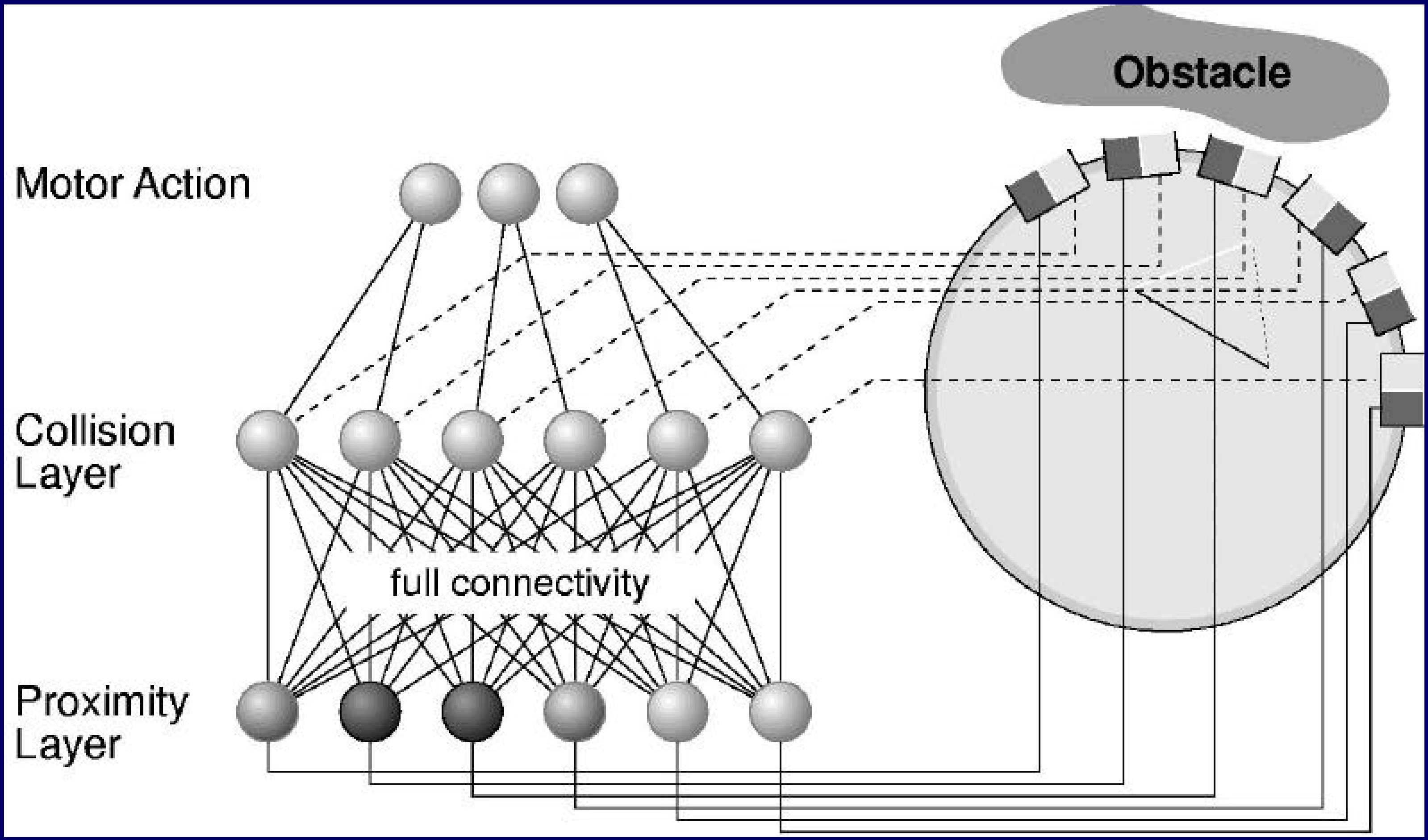
Initial design decisions
“low-level specifications”

- default forward speed
- basic reflexes:
  - hitting obstacle on right, turn left
  - hitting obstacle on left, turn right
  - turn towards light source (left and right)

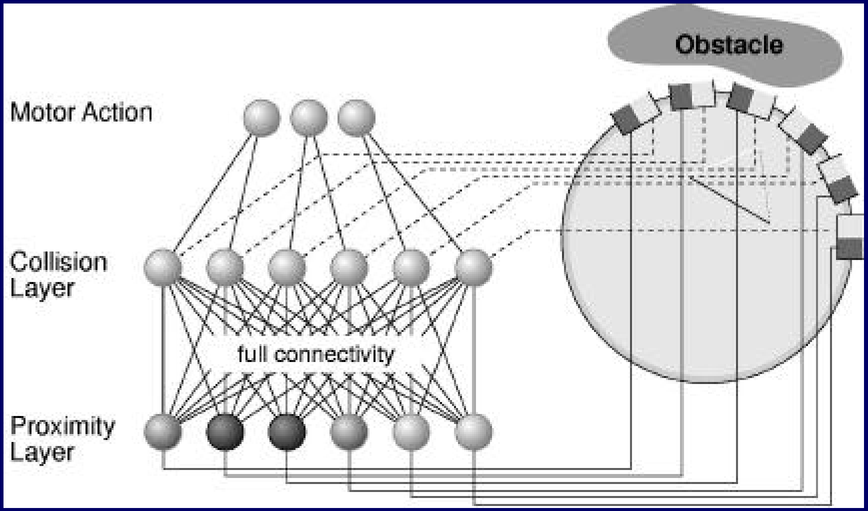
DAC – Distributed Adaptive Control
Embedding the neural network

DAC – Distributed Adaptive Control
Embedding the neural network

DAC - the embedded neural network



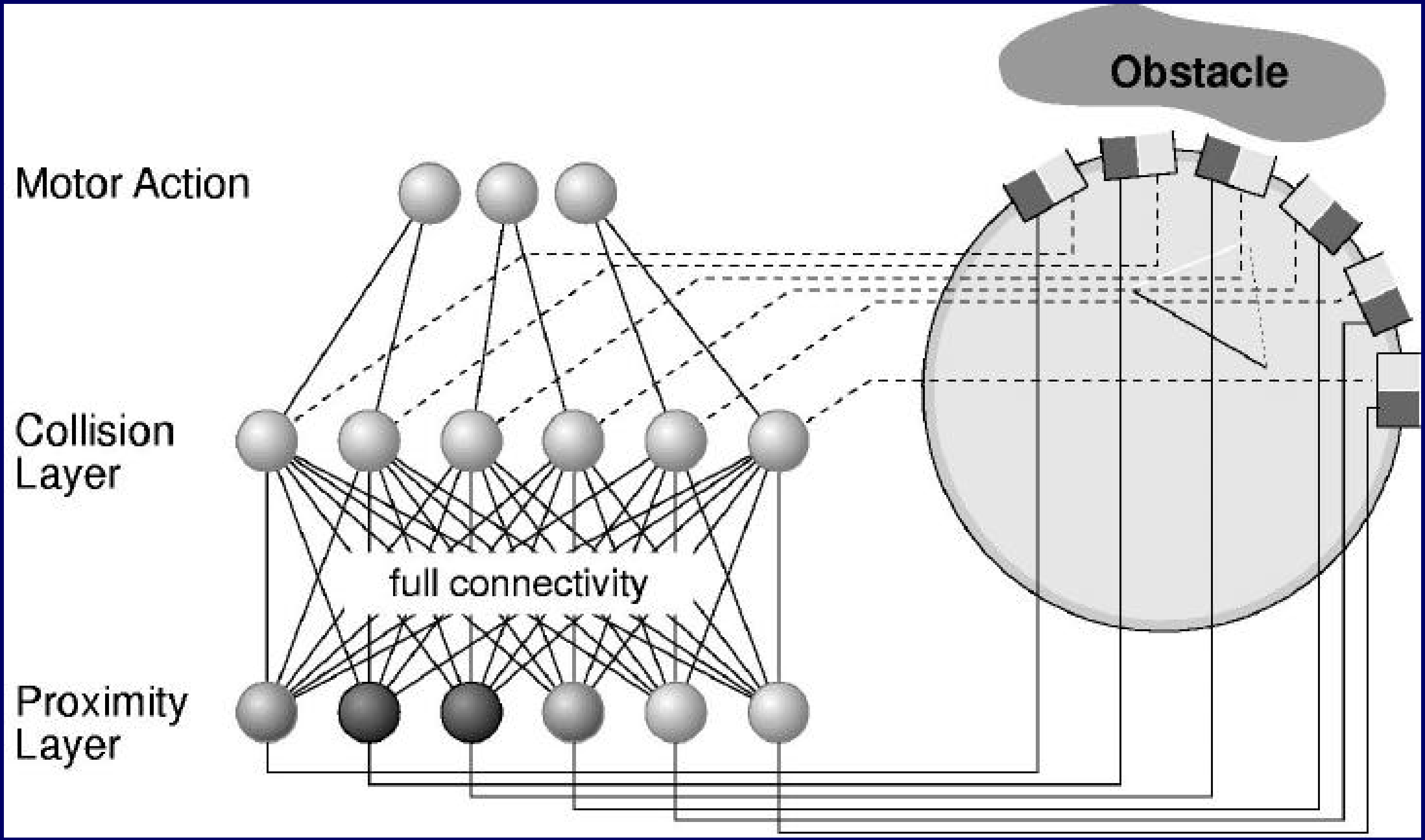
DAC - the embedded neural network formal description



Hebbian Learning

"When an axon of cell A is near enough to excite a cell B and repeatedly … takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased." (Donald Hebb, 1949)

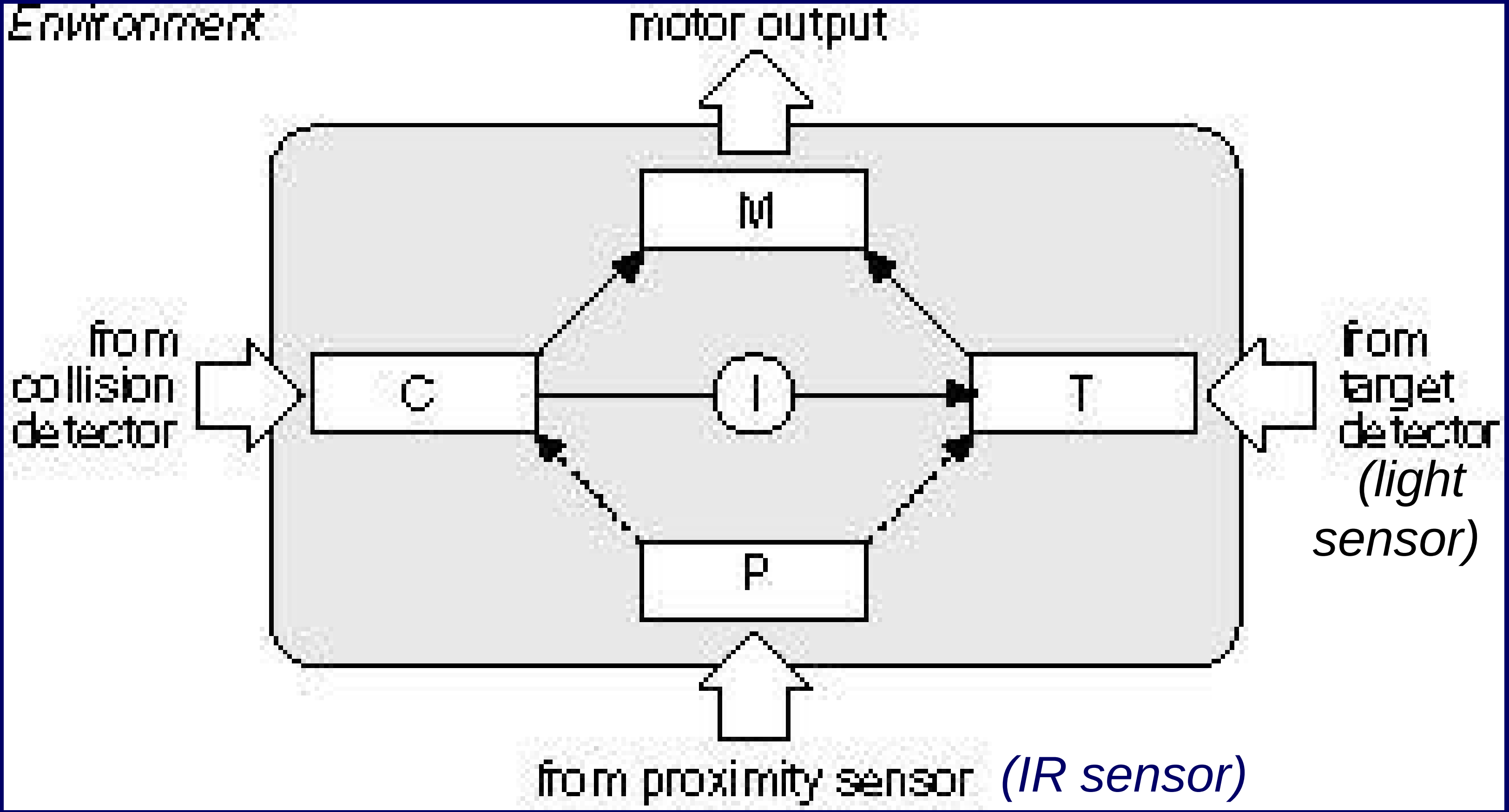
What will happen?



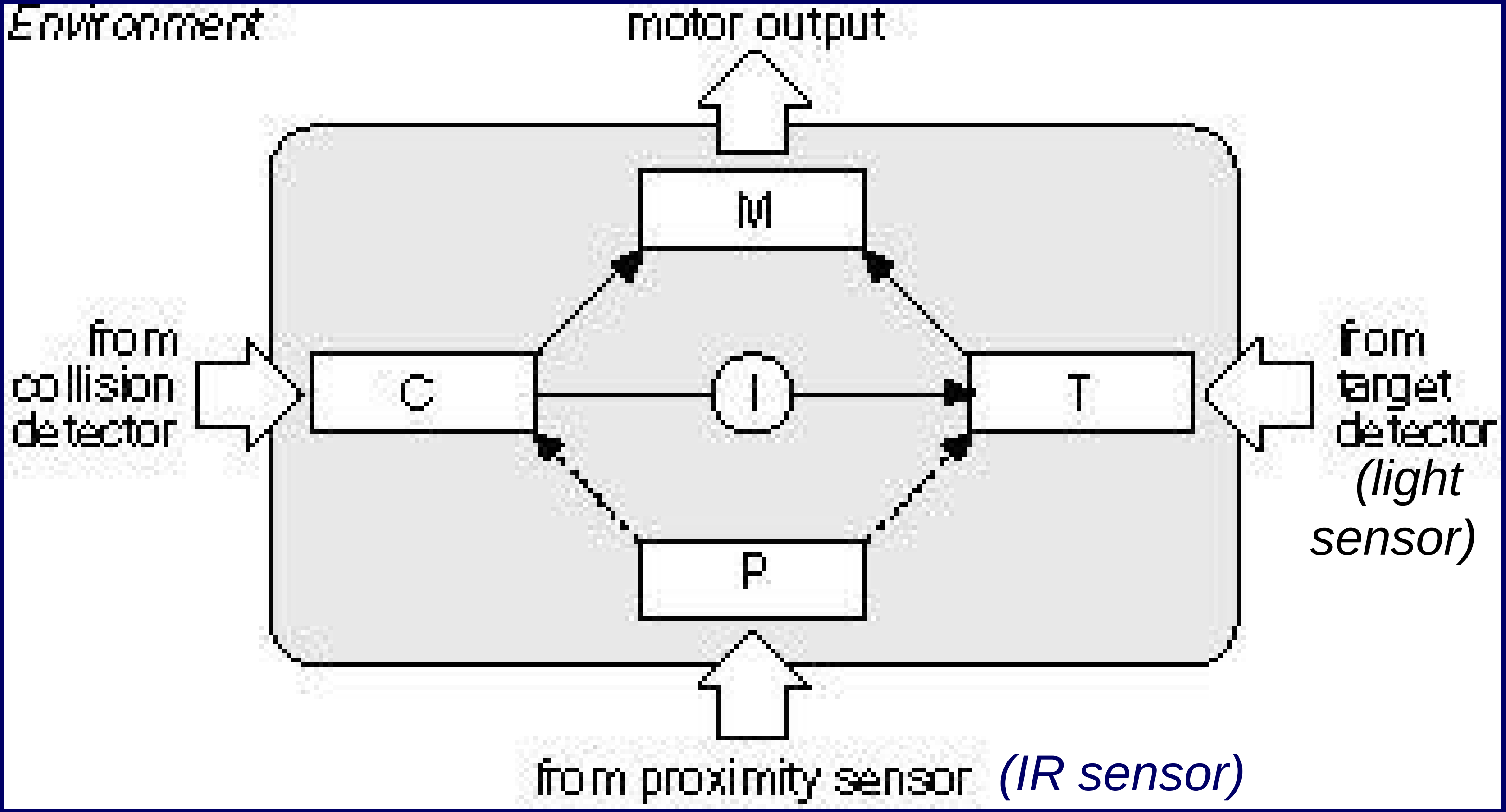
DAC: Demonstration
Learning obstacle avoidance

Demo Zurich

Including the light-turning reflex



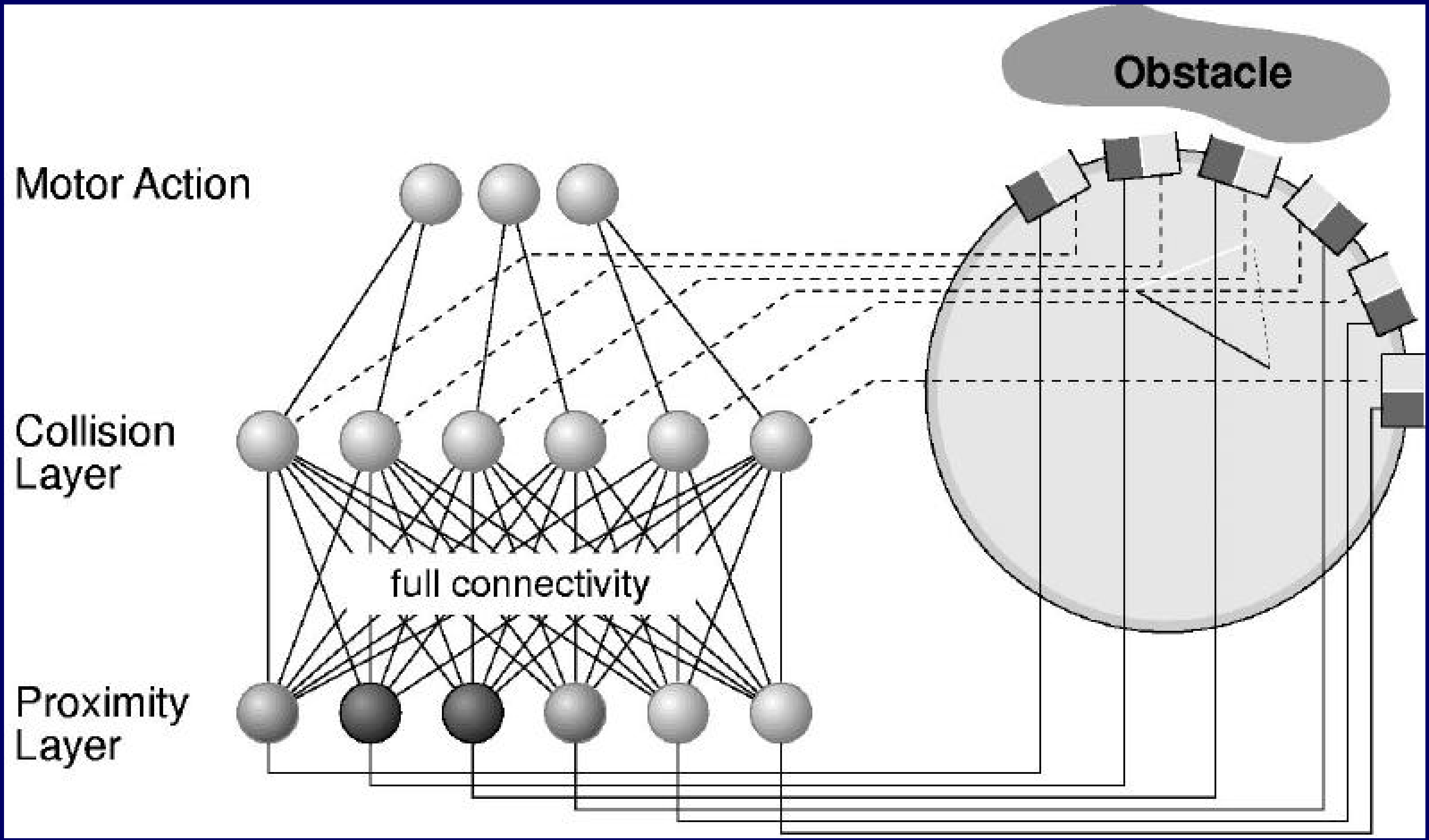
Including the light-turning reflex



Summary: The Four or Five Basics of Neural Networks

- ***Embedding the Network in the Agent***
- Connectivity
- Characteristics of the Nodes
- Propagation Rule
- Learning Rule

DAC - the embedded neural network



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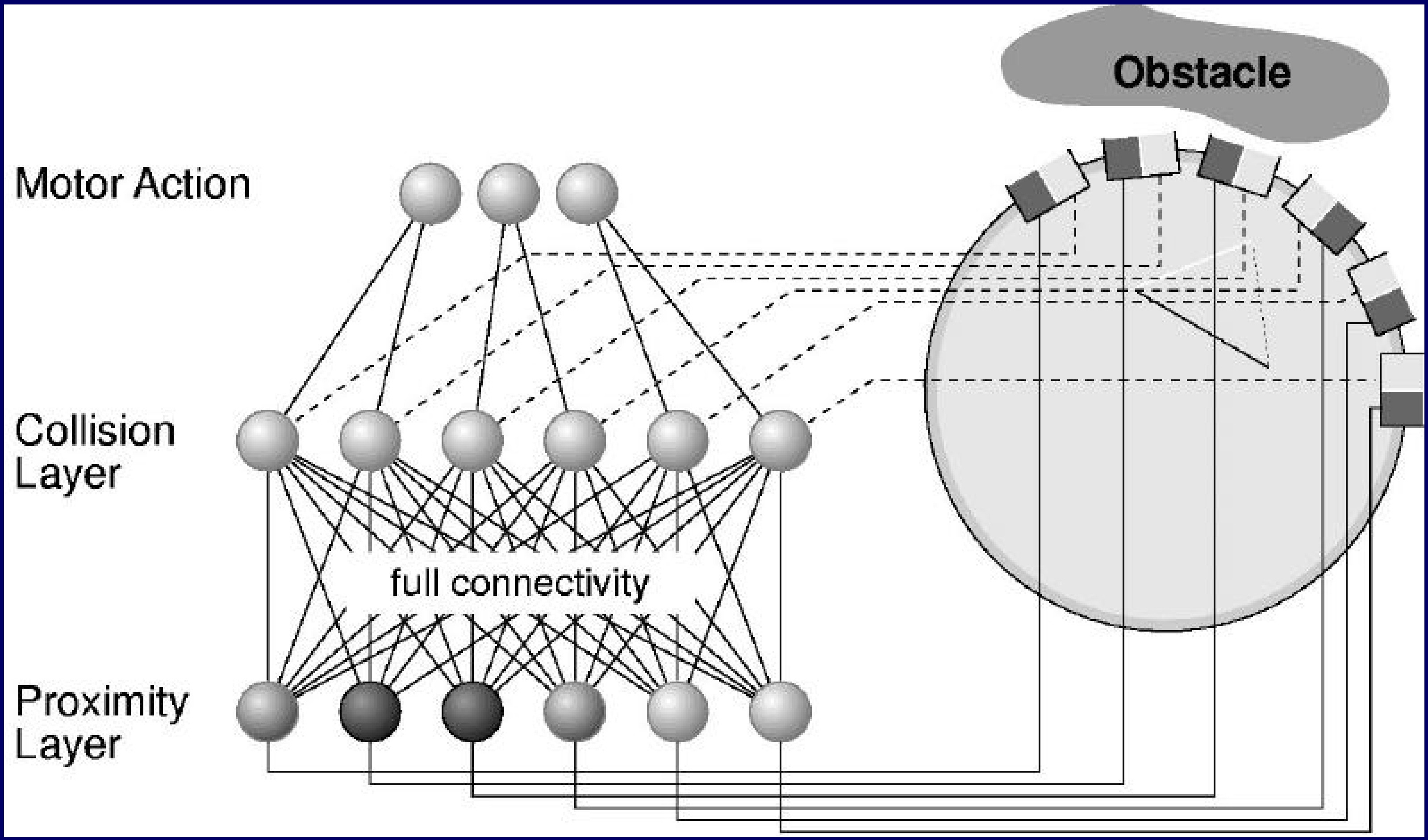

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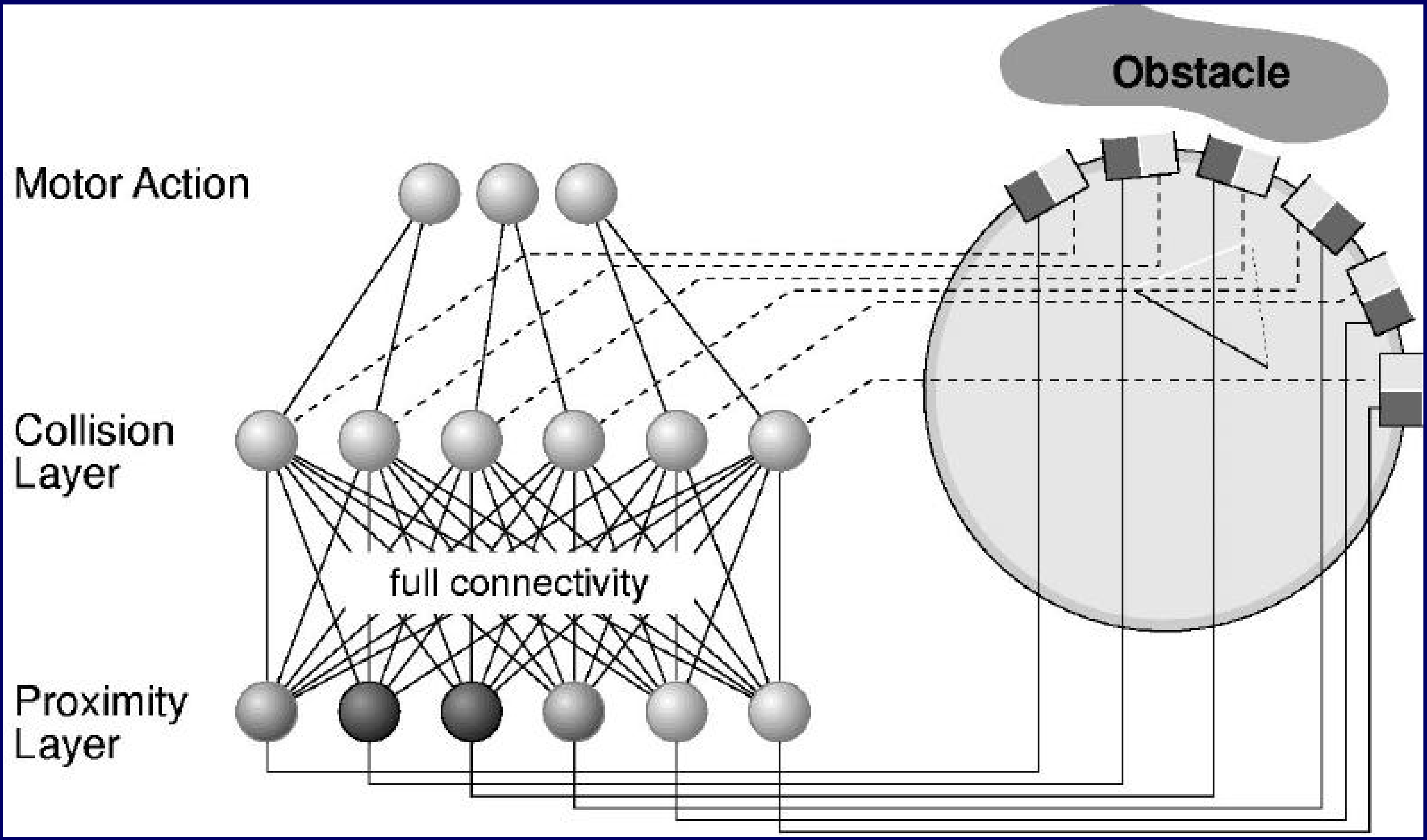

Node Characteristics

The Four or Five Basics of Neural Networks

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The Four or Five Basics of Neural Networks

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- ***Learning Rule***

Learning rule - and forgetting

Summary of the DAC architecture

- learning to “anticipate” obstacles
- collision sensors, proximity sensors: different physical processes --> redundancy principle
- robust behavior (noise and fault tolerance; generalization)
- learning continuous
- forgetting
- very simple abstractions but extremely powerful

This concludes chapter 5

“Subsumption Architecture” - “Behavior-based approach”

beginning of “embodied artificial intelligence”

Rodney Brooks

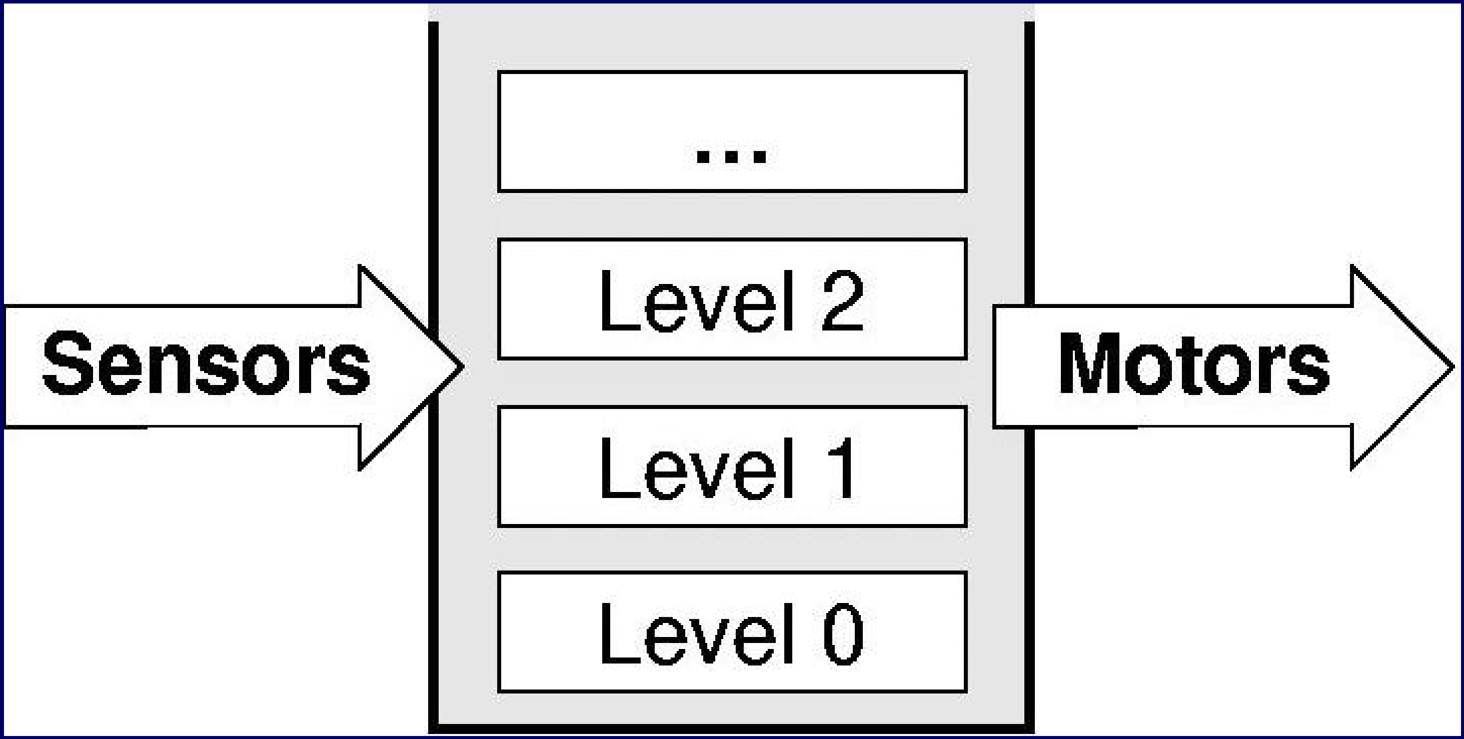
MIT Artificial Intelligence Laboratory (now: CSAIL - Computer Science and Artificial Intelligence Laboratory)

1986: “A robust layered control system for a mobile robot.” IEEE Journal of Robotics and Automation, TA-2. (also published as MIT AI Memo 864)

ftp://publications.ai.mit.edu/

Traditional vs. “behavior-based” decomposition

Levels of Competence - “Behaviors”
Tight sensory-motor coupling



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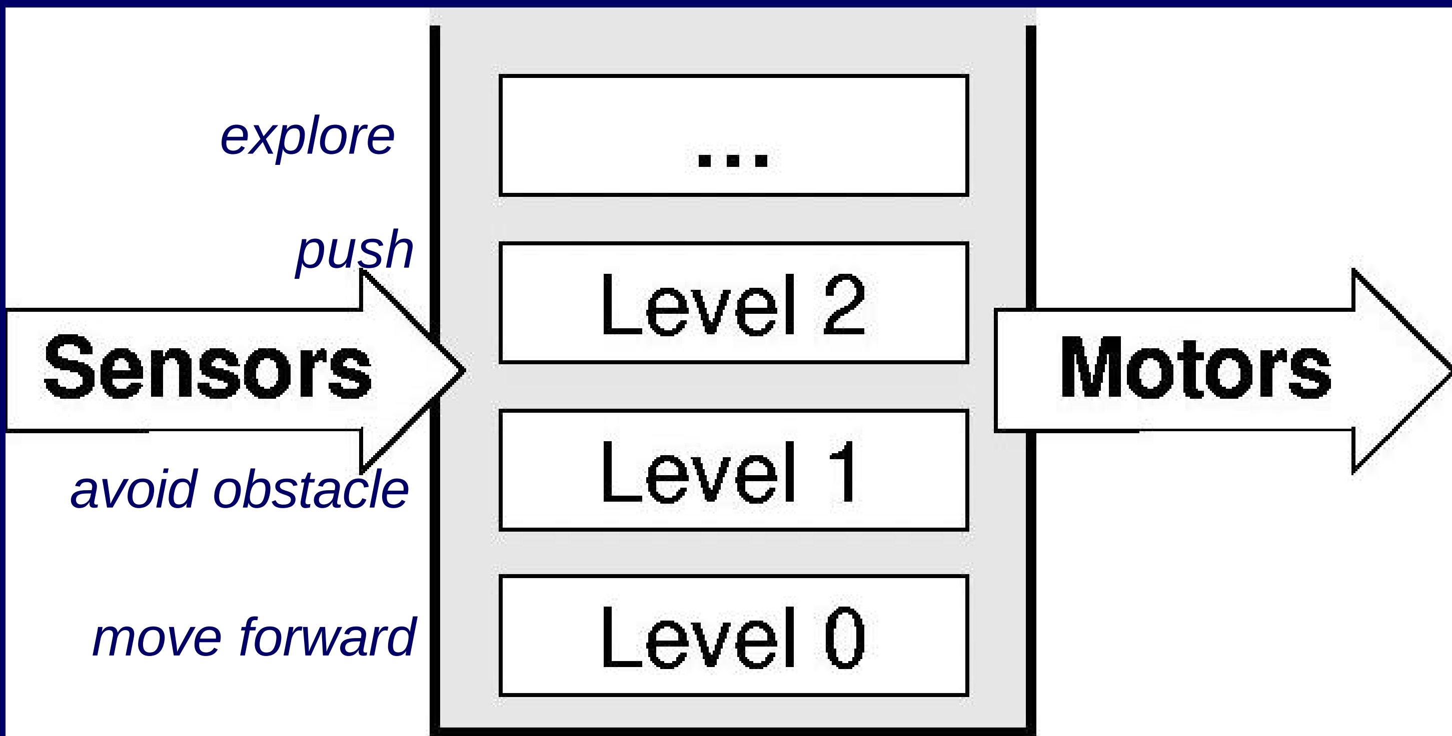
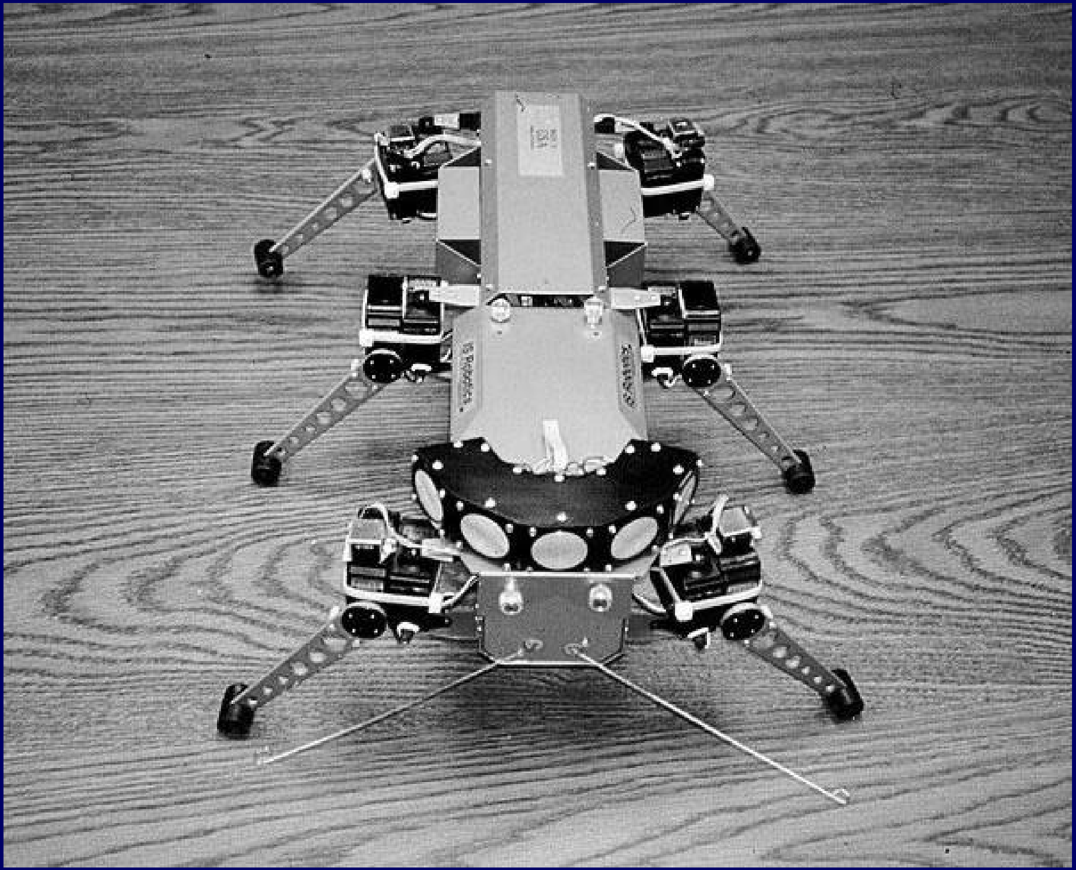


augmented finite state machines

suppression and inhibition links between layers

Ghengis



The principle of "parallel, loosely coupled processes"

Intelligent behavior:

- emergent from agent-environment interaction
- based on large number of parallel, loosely coupled processes
- asynchronous
- coupled through agent's sensory-motor system and environment

Scaling issue

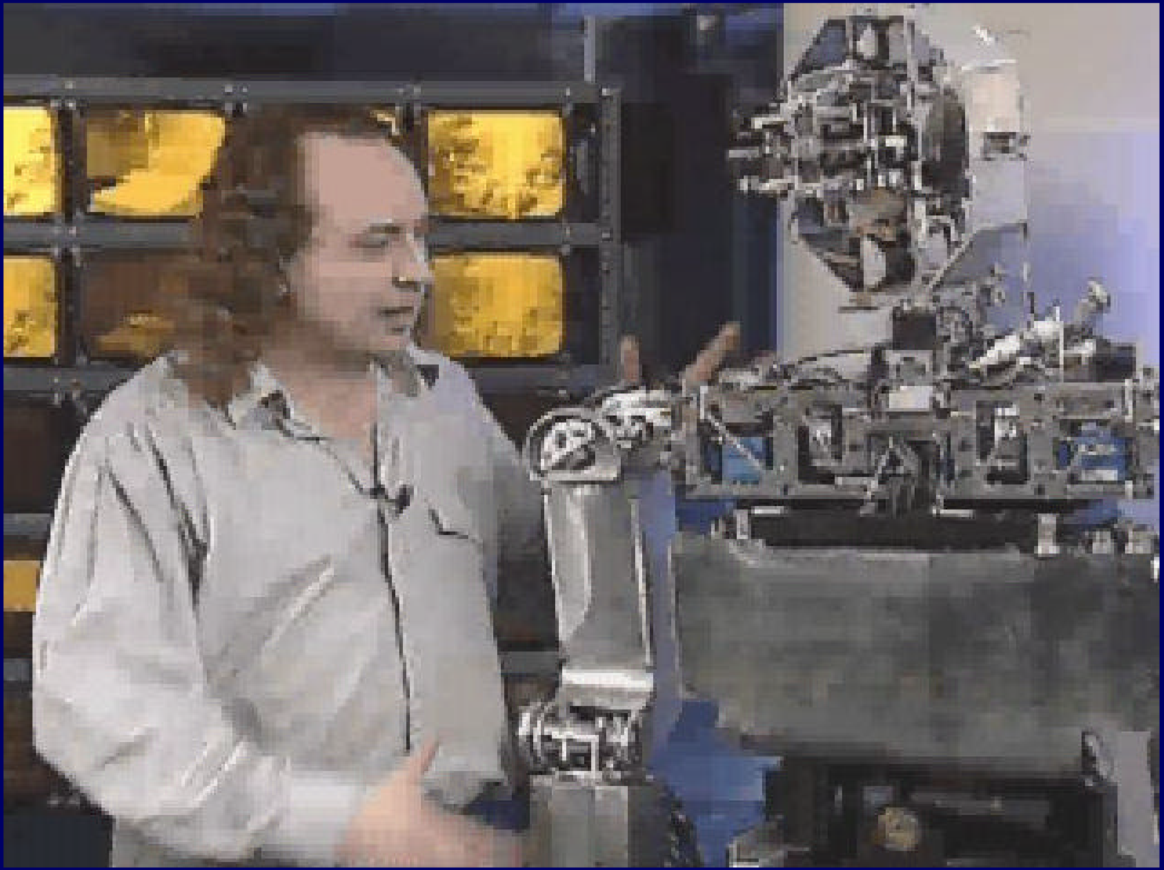
insects level --> human-level ??

Debate:

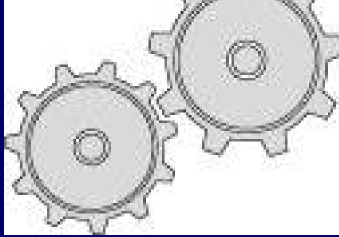
David Kirsh: “Today the earwig, tomorrow man?” (1991)

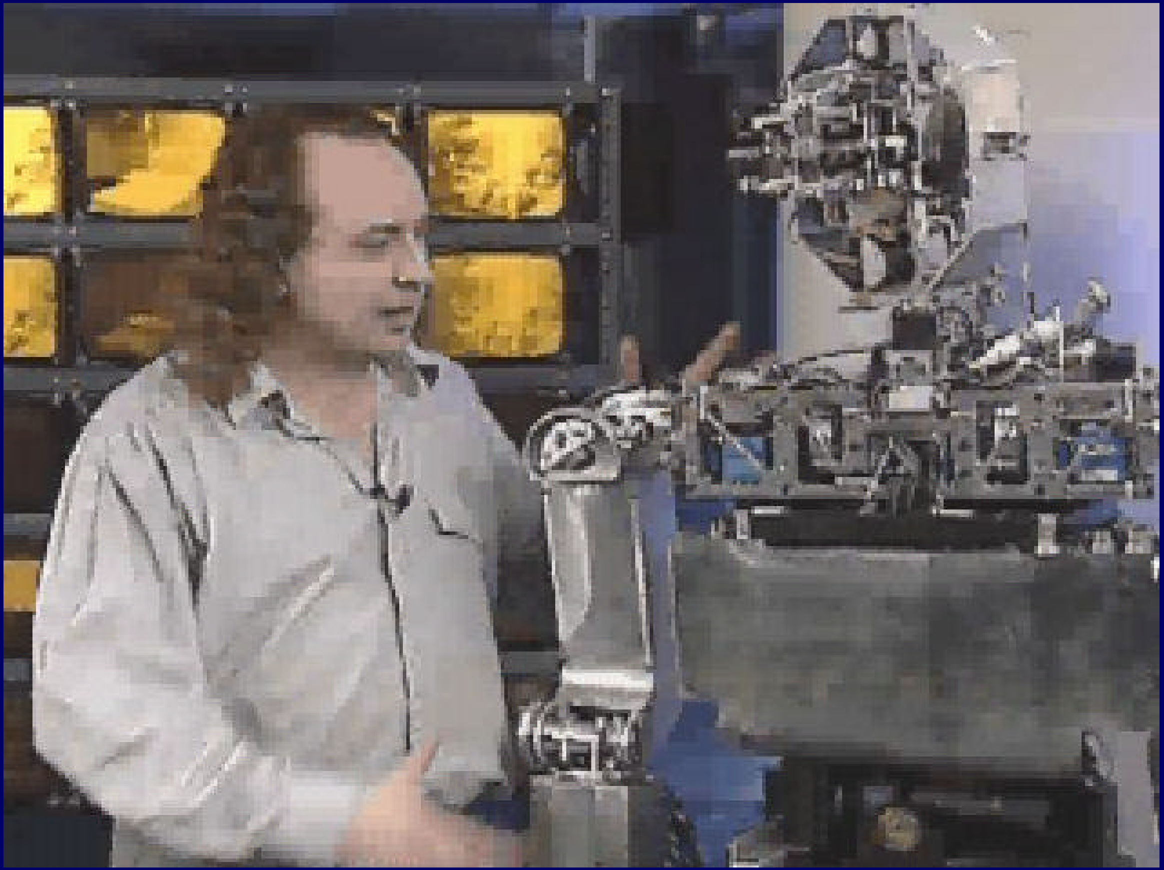
Rodney Brooks: “From earwigs to humans.” (1997)

Cog



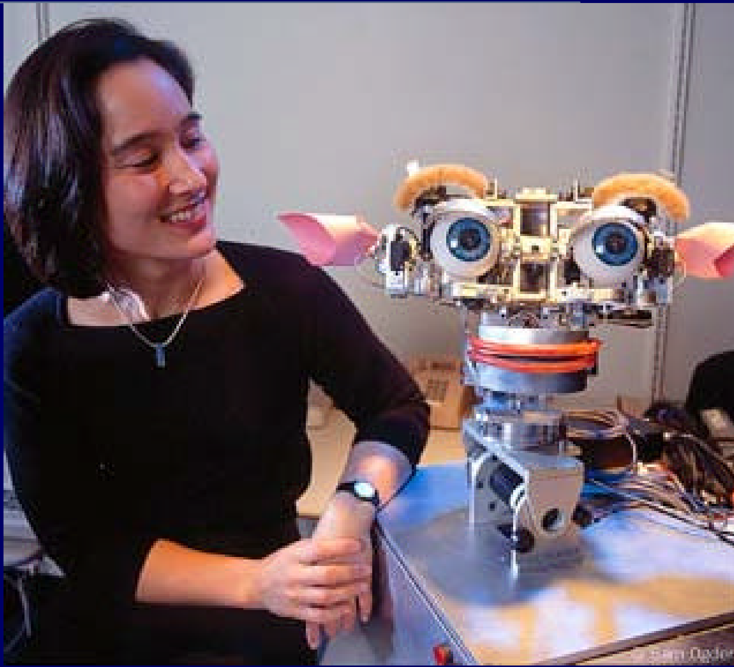
Cog
Cognition and Cog Wheels





Video

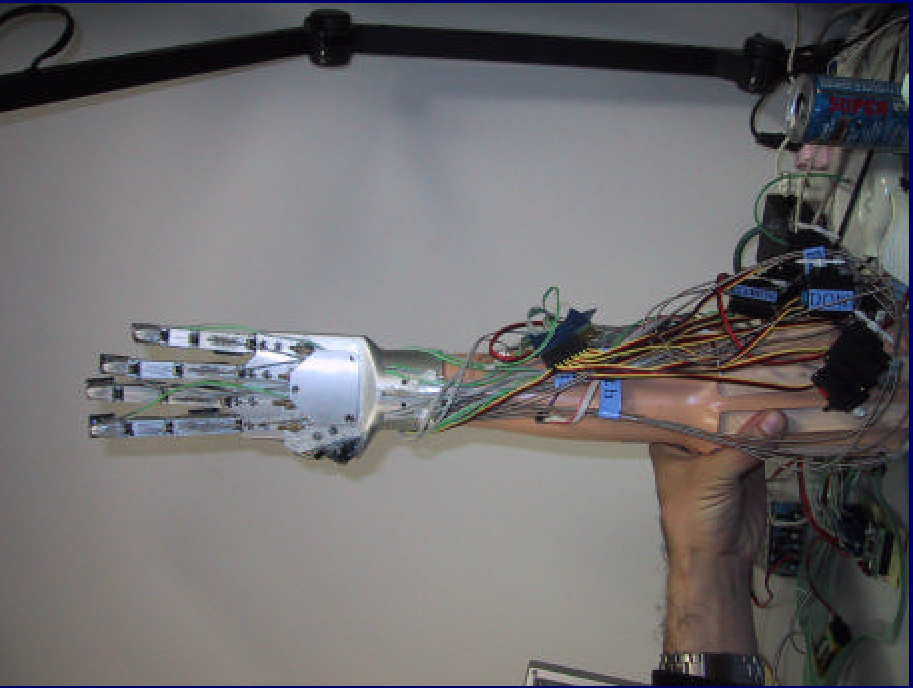
Kismet - the social interaction robot



Cynthia Breazeal, MIT Media Lab
(prefiously MIT AI Lab)

Now: The latest from Japan

Prof. Hiroshi Yokoi
Complex Systems Laboratory
Hokkaido University



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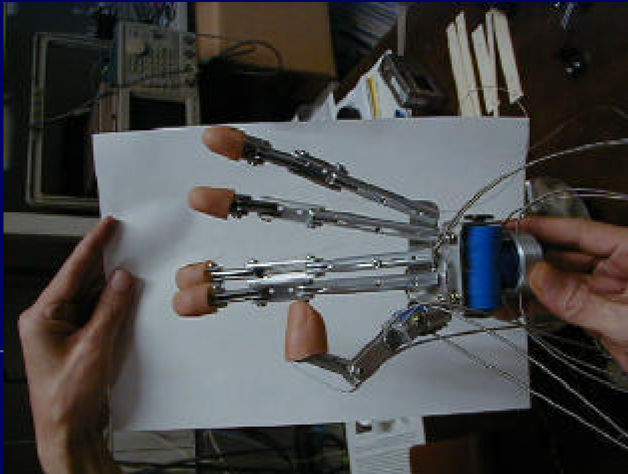

Assignments

- Read the remainder of chapter 5 and chapter 7 of “Understanding Intelligence”
- Tokyo students: 5min statement on the debate between David Kirsh and Rodney Brooks on earwigs and humans (scalability of the behavior-based approach to robotics).

Thank you for your kind attention!

CU all next week in the

GLOBAL VIRTUAL LECTURE HALL