Android Robotics

-Understanding humans by building robots -

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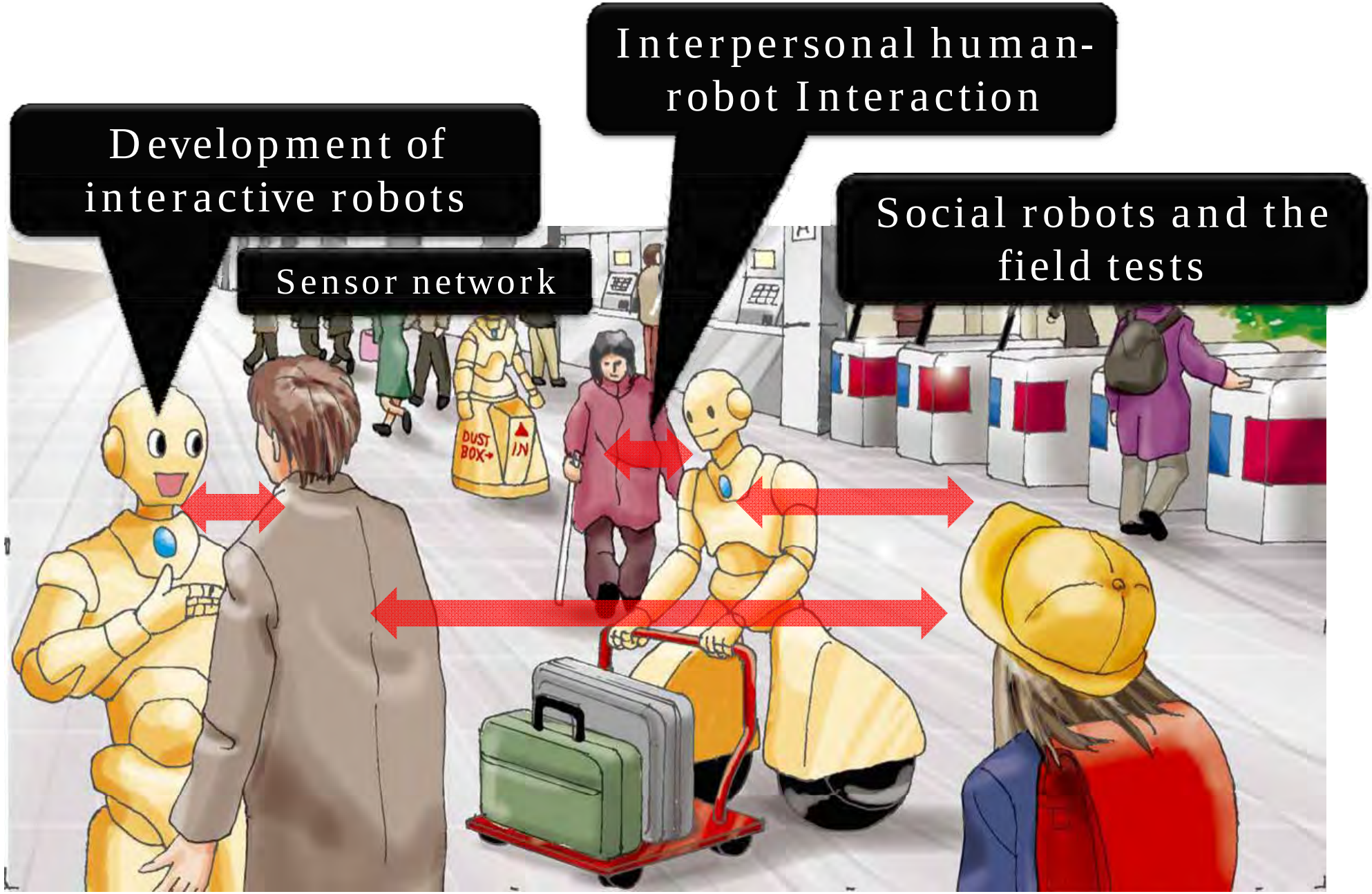
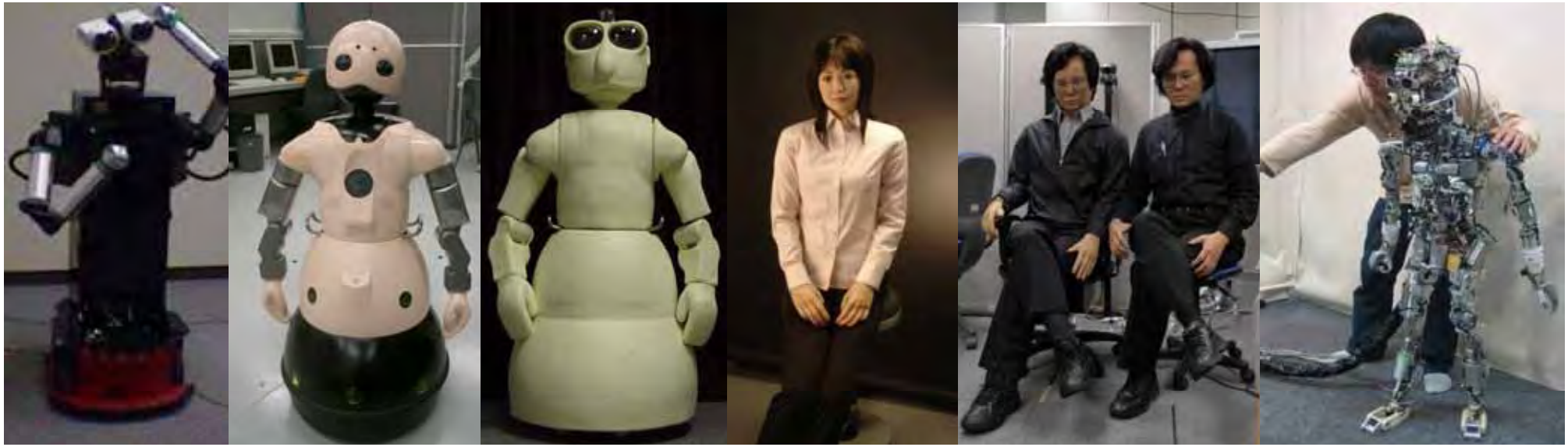
Interactive humanoids and androids


Development of interactive robots
Interpersonal human-robot Interaction
Social robots and the field tests
Sensor network
DUST BOX
IN

Robots getting close to human



Interactive humanoids | Android | Geminoid | Bio-mimetic Humanoid

Biological principle

Humanlike development

Bio-mimetic mechanisms

Learning and Development of the software

Conversation

Perception

Movement

Appearance

Human

Humanlike presence

Human likeness

Appearance and behavior

Interactive humanoids that can play with children

Robovie developed by ATR IRC

- Autonomous interactive robots that have various sensors
- 300 behaviors
- 700 rules for deciding execution order of the behaviors

Studies on interactive robots

for developing interactive and social robots

Manipulation

Navigation

Android Science

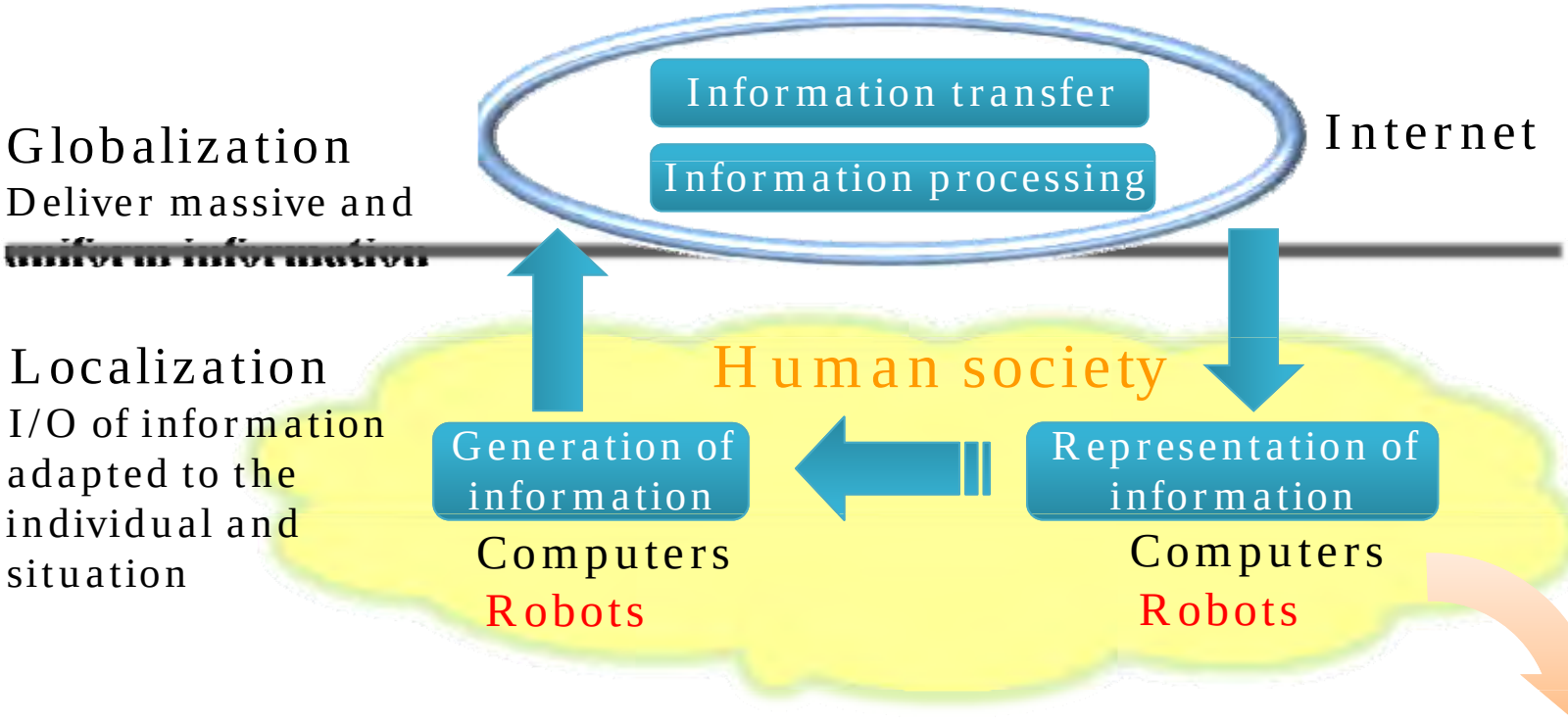
Interaction

Cognitive science, Psychology, and
Social science using robots as test beds

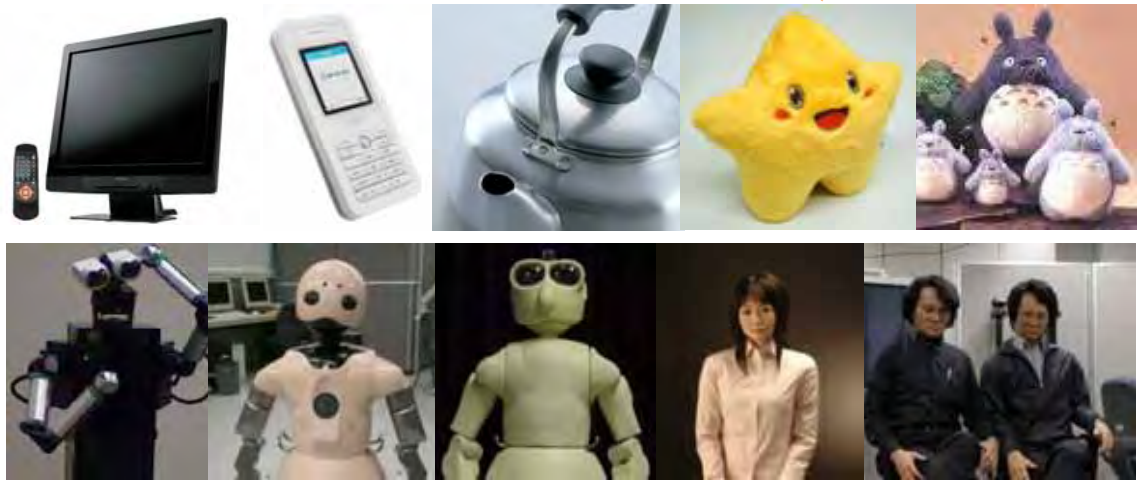
Robots interact with humans
based on knowledge about the human

Humans interact with robots by anthropomorphizing them

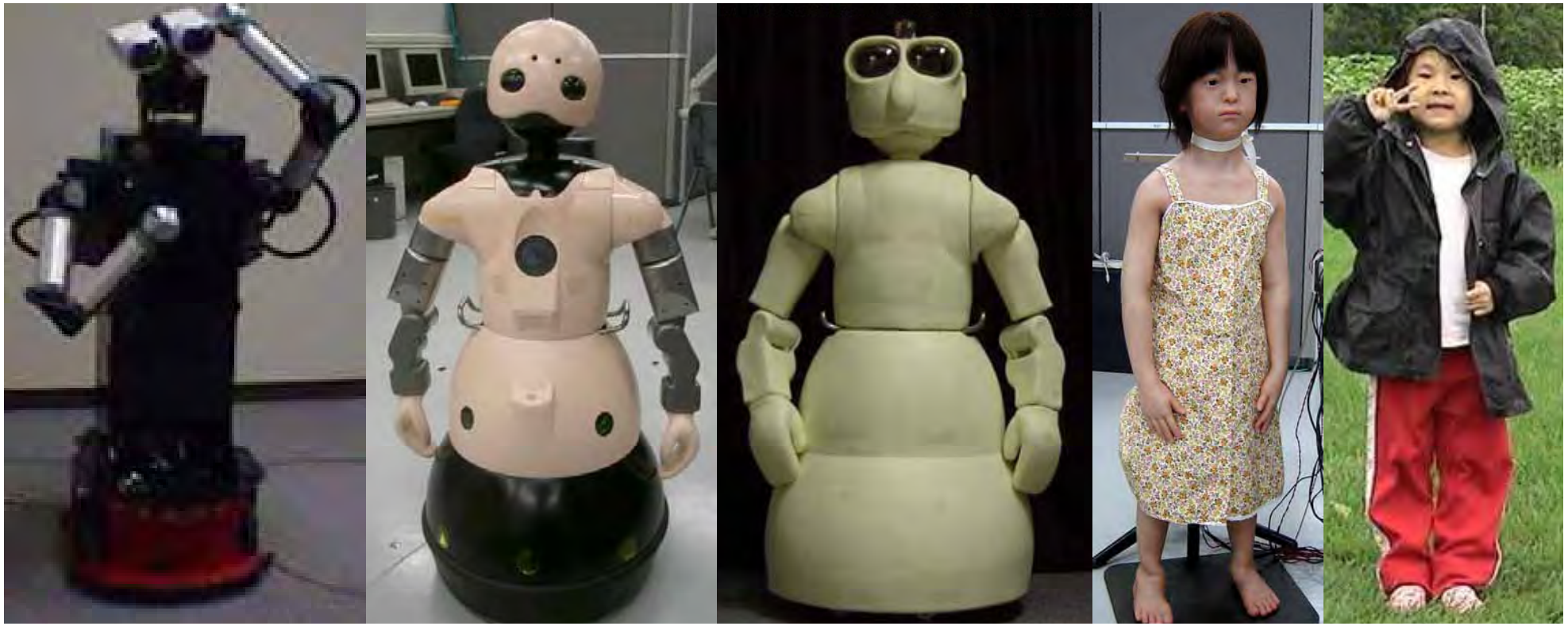
What is the ideal media?



- A human anthropomorphizes the object for conversation.
- A humanoid robot is better than others for the anthropomorphizing.
- Robots generates information by interacting with humans.



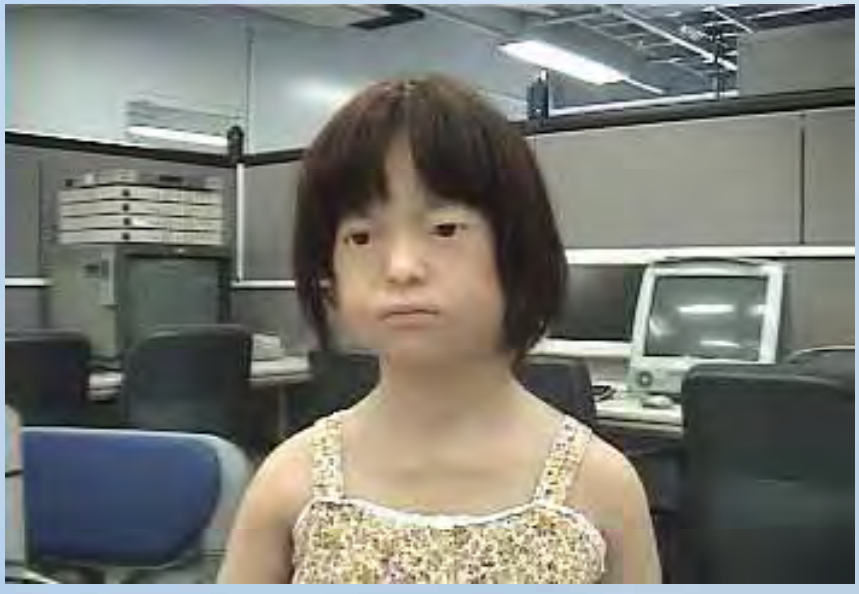
Appearance and Behavior



- Which is more important for interactive robots, appearance or behavior?
- What is the ideal design for humans?

Humanlike Appearance

Development of the child android and the uncanny valley



Humanlike Appearance

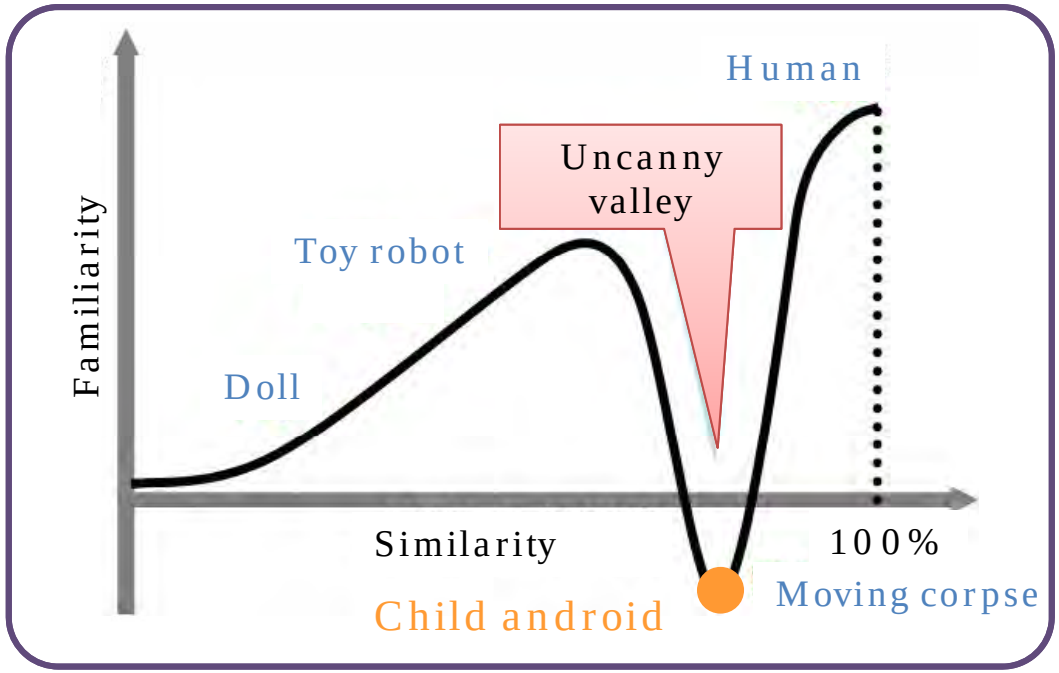
Child android

- 120cm, 5years old
- Silicon skin
- Sensitive Piezo sensor
- DOF
  - Eys:5, Mouth:1, Neck:3

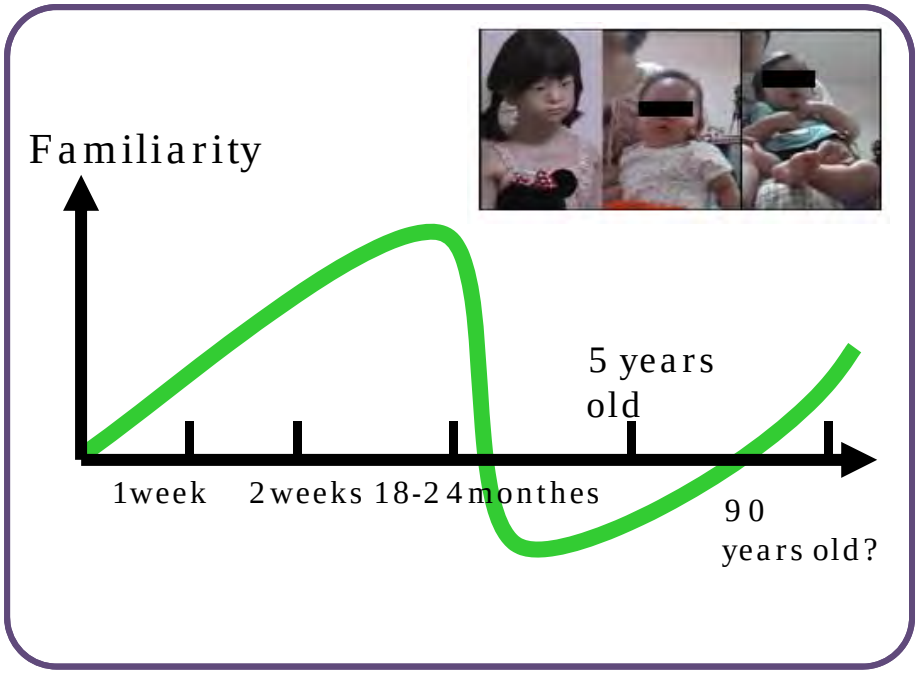
The first contact

Uncanny valley

[Mori et al. '97]



Original uncanny valley



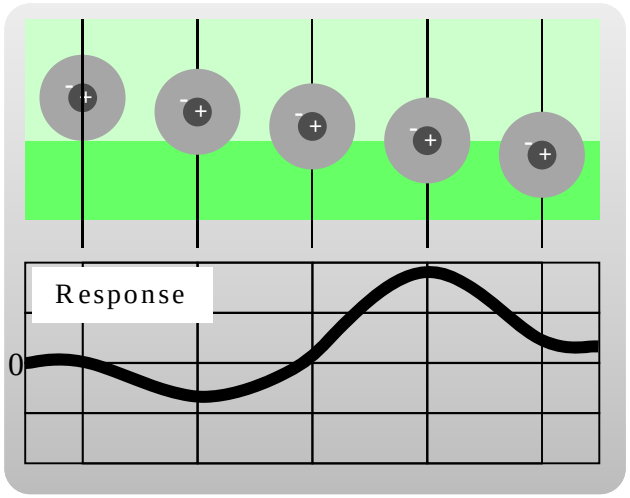
Another uncanny valley

with Itakura, Kyoto University

- The humanlike robot needs to have humanlike movements.
- Mechanical-looking robots can have robot-like movements.

- Subjects from different ages (2 weeks to 5 years)
- Record subjects' behaviors and eye motions

Lateral Inhibition Hypothesis



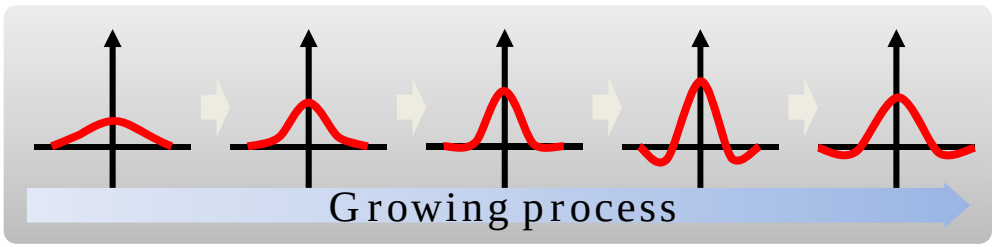
Lateral inhibition is perhaps the most fundamental operation of brain circuitry and integral to the operation of all structures.

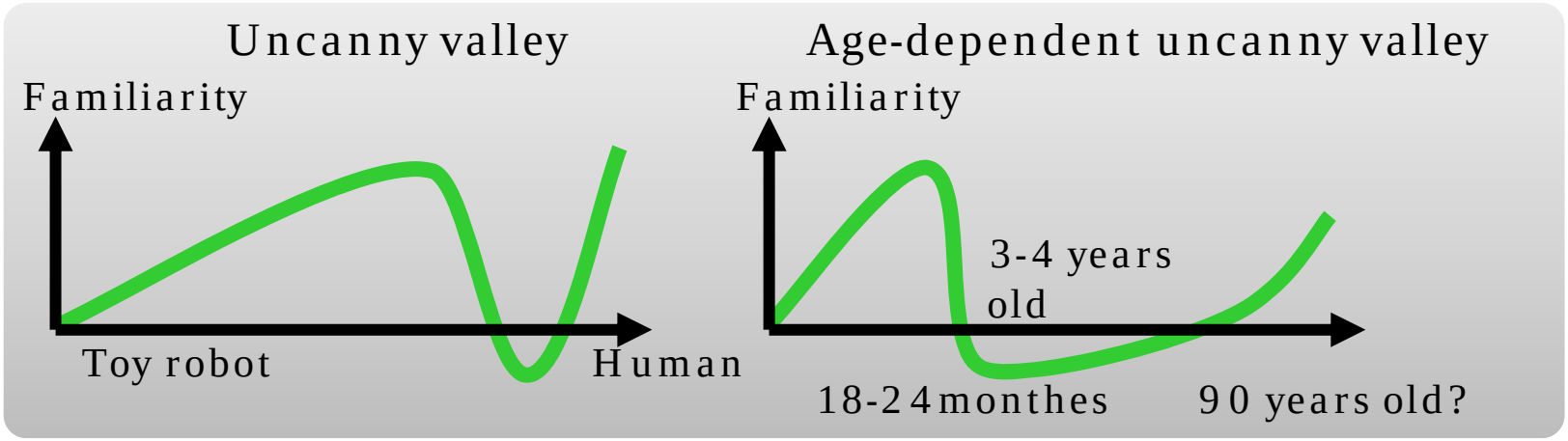
Neural network

Basal ganglion

Face recognition?

Human identification?





Humanlike Movement

Development of the female android Integrated with sensor network

Humanlike Movement

Humanlike Appearance

Making of the adult android

with KOKORO Co., Ltd.

Inside mechanism

- 43 DOF with pneumatic actuators (17 DOF for the head)
- Humanlike shoulders and chest movements

Subconscious and reactive movements

Android

Human

Subconscious movement

Reactive movement

- Human's reactions are more complicated.
- Human uses multiple modalities.

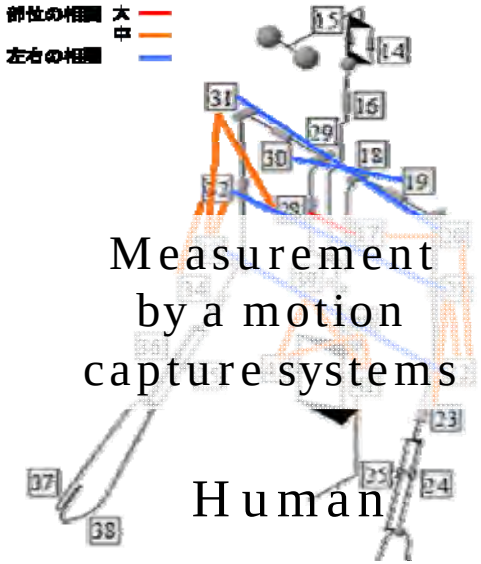
Humanlike movements

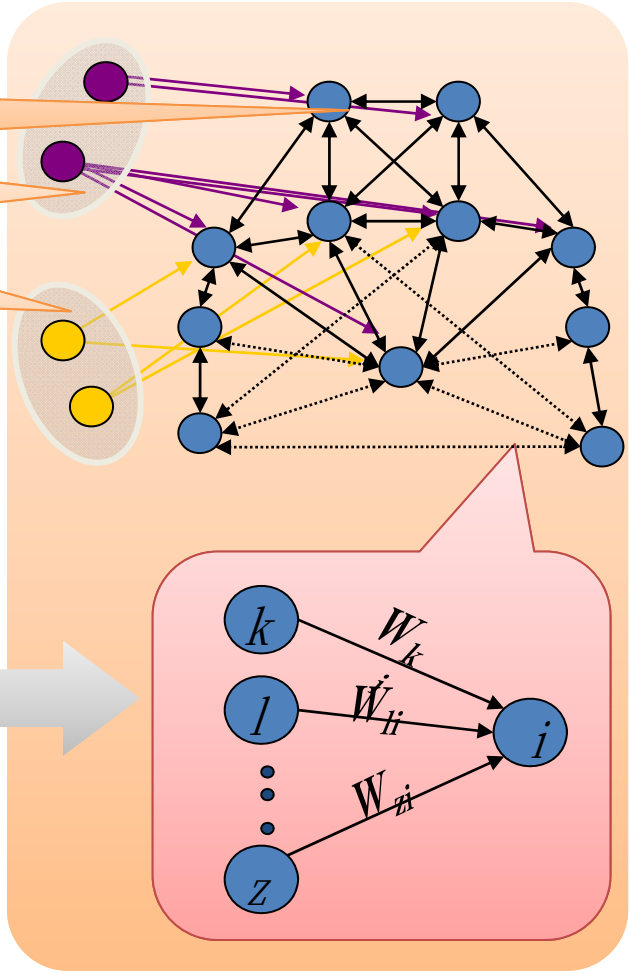
Motion generation by CPGs and neural networks

Each neuron controls each actuator

CPG

Sensors





Humanlike Perception

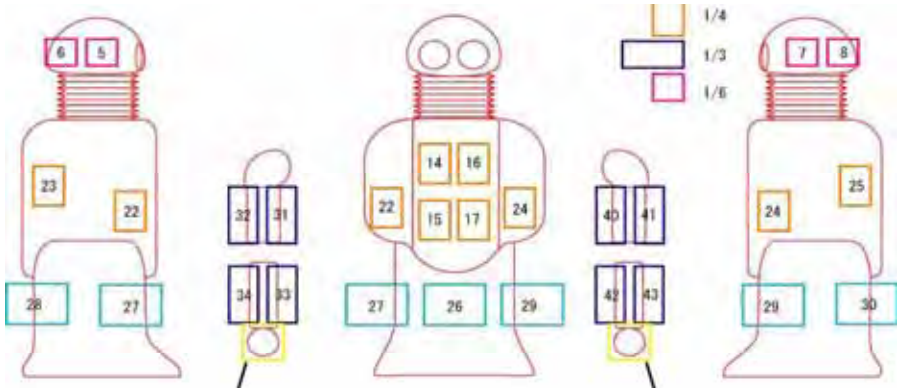
Development of the skin sensor and the sensor network for the android

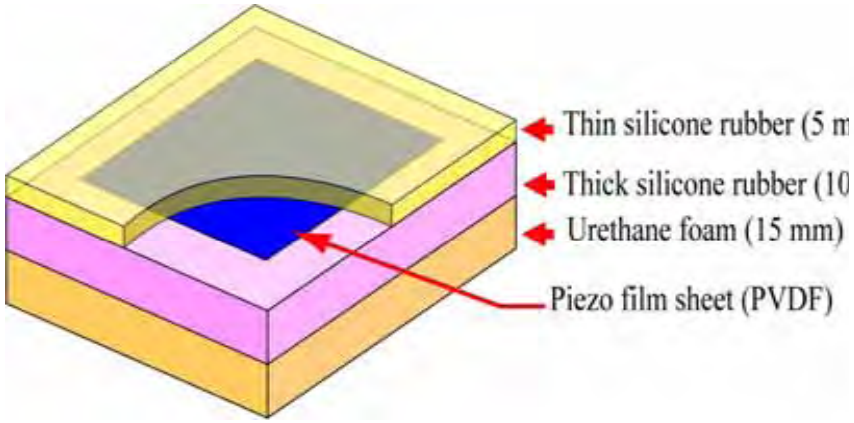
Humanlike Perception

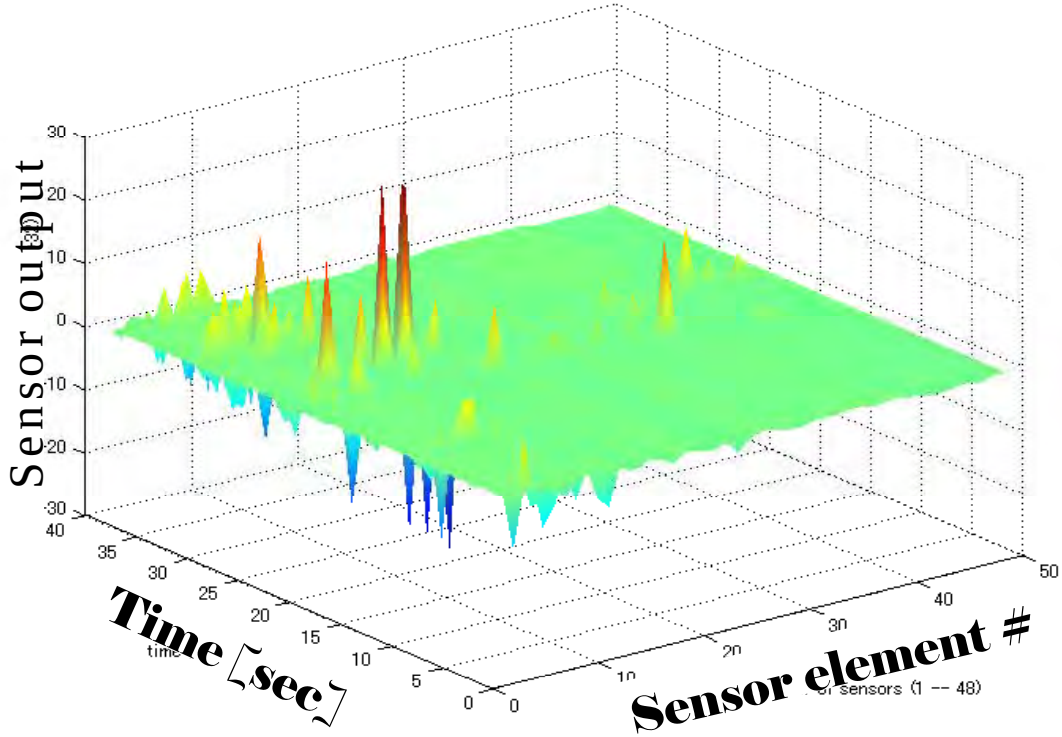
Humanlike Movement

Humanlike Appearance

Robots with soft sensor skin



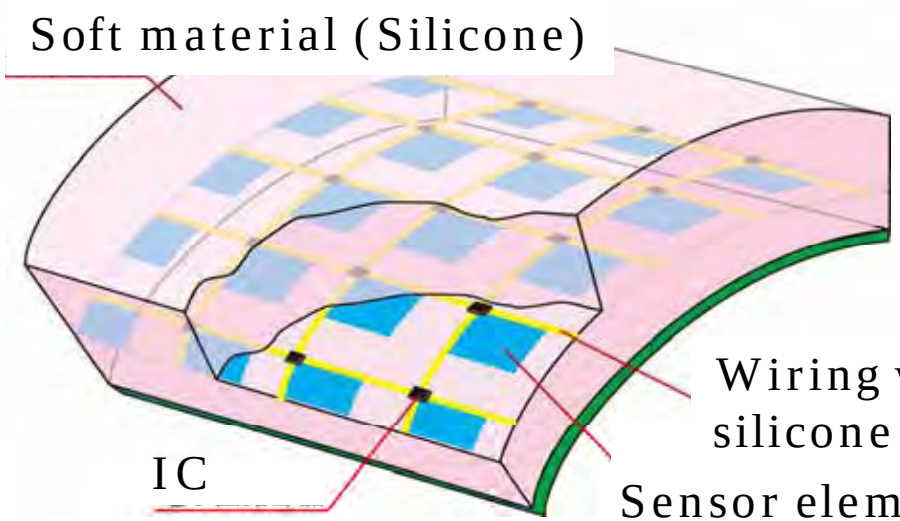


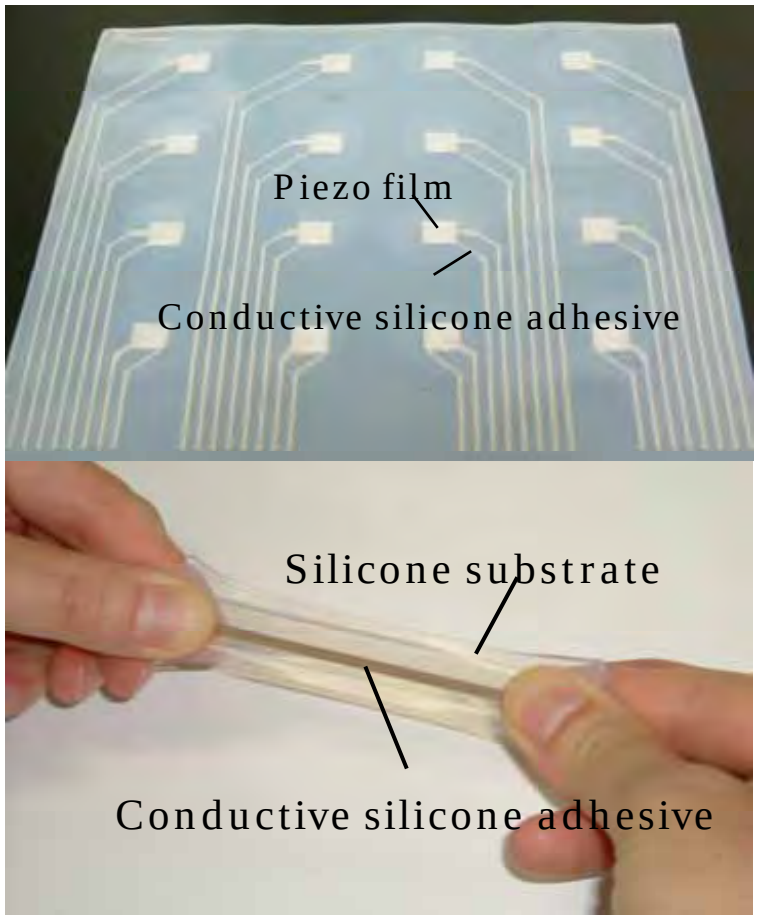


An adult hugs Robovie-IIS

Improvement of the soft sensor skin

with Suganuma and Inoue (Osaka Univ.)



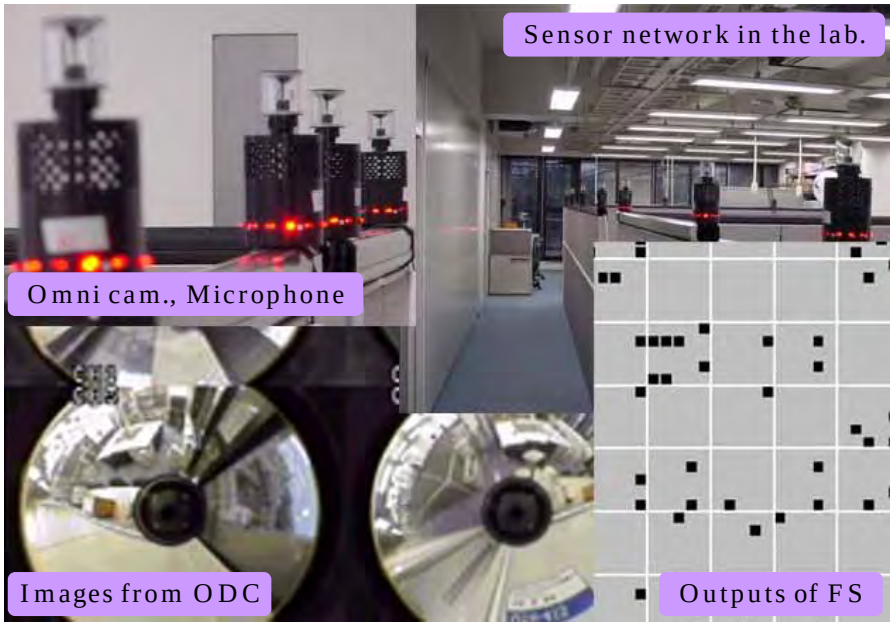


- High-density arrangement of sensor elements
- Simple wiring to the host PC
- Robust wiring against ripping

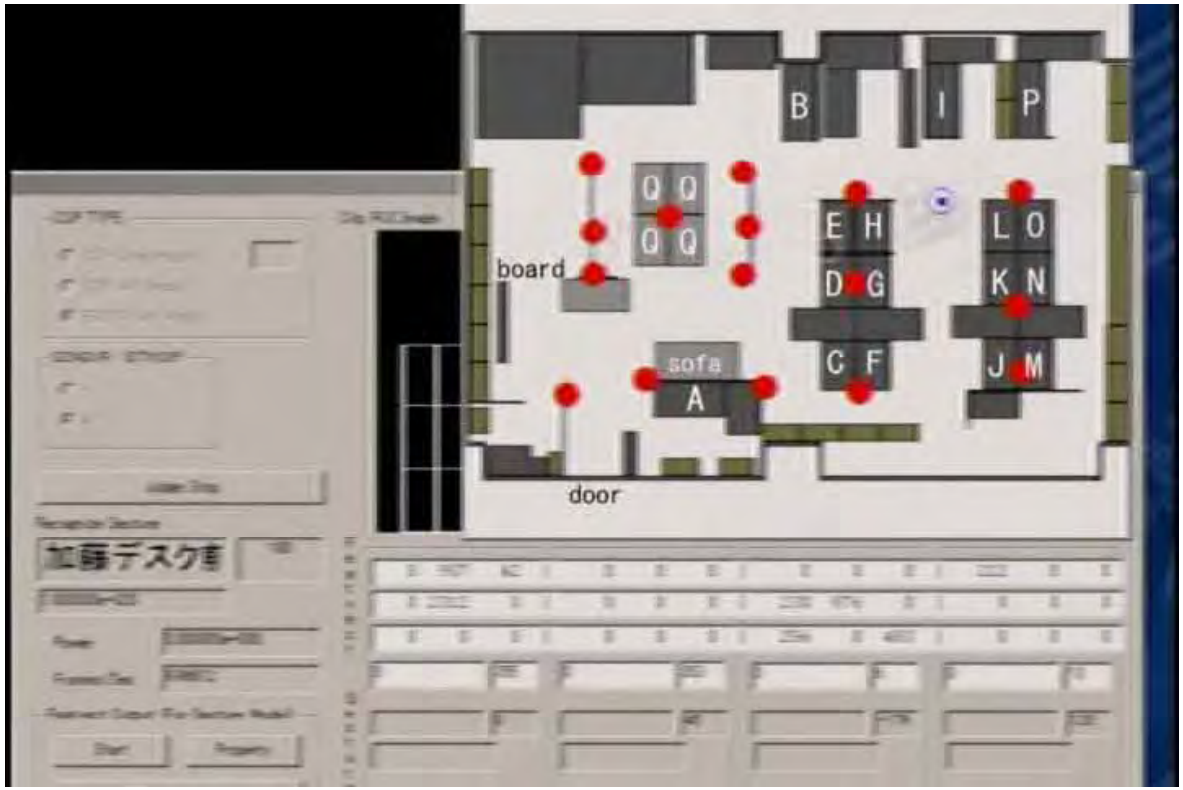
→ Wiring with conductive silicone adhesive & Self-organizing sensor network

Sensor network

- Perceptual Information Infrastructure -



● Omnidirectional cameras, floor sensors, microphones and infra-red motion detectors covers the whole laboratory.



● Tracking a person and recognizing the behaviors with omnidirectional cameras.

Very stable tracking by laser range finders and cameras

Human behavior recognition by the sensor network

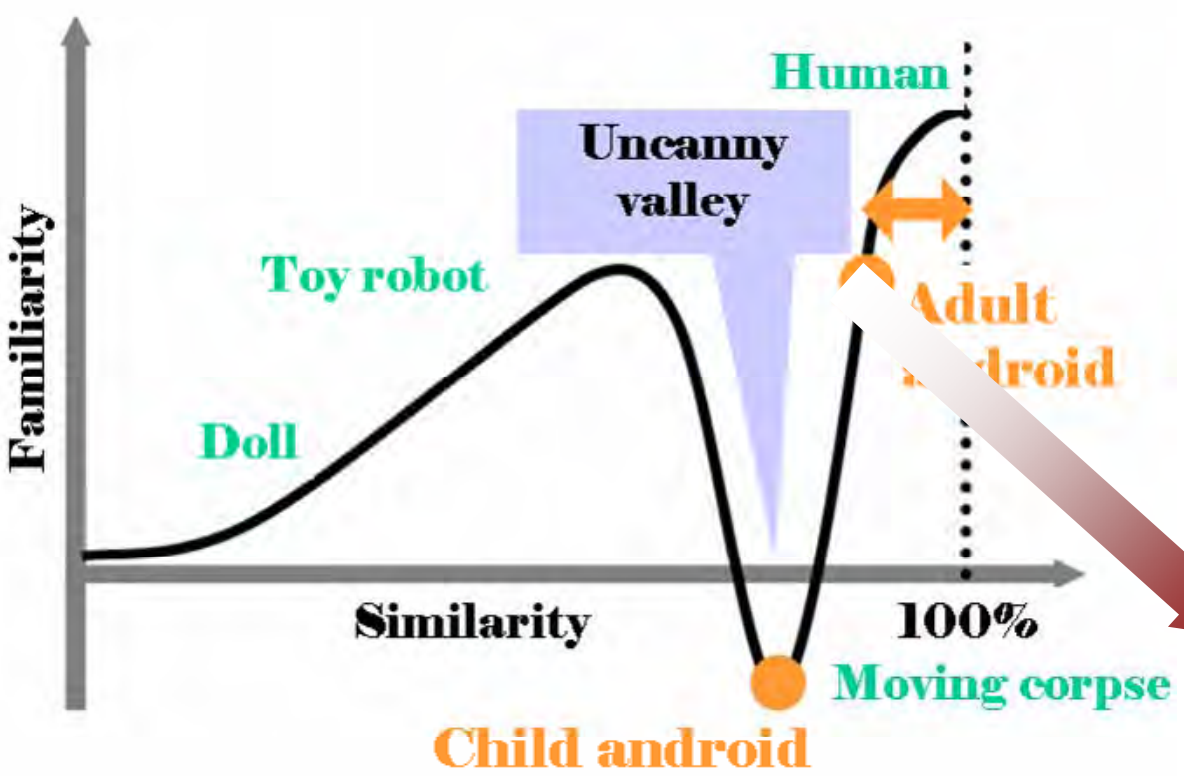
Distributed touch sensors → Position ← Position model

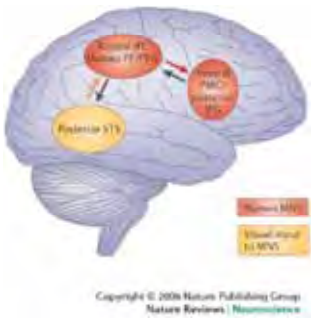
Distributed vision
Gesture recognition by vision → Behavior ← Behavior model

Distributed audition
Dynamic formation of
Microphone arrays → Dialogue ← Dialogue model

Uncanny valley

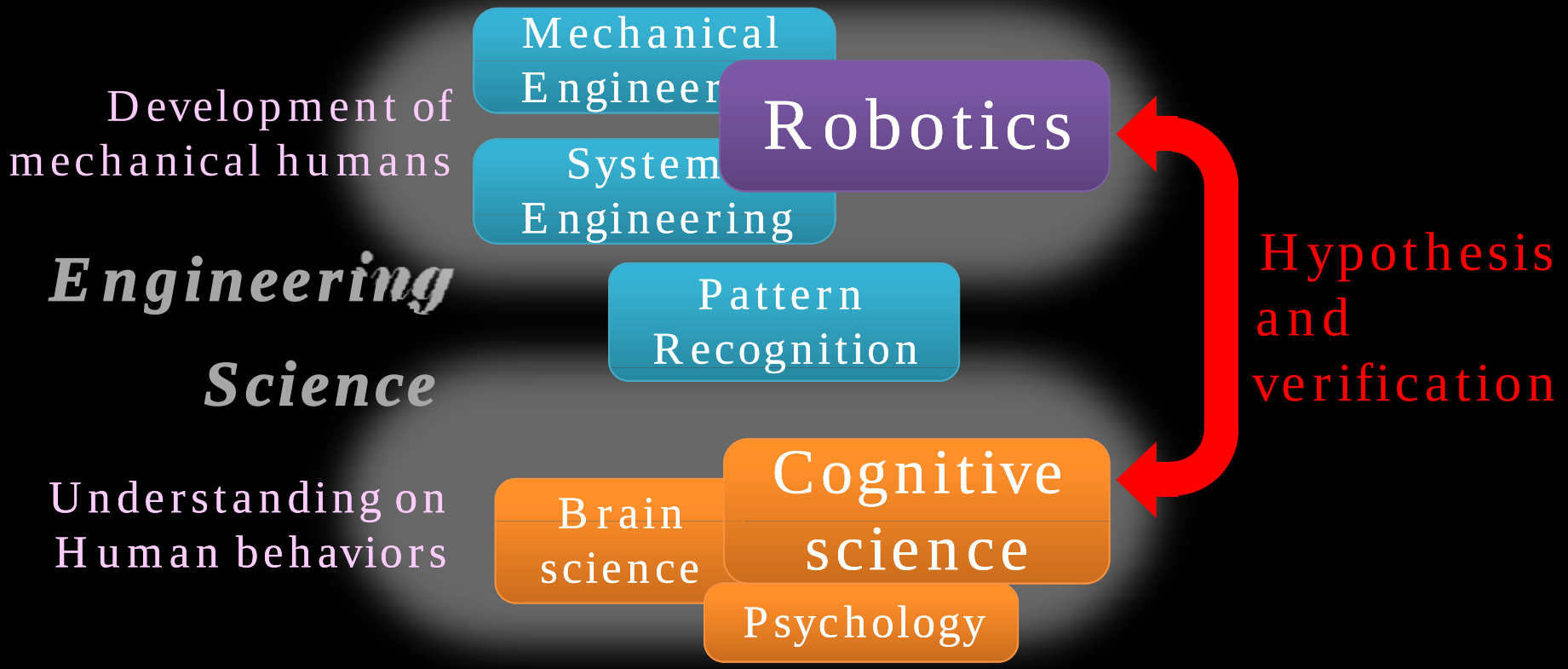
with T. Chaminade and A. Saygin





Android Science

Robotics and Cognitive Science



Scientific issue

Human likeness (appearance , movement, perception)

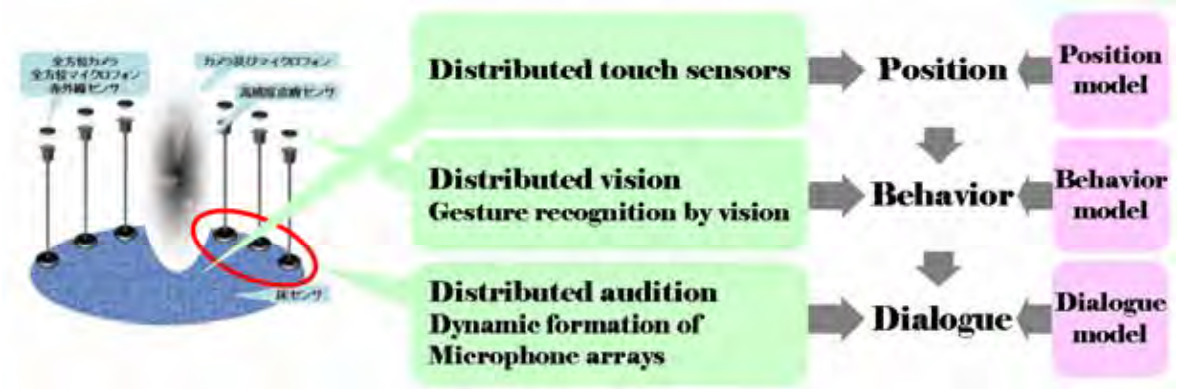
Engineering issue

Simple and interactive communication tasks

Bottleneck of autonomous robots

Humanlike appearance
Humanlike behavior
Humanlike perception
Humanlike conversation?

- People expect that humanlike robots can talk.
- However, it is a very hard problem…



Humanlike Conversation

Development of the geminoid
that is a tele-operated android of an existing person

Humanlike Conversation

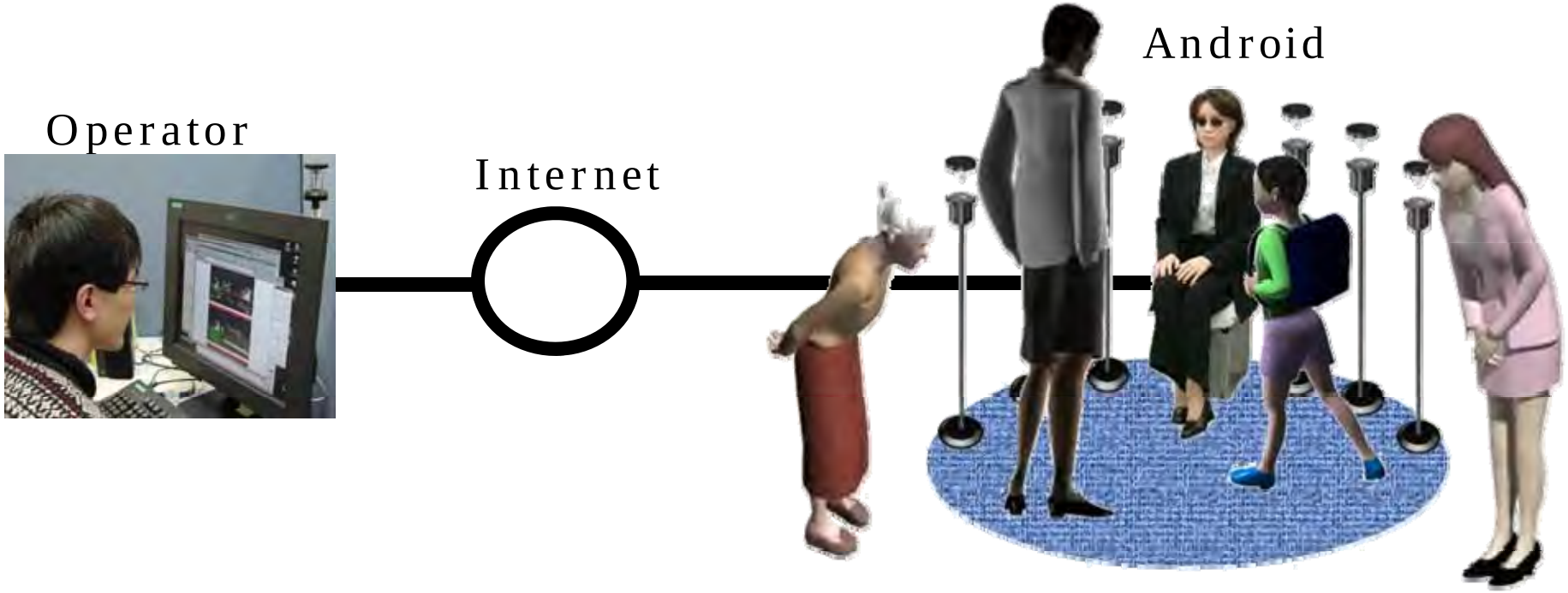
Humanlike Perception

Humanlike Movement

Humanlike Appearance

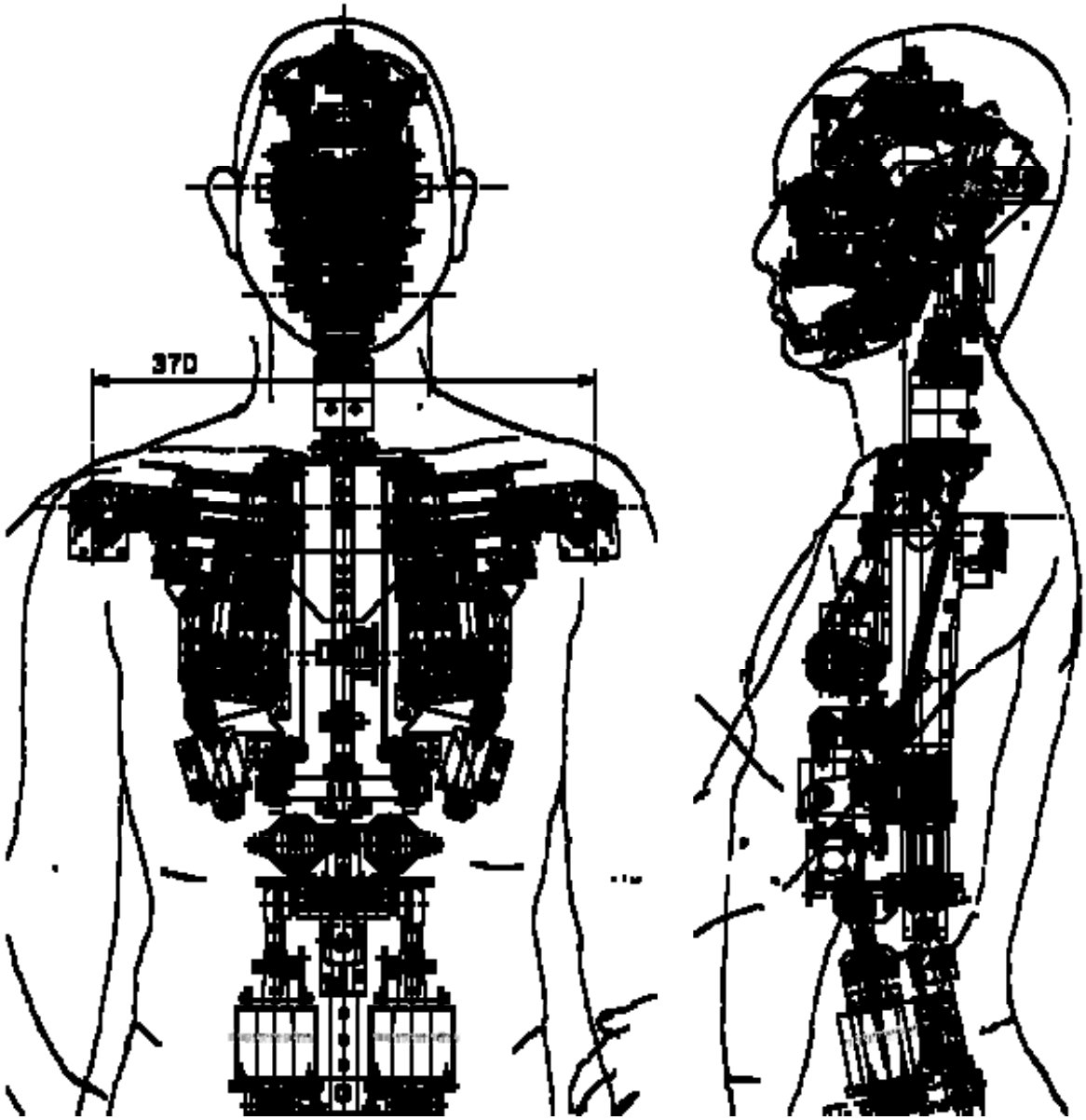
An approach for solving the bottleneck of autonomous robots

Tele-interaction by using semi-autonomous androids and humanoids



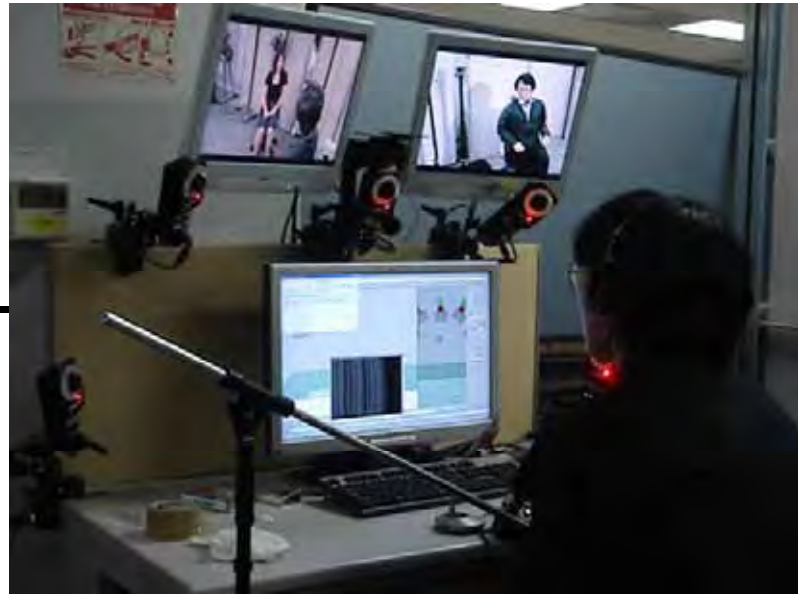
- Long term interaction and conversation
- More precise cognitive/psychological tests by using own androids
- Exist different places simultaneously

Development of the geminoid
-Tele-operated android of an existing person -



Tele-operation system through the Internet

Internet



- Motion capture system for measuring the rip movements
- Behavior selection by using GUI (6 behaviors)

Definition of geminoid

Humanoid = Humanlike robot
Android = Robot that has human appearance and behavior
Geminoid = Tele-operated android of an existent person

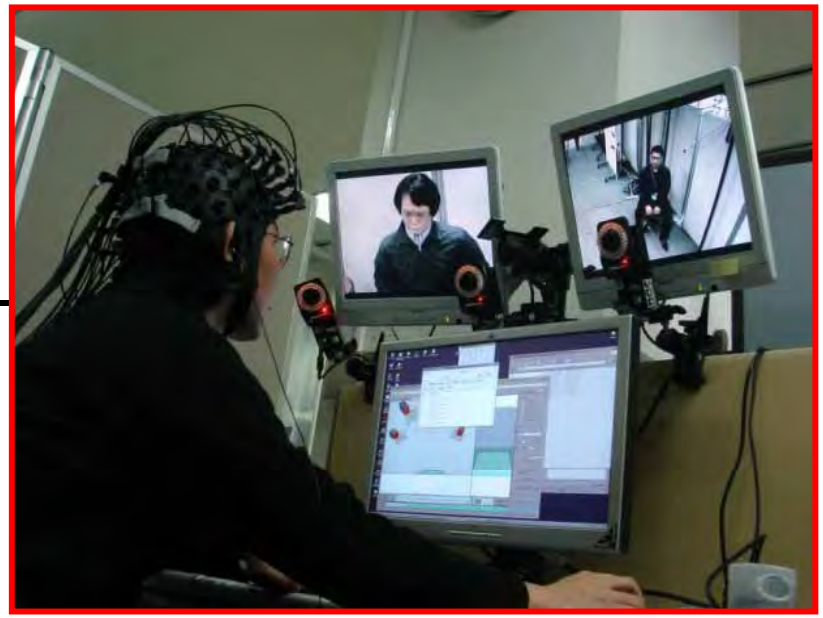
Humanoid

Android

Geminoid

Touch by someone

Internet



Adaptation to the different body

- While I operate the geminoid, I unconsciously adapt my movements to the geminoid's movements.

Sharing of information through the geminoid

- When the visitor touch to the Geminod, I get a feeling to be toughed (demeaning).

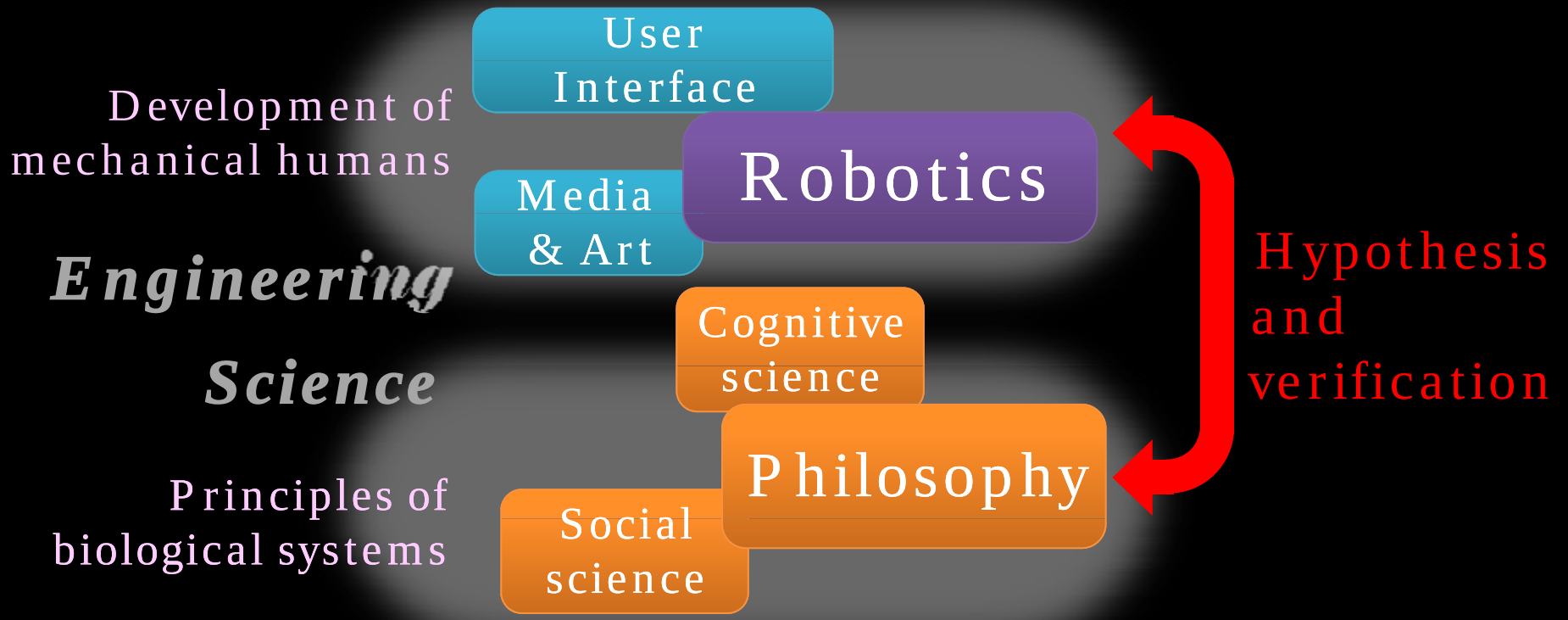
Meeting by using the geminoid

Strong entrainment in the conversation

- Both of I and the visitors can quickly, less than 5 minutes, adapt to the conversation through the geminoid.

Android Philosophy (?)

Robotics and Philosophy



Scientific issue

Human presence (self and others' observations, ego, adaptation to the different body, body and mind

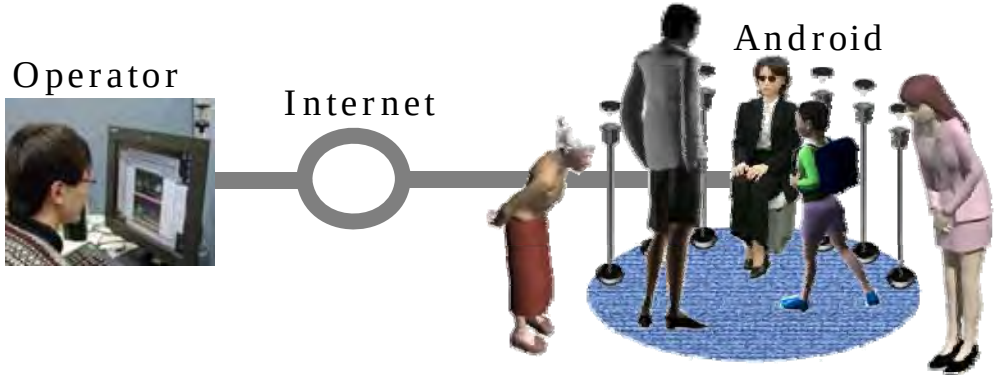
Engineering issue

Tele-presence technologies using the Geminoid

Necessity of humanlike mechanisms

Humanlike appearance
Humanlike behavior
Humanlike perception
Humanlike conversation
Humanlike mechanism?

- The robot needs to have more humanlike mechanism for more flexible movement.
- How to control the complicated system?

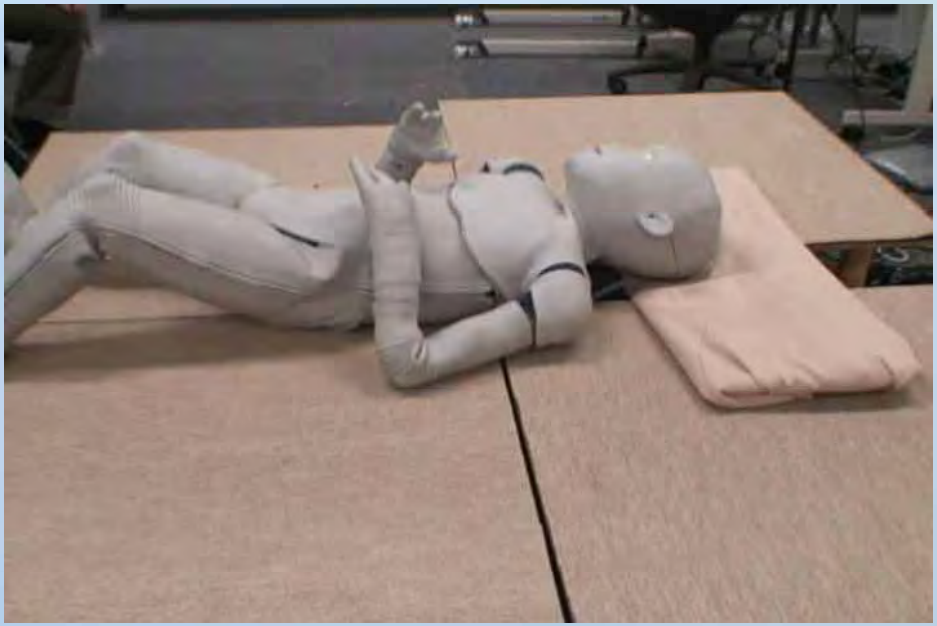


Jst Erato
Asada Project

Humanlike developmental software-mechanism

Development of the CB^2

that has complicated mechanisms



Humanlike Development

Humanlike Conversation

Humanlike Perception

Humanlike Movement

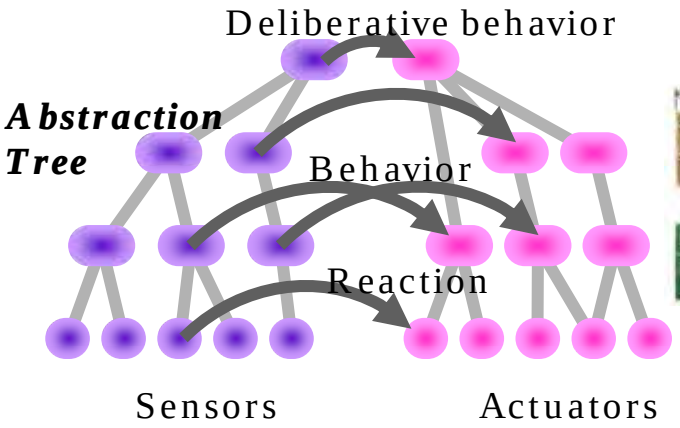
Humanlike Appearance

A new issue for complicated humanoids

Jst Erato Asada Project
with Prof. Asada

CB² - a growing humanoid -

- Height: 130cm, Weight: 33kg
- 56 actuators on the whole body
- Artificial vocal cord
- 197 tactile sensors, 2 cameras, 2 microphones
- Self-organizing sub-processor network



Self-organizing controller/computer networks for sensory motor mapping

- It is not easy to develop the software for the complicated hardware.
- The hardware system is going to be more complicated.

Human developmental process

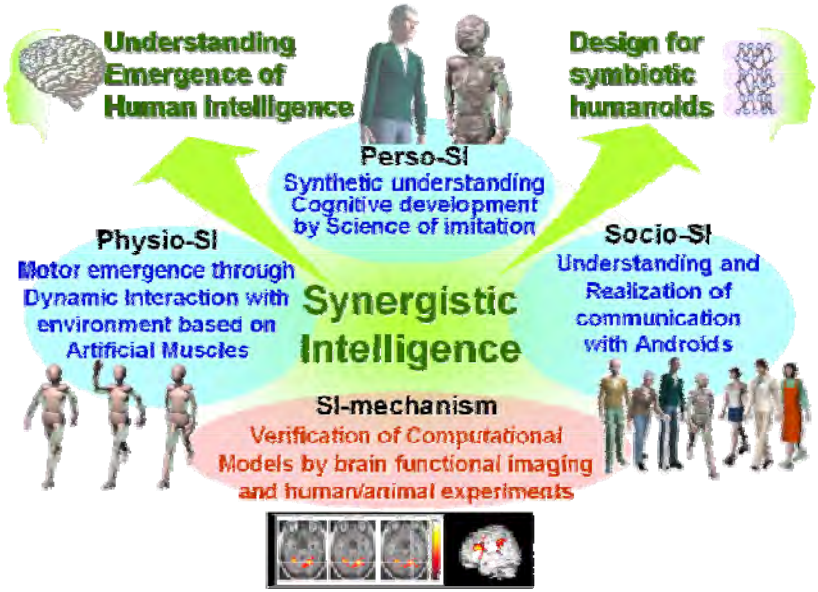
Development in the mother's body

Development in the external world

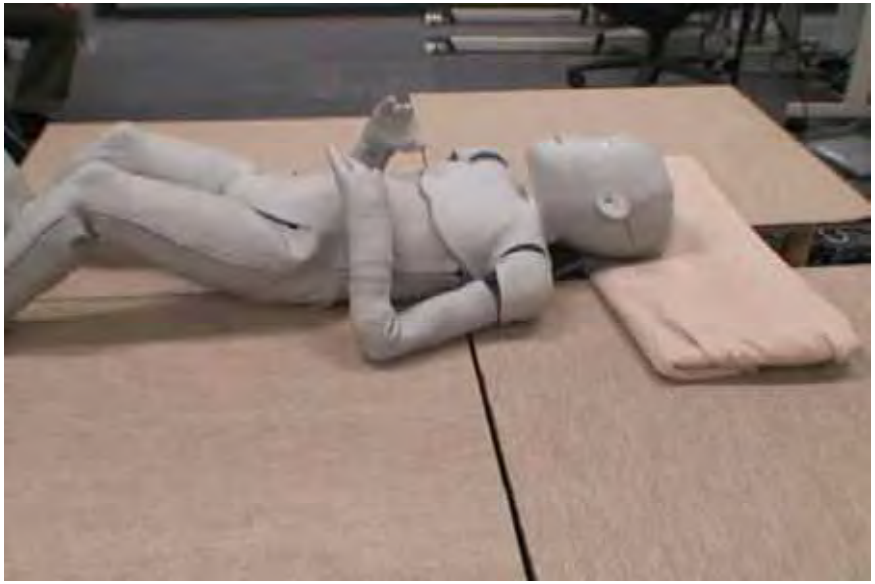
Developmental process as a biological system

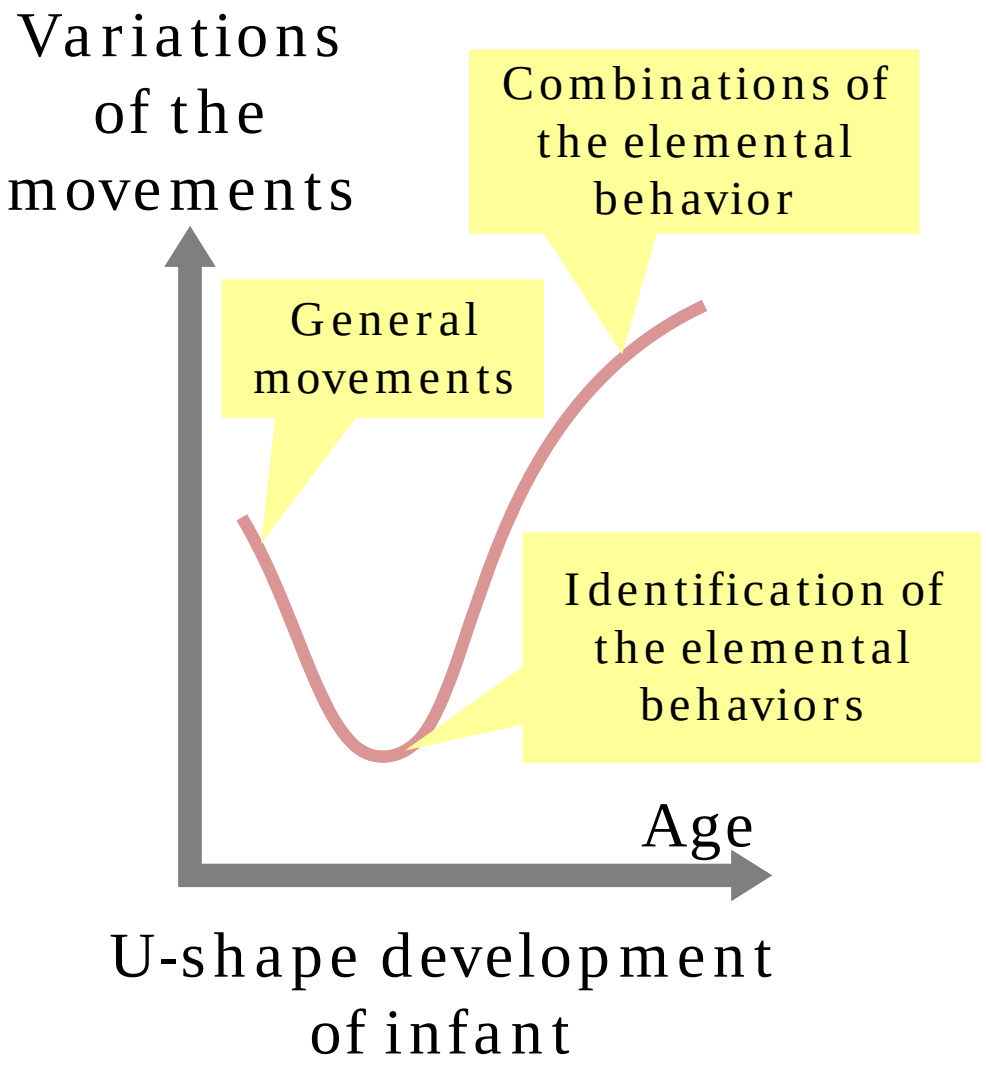
Developmental process as a social system

- Learn from the human developmental process and the cognitive model.
- Focus on the social development.



The growing humanoid

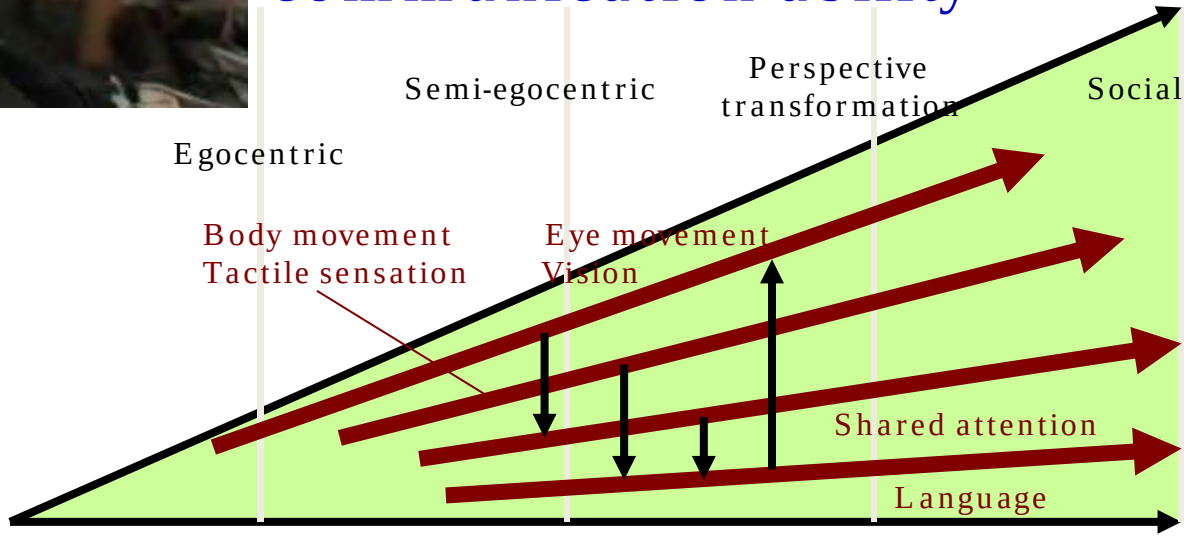




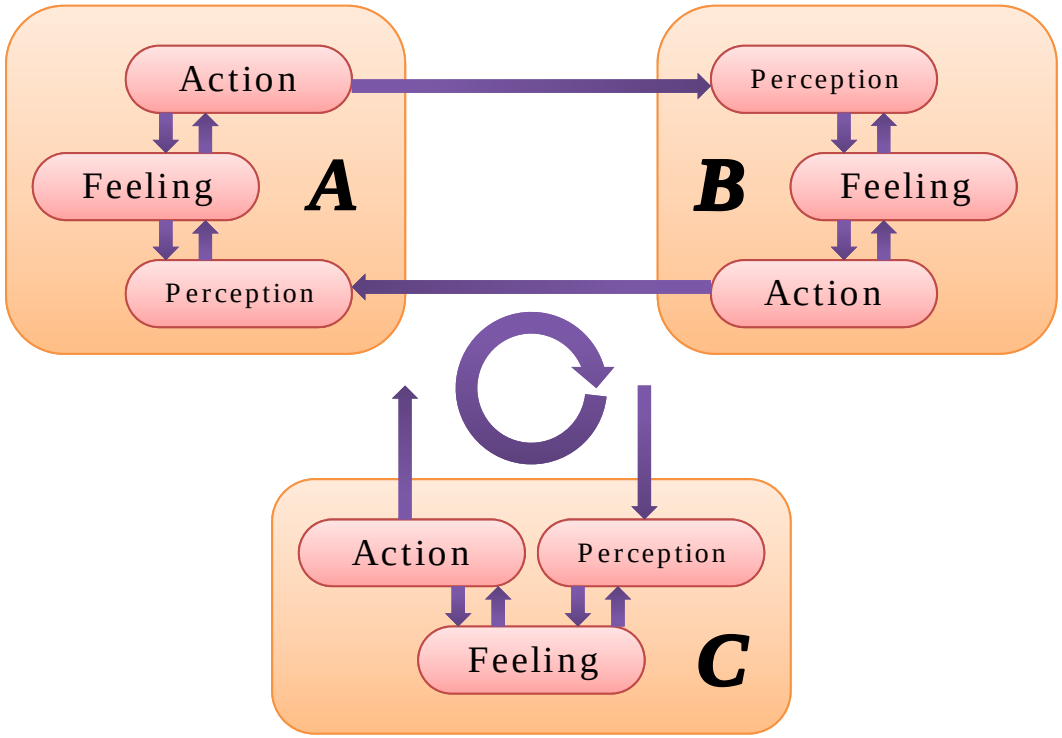
U-shape development of infant

Development of the multiple modalities

- Development of multimodalities.
- The robot integrates the multiple modalities through interactions with people.
- Study the developmental process of the communication ability



Development of the social relationship



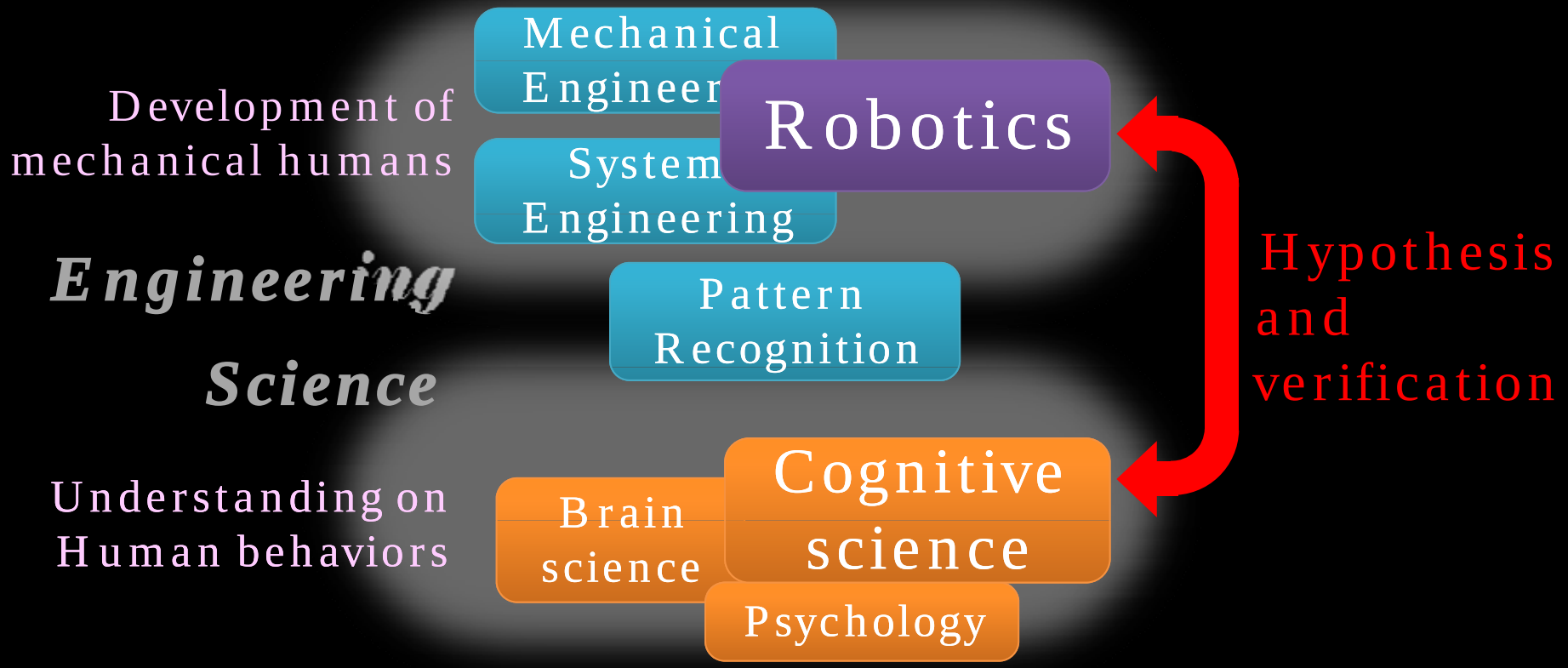
- Self-other distinction
- Cascades among action , perception and feeling.
- Interaction cascade, such as turn taking, influence to the internal cascades or rhythmic generator.

Learning of physical interaction

• The robot leans how to use and organize the complicated mechanism for standing up and walking through interactions with the care giver.

Cognitive Developmental Robotics

Robotics and Cognitive and Brain Science



Scientific issue

Human likeness developmental process

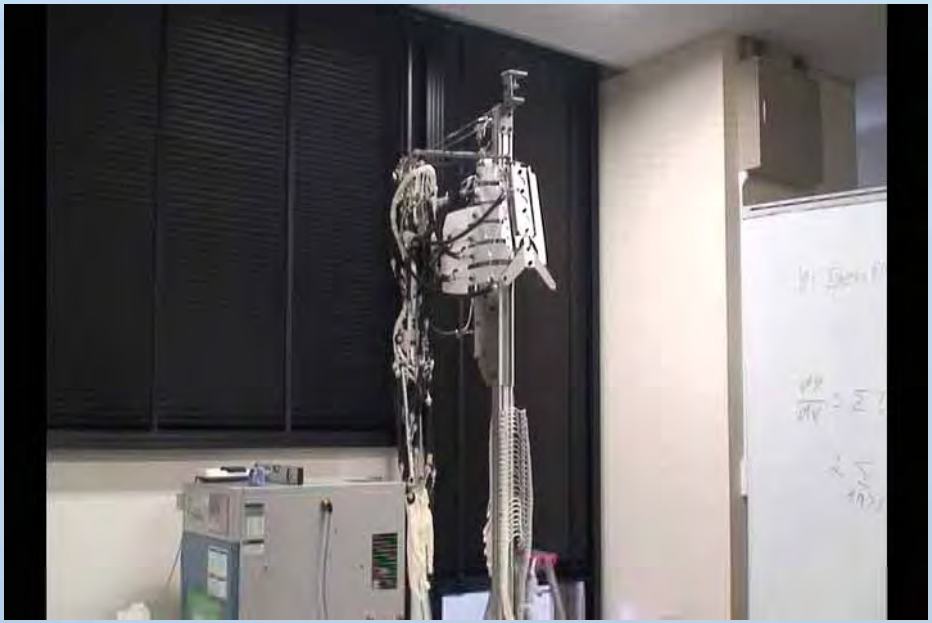
Engineering issue

Development of complicated software

Life Science
Information System
Nano Material
Robotics

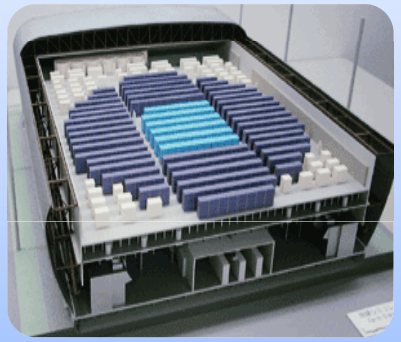
Humanlike principle

Bio-inspired principles for robust robots



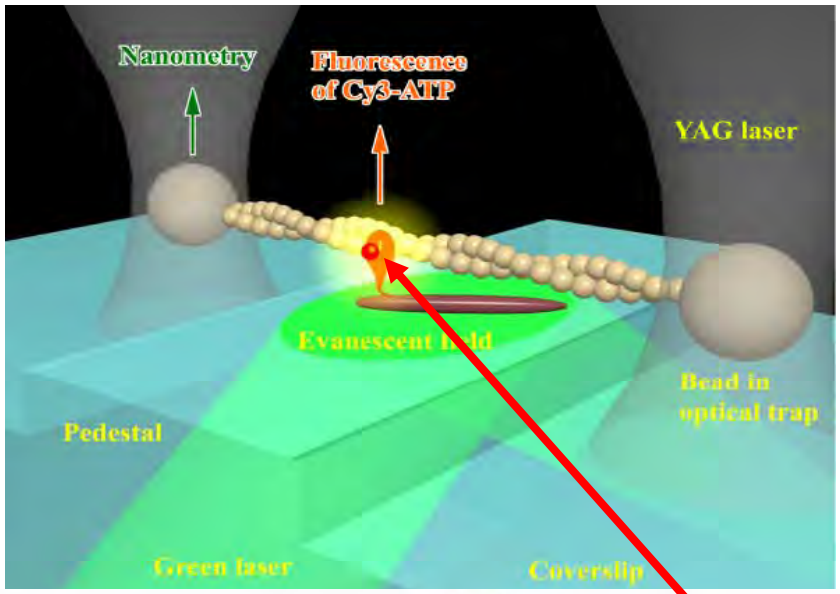
- ***Humanlike Principle***
- ***Humanlike Development***
- ***Humanlike Conversation***
- ***Humanlike Perception***
- ***Humanlike Movement***
- ***Humanlike Appearance***

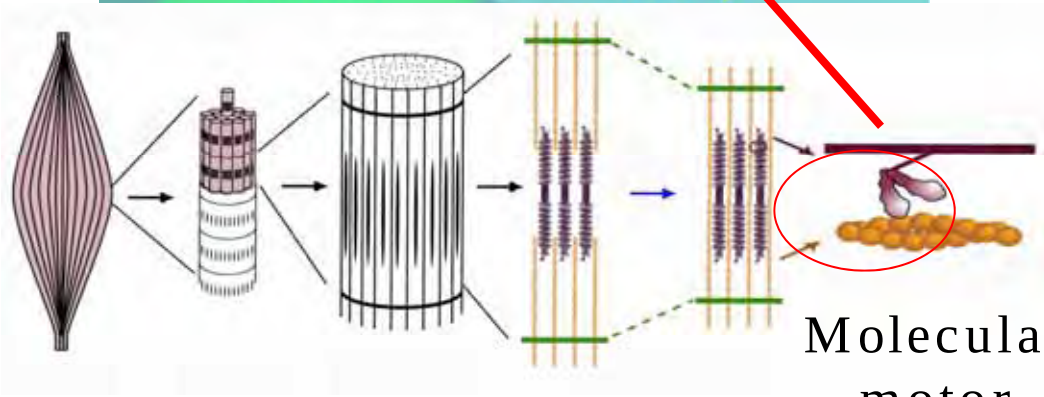
Differences between biological systems and artificial systems

Brain and computer	Energy	Principle
Neural network of the human cerebral  Ultra complicated system with 14billion neurons 50trillion connections	1watt	Using noise (biological fluctuation)? Clever control? Can it suppress the noise?
Super computer  10billion transistors	50,000 watts	Accurate and high speed control by suppressing the noise Activate by suppressing noise

Yuragi (attractor switching by noise) in the molecular motor for human muscle

by Prof. Yanagida





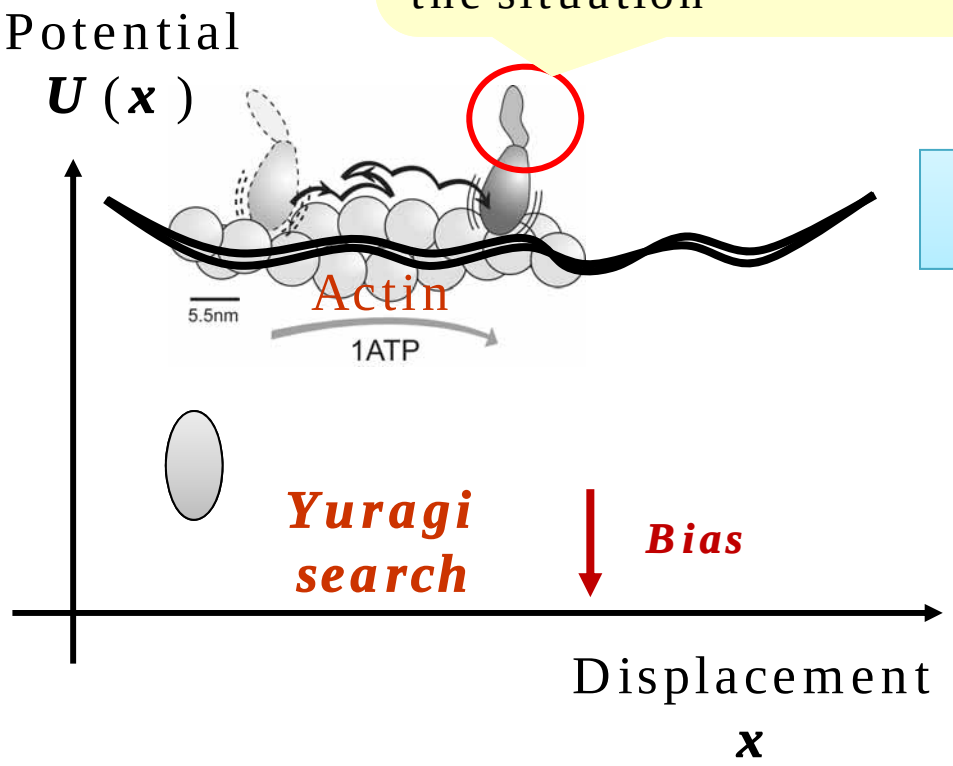
Molecular motor

- Myosin moves on the actin with the thermal noise and the mechanical structure of the myosin decides the moving direction.

Ishijima, et al., Cell 92 (1998)
Kitamura et al., Nature (1999),
Biophysics (20005)

The mechanism to use thermal noise in muscle molecular motor

Strain sensor determines the velocity, power and displacement according to the situation



Yuragi formula
(Biased Brownian movement)

$$\frac{dx}{dt} = -\frac{1}{\rho}\frac{\partial U(x,t)}{\partial x}B + \sqrt{\frac{2kT}{\rho}}\eta(t)$$

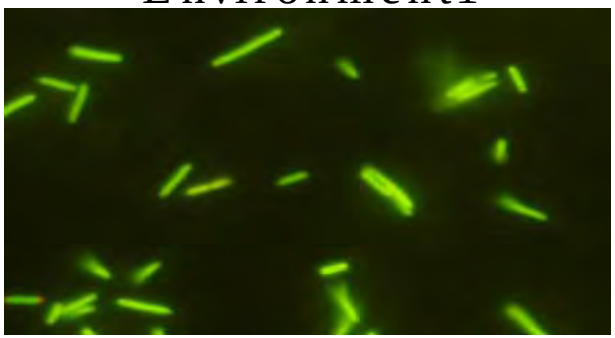
Potential Bias + ***Yuragi***

- The moving distance and the power is determined by modulated potential according to the internal and external states. (Bias by strain sensor)
- Langevin equation (Stochastic differential equation)

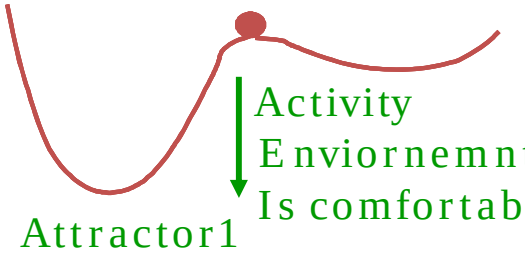
Adaptation to the environment by thermal fluctuation in gene expression (Cell level ***Yuragi***) by Prof. Yomo

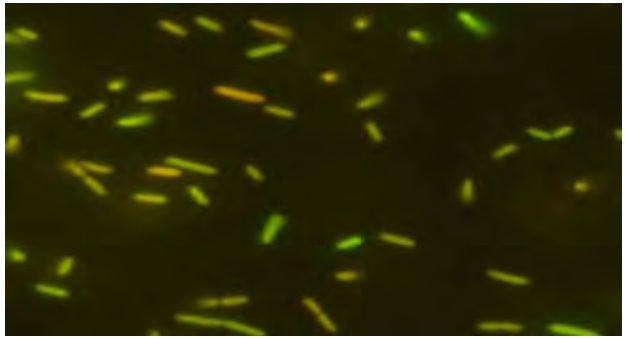
← Environmental change ← Original environment → Environmental change →

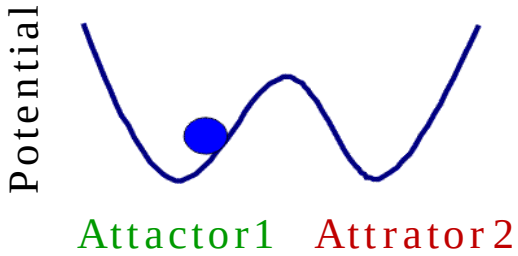
Environment1



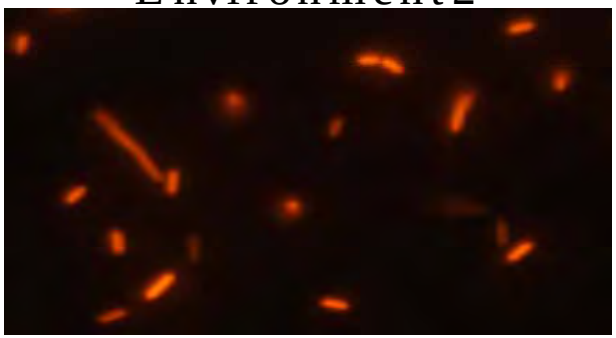
Glutamine deficiency



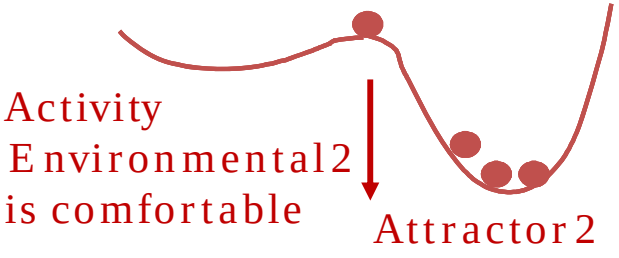




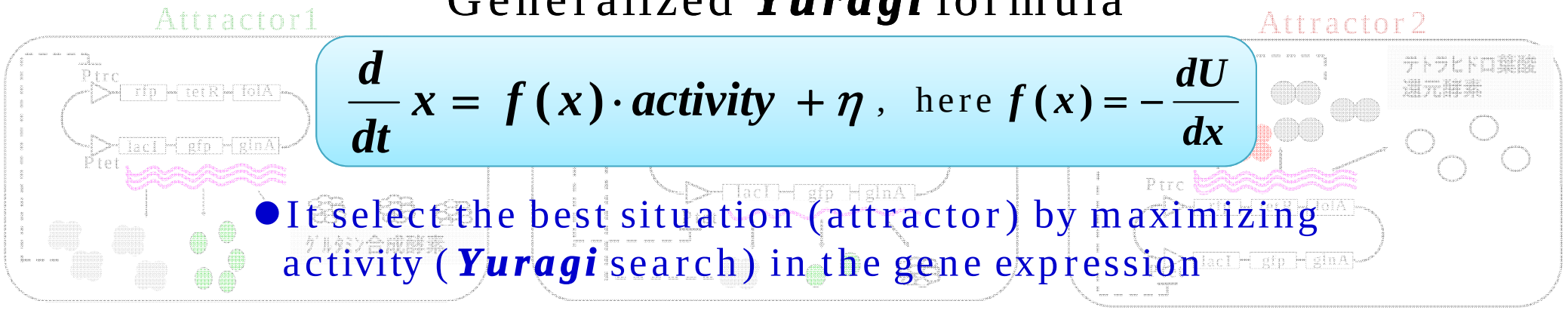
Environment2



Tetrahydrofolate deficiency



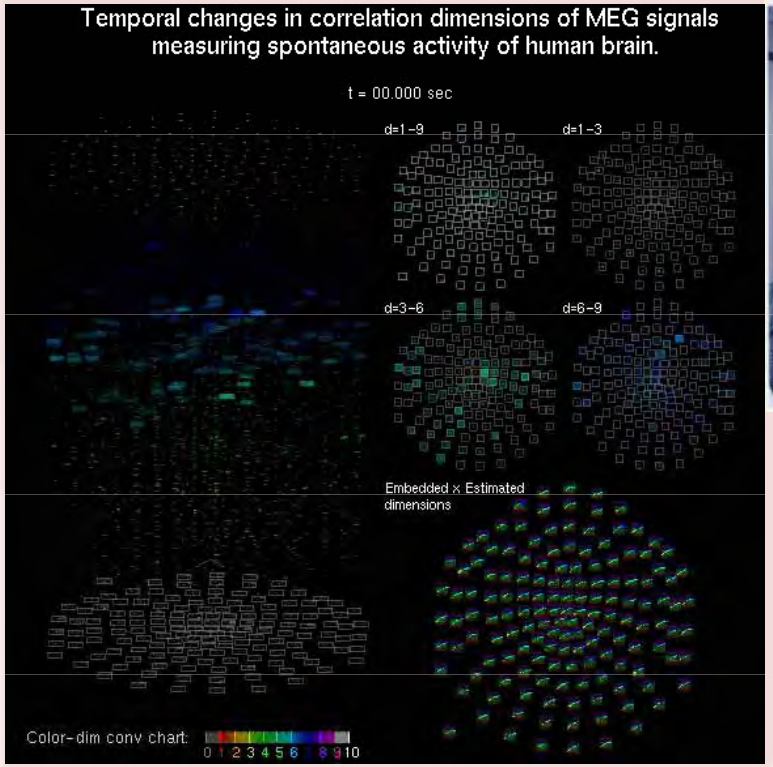
Generalized ***Yuragi*** formula



$$\frac{d}{dt}x = f(x)\cdot activity + \eta, \quad \text{here } f(x) = -\frac{dU}{dx}$$

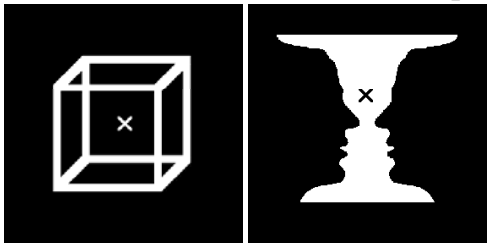
- It select the best situation (attractor) by maximizing activity (***Yuragi*** search) in the gene expression

Yuragi in visual cognition of human brain
(System level ***Yuragi***) by Prof. Yanagida

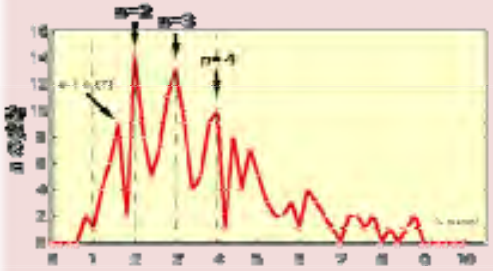


MEG

Necker cube Face or cup

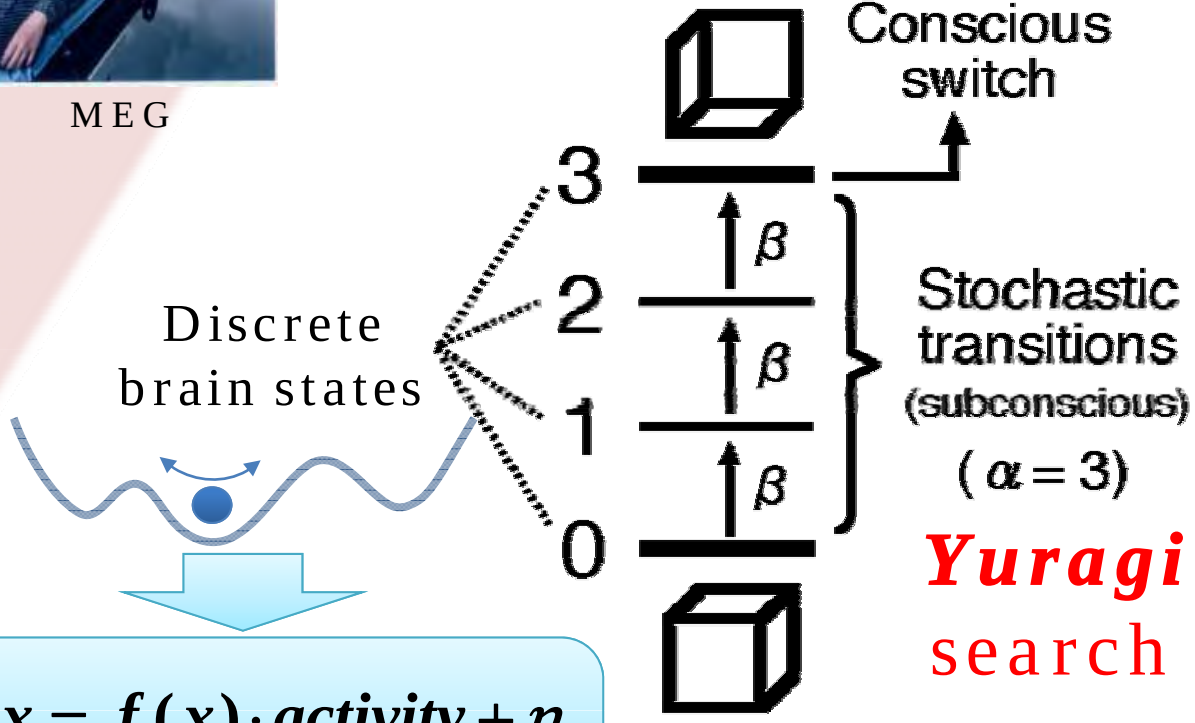


Cognition of ambiguous figure



Yuragi of brain activity

Distribution of the discrete states



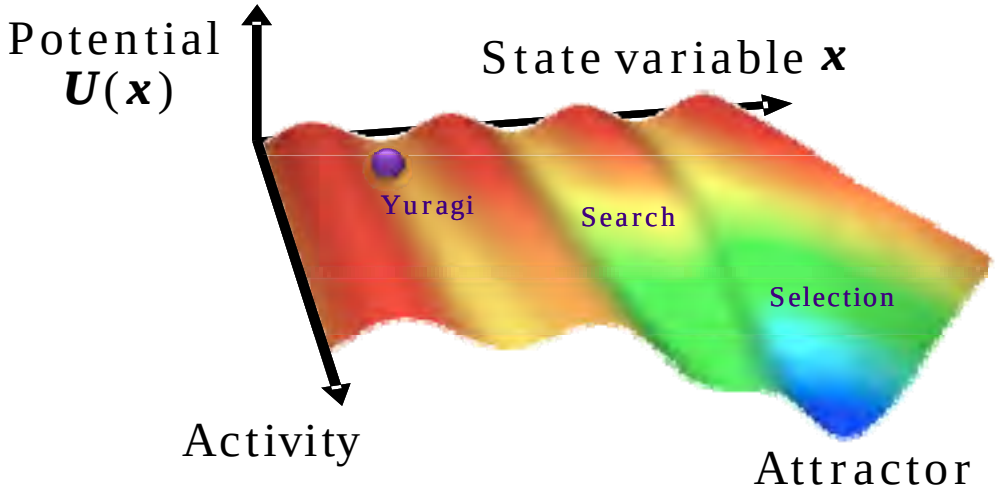
$$\frac{d}{dt}x = f(x)\cdot activity + \eta$$

Potential Consistency + ***Yuragi***

Yuragi Formula

$$\frac{d}{dt}x = f(x) \cdot activity + \eta$$

The control structure that has attractors	Condition of the system	Thermal fluctuation, Spontaneous fluctuation
Structure that accepts use of Yuragi $f(x) = -dU/dx$	Degree of comfortable feeling	Structure of Yuragi

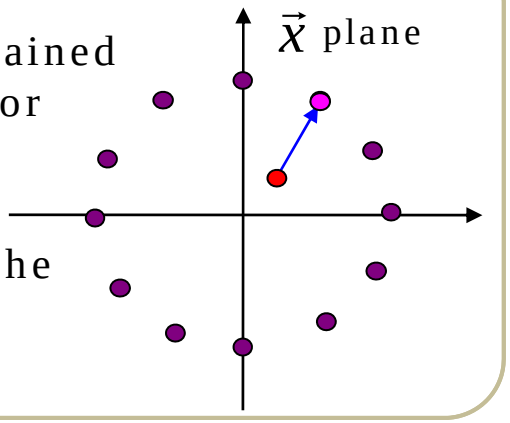


Simple artificial creature like an insect

High activity

Action is entrained by the attractor

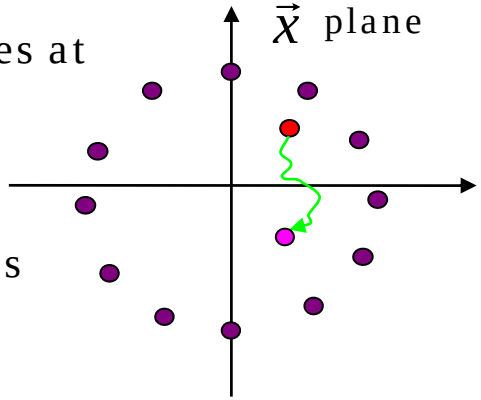
Robot takes the same action



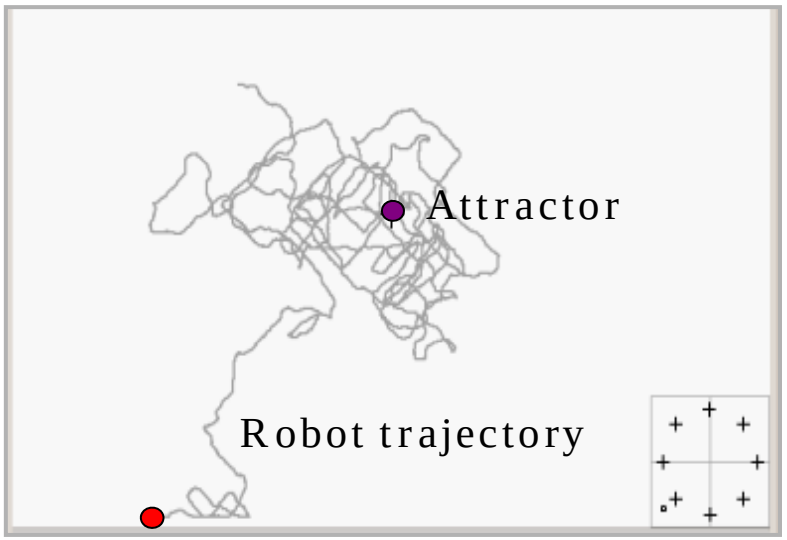
Low activity

Action changes at random

Robot changes the action



Simulation results



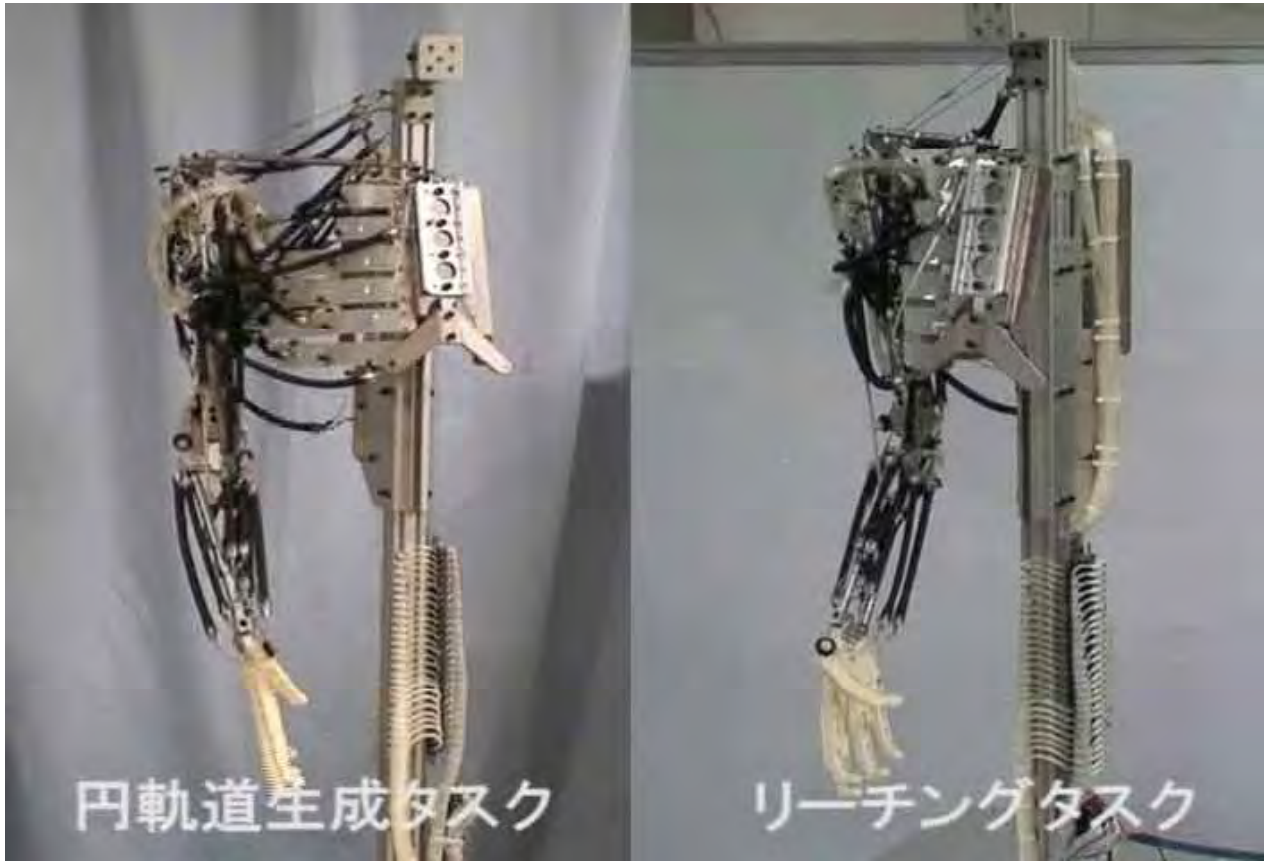
- The robot can reach to the goal by using the noise and changing the activity

Simple artificial creature

One motor and one light sensor

Microphone and sound source

Complicated bio-mimetic arm robot



Structure
- Human bone structure
- Human muscle structure

Actuator
- 26 DOFs
- Pneumatic artificial muscle

- How do we control the very complicated robot?
- The robot finds how to move the attractors with noise.

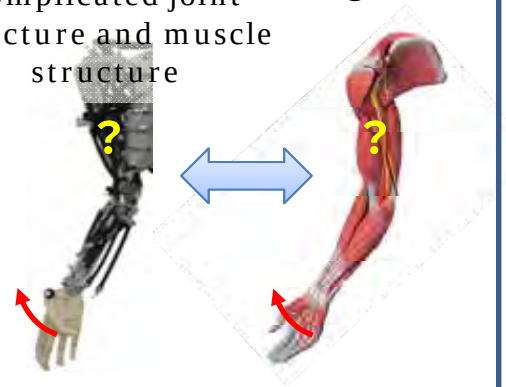
Complicated robot control for which the previous method cannot apply

Previous robot

Motor movements correspond to the joint movement (N=1)

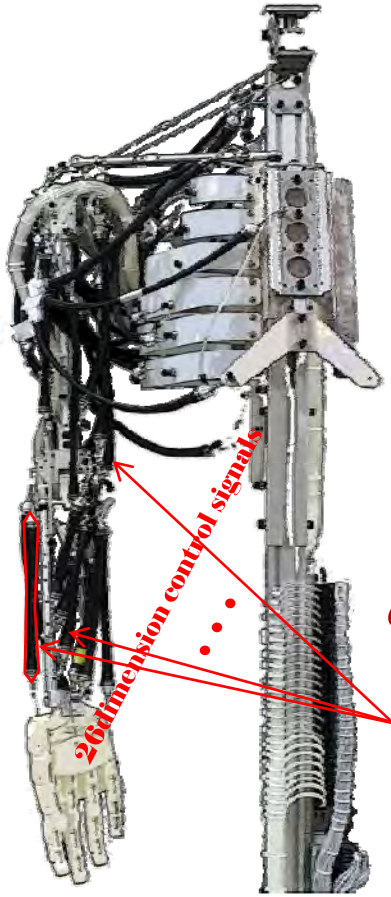
Robot that has complicated joint structure and muscle structure

Organism



Muscles movements do not simply correspond to the joint movement (N≧26)

Suppose it has 26 actuators that has binary states, on or off. There are 2^{26} combinations.



Take Put Throw

Selection of objective task

activity = task achievement

Bend Stretch Grab

Selection of basic behaviors

activity = behavior achievement

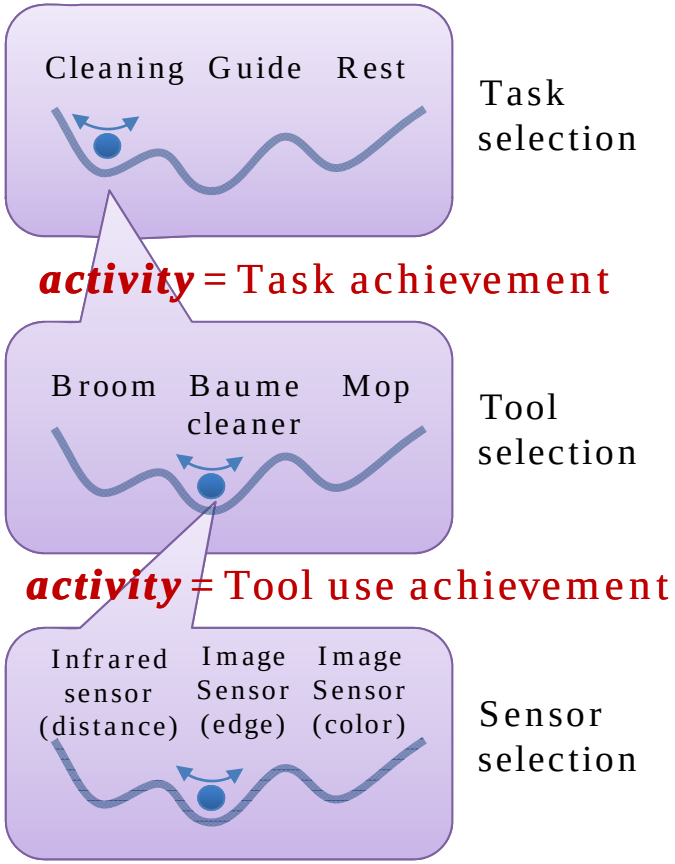
26 dimension control space

Control of 26 actuators

- Find the structure $f(x)$ of the unknown problem space with Yuragi in each layer and perform flexible selection.
- Upper layer determines the activity of the lower layer.
- Memorize the found attractor structure $f(x)$ and efficiently use by learning

Complicated robot control

Role sharing among multiple robots in dynamical environments



- The upper layer automatically determines the activity of the lower layer by giving an activity, such as “comfortable”, to the top layer.

Yuragi is a new basic method

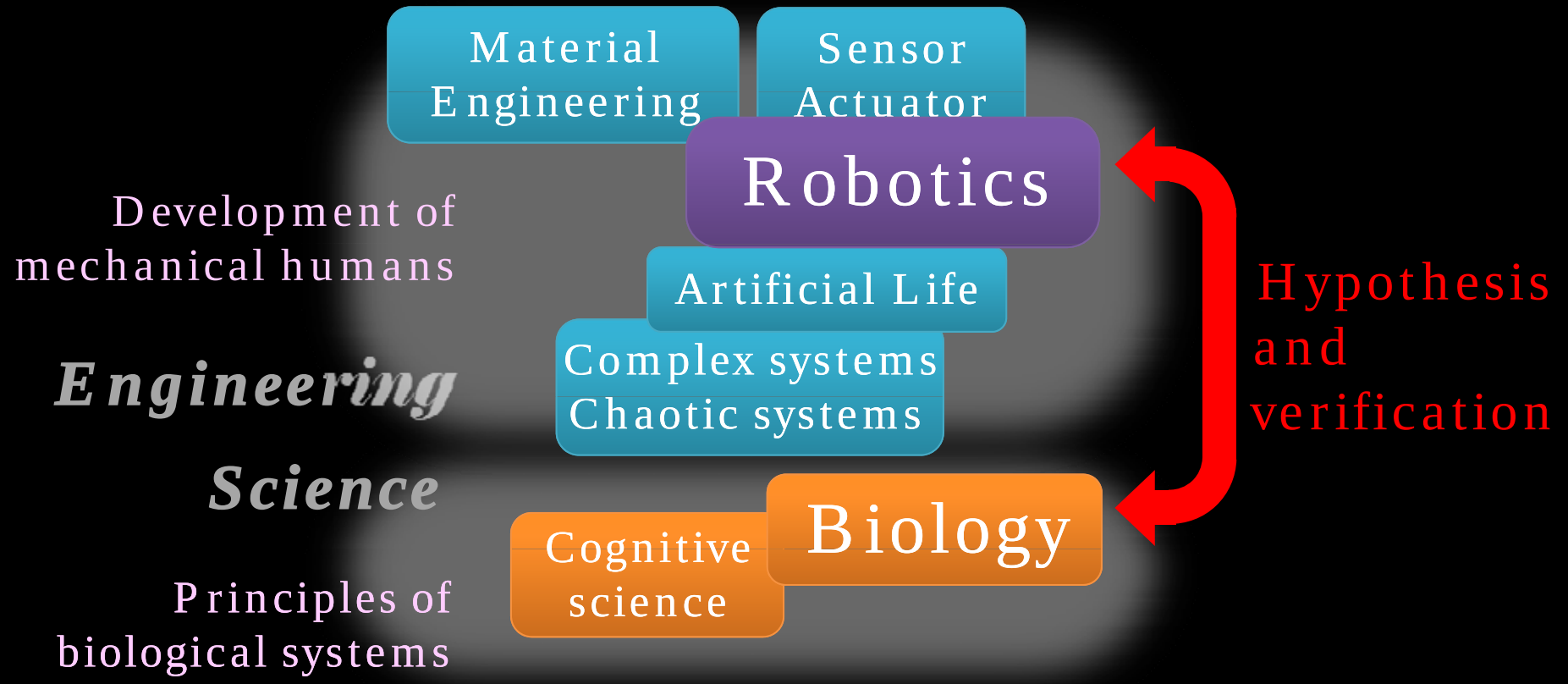
- Traditional control methods, neural networks and Fuzzy control cannot handle dynamically changing problems and unknown problems.
- ***Yuragi*** can obtain (sub) optimal solution without precise modeling.

	Traditional control method (PID)	Neural network	Fuzzy	***Yuragi***
Precise and quick	◎	○	△	△
Complicated problems	×	○	○	○
Adaptation to dynamically changing problems	×	△ Online learning	×	○
Adaptation to new or rare cases	×	△ It cannot learn	△	○
Coverage	Problems describable with linear models	Problems describable with nonlinear models	Partially non-describable problems	Non-describable problems

Simulated annealing (SA) is a parameter optimization method by reducing the temperature (reducing the noise). It can be applied to problems represented with models. On the other hand, ***Yuragi*** is a search method for situations where the dynamically changing ***activity*** is maximized.

Biological Robotics

Robotics and Biology



Scientific issue

Principles of the biological systems

Engineering issue

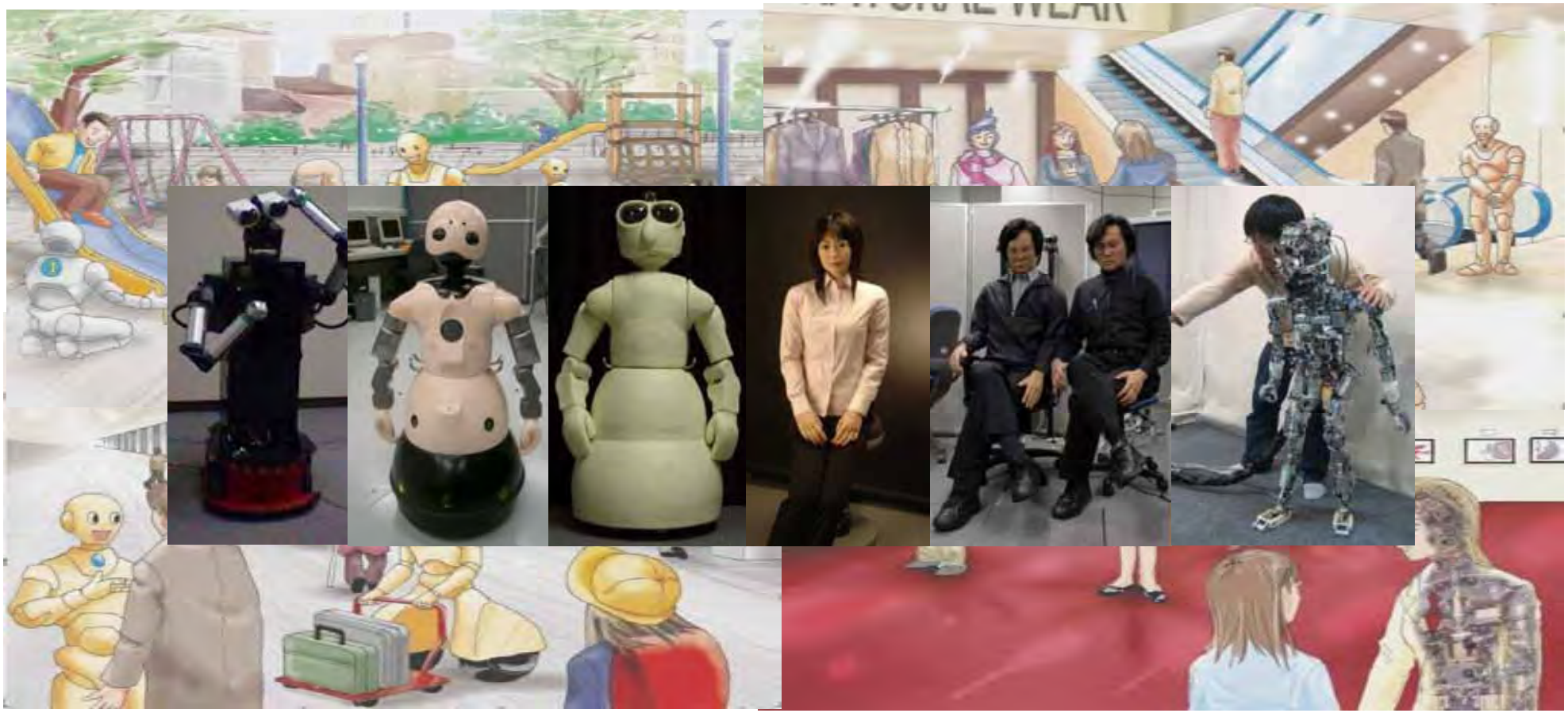
Humanlike robust and energy conservation systems

Our future life with robots

- Robots give services through simple communication
- Robots works as partners of humans

Conclusion

Robotics is science for understanding humans.
Robotics is engineering for developing our future life.
Various research areas are integrated in robotics.



Collaborators

Development of the androids	KOKORO
Development of the humanoids	Mitsubishi Heavy Industry
	Vstone
Soft skin sensor	Prof. Suganuma and Prof. Inoue, Osaka University
Linear actuator	Prof. Hirata, Osaka University
HRI studies	Dr. Kanda, Dr. Miyashita, Dr. Ishii, Mr. Nishio,
	Dr. Hagita, ATR IRC
	Prof. Imai, Keio University
	Prof. Ono, Future University Hakodate
	Prof. Kahn, Univ. Washington
	Dr. Movellan, Univ. California, San Diego
Cognitive studies	Prof. Hiraki , Tokyo University
	Prof. Itakura , Kyoto University
	Dr. Chaminade, Dr. Saygin, UCL
Cognitive Robotics	Prof. Asada, Osaka University
	Dr. Yoshikawa, Dr. Minato, Osaka University
Bio-inspired Robotics	Prof. Matsumoto, Prof. Koizumi,
	Prof. Nakamura, Osaka University