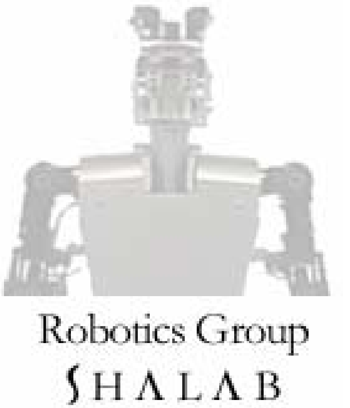
KANSEI ROBOTICS

New relationship between human and machine

- machine with a heart –

Shuji Hashimoto

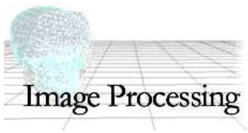
Humanoid Robotics Institute
Waseda University



About my laboratory

ʃHALAB

established in 1991
at Dept. of Applied Physics

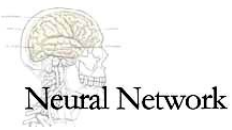


Vision and Image Processing Group

- Facial Image Processing
- CG and Visual inspection
- Database and Data visualization

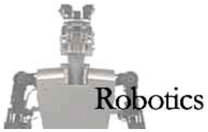
Multimedia Processing Group

- Sound Creation
- Advanced musical instruments
- Sound database



Meta Algorithm Group

- Neural Network / Genetic Algorithm
- Reinforcement Learning
- Stochastic optimization

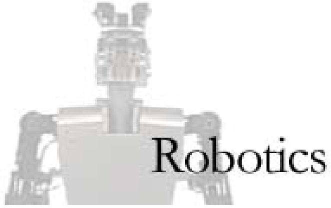


Robotics Group

- Humanoid robot / autonomous robot
- Robot vision / map building robot
- Robotic interface

Robotics Group

Robotics Group
SHALAB

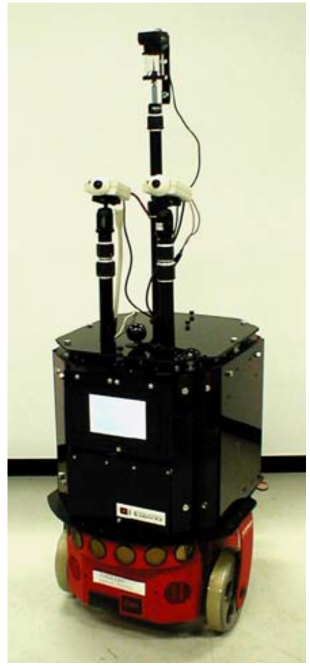


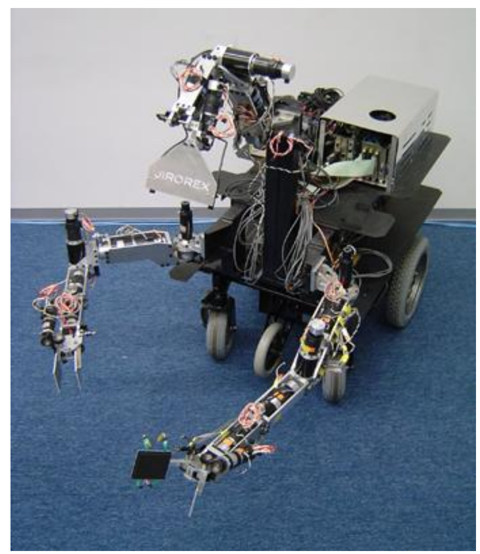
- Multimodal Robots
  - Autonomous Humanoid robot “iSHA”
  - Integrated Communicarive Robot “BUGNOID”
  - Coaching a robot
  - Module-type robot
  - GPS embedded autonomous robot
- Haptic Interface and advanced interface
  - Hand-Shaped Force Interface
  - Haptic and Tactile Display for Human Tele-communication
  - Handshake Telephone System
  - Motion Interface for Omni-Directional Vehicle
- Survival Robot in Outdoor Environment (1998~)
- Chemical Robotics

Our Mission: Kansei Interface

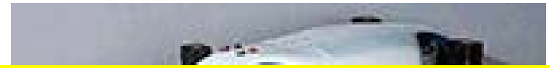
- How to sense
- How to understand
- How to transform
- How to display
- For human-machine Communication
- For human-human Communication

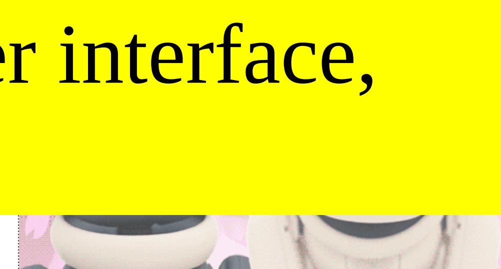
Robots in Hashimoto Lab.



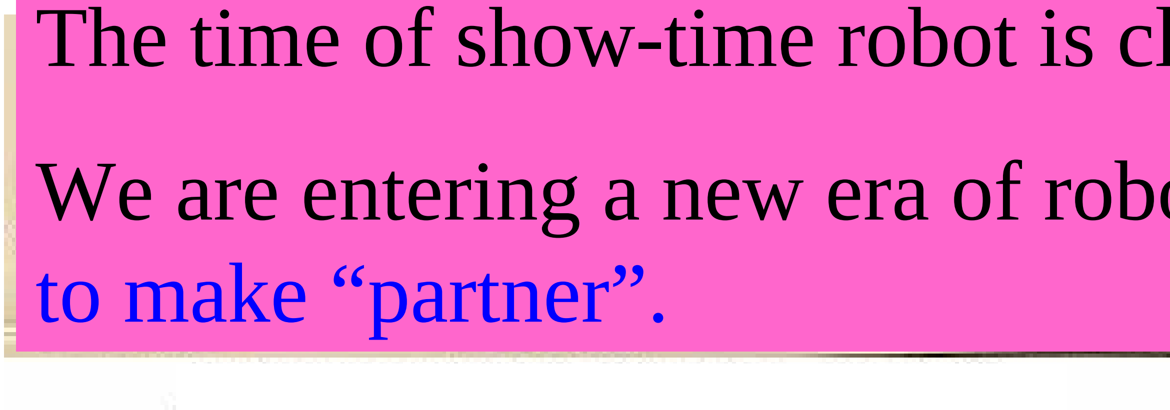


Consumer Robots Business seems to have been launched





We need much more efforts to raise up Robotic Industry in various fields not only for entertainment but also for production, medical appliance, home works, computer interface, welfare, etc.




The time of show-time robot is closing.

We are entering a new era of robotic technology to make “partner”.

From Tool to Partner

Establishing a new relationship between human and machine.

- Automation
  - Plant, Observation, Control, Measurement
  - "Physics"
- Robot in Factory
  - Production, Planning, Learning, Adaptation
  - “Physics+Logic"
- Robot in Human Environment
  - Autonomous, Collaboration with human,
  - “Physics+Logic+KANSEI”

Advancement of Interface

Touch, Pressure	Physical	Force	Objective	
"Walk", "Stop"	Logical	Command		Value Signal
"Advance by 1m	Numerical	Volume		
"Walk a little bit faster"	Fuzzy	Degree		Symbol Information
"Push tenderly"	Kansei	Quality	Subjective	

What is Kansei ?

- **subjectivity, multivocality**
- **Ambiguity**

感性

- **Kansei is emotion ?**
- **Kansei is intuitiveness ?**

心

- **Another human ability of understanding.**
- **An imaginary organ to generate Kansei**

= KOKORO（≒ Heart）

Computer Conducting System

Robot for interactive musical performance

Example I:

Interactive System at exhibitions, museums in the theatre (1998)

- embedding a model of artificial emotional state based on neural network (Kohonen's Self-Organizing Map)

collaboration with Antonio Camurri, Univ. Genoa

Example II:

Virtual Musical Environment with an omni-directional vehicle (1999)

- Robot as a dance partner with humans

Example I

Art installation with *visitor robot* for *“Arti Visive 2”* multimedia exhibition, which was held at Palazzo Ducale, in Genoa, Italy on October 2nd, 1998.

Acknowledgement: I would like to thank to composer Riccardo Dapelo, and scenographer Emanuela Picchiardi.

Example II

A performance of "*iDance*™" and "MIIDItro™" with dancers for presenting at an international computer music conference (ICMC99 and ICMC2000).

Acknowledgement: I would like to thank to dancers, Tatsuya Hashimoto and Eri Nomura at the dance performance.

Machine with KANSEI

Robotics Group
SHALAB

- Machine with Heart
- Machine with KOKORO「心」
- **"KOKORO" is an imaginary organ to generate KANSEI.**

Machine needs KOKORO

to understand human KANSEI

The road to real Humanoid

Questions

- Is it possible technically to make a robot with KOKORO ?
- Is there any problem from ethical point of view ?

- If we need a real partner, we need a robot with KOKORO.
- Real partner is not a slave.

Approaches to make a machine with KOKORO

- Top down
  - Imitate human/creature behavior that looks to have KOKORO
  - Design based on knowledge

- Bottom up
  - Make seeds and design the environment
  - Expect their growth

Top down Approach on KANSEI Robotics

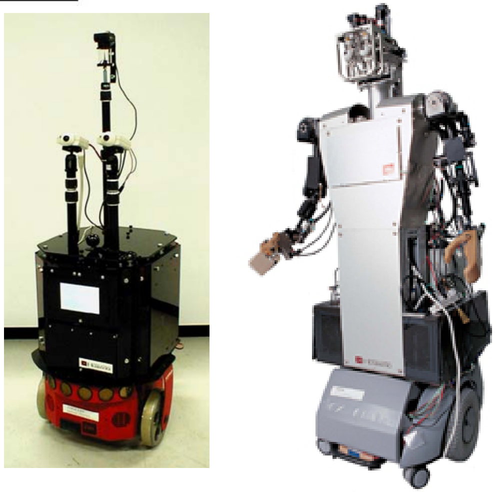
Humans

Intelligent / Kansei Information Processing

- to understand "intention" of a partner

- Physical Modeling of Face
- Face Detection from scene
- Haptic/tactile communication

Sharing Physical & Informational Space



Machines

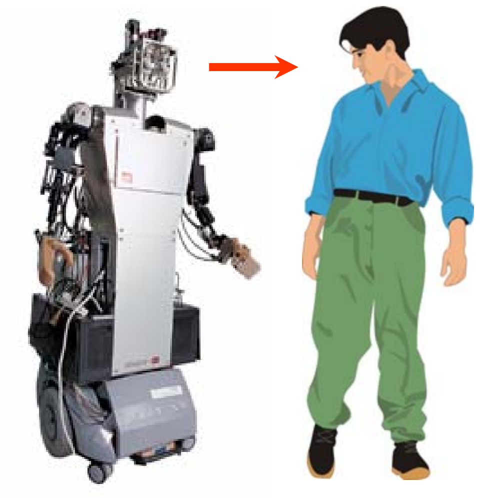
Analysis and Modeling

Integrated robot interface

- Multimodal interface
- assuming physical contact with people

Autonomous Humanoid Robot "iSHA"

- Toward a multimodal communicative machine
  - The robot must achieve a given task in different ways
  - User can choose the channel according to the situation



- Some examples to draw its attention (makes the robot turn to human):
  - Making a sound
  - By speech "Turn left"
  - By any objects
  - Body push
  - Grasp the hand and pull it

A Layered Communication Model in “iSHA”

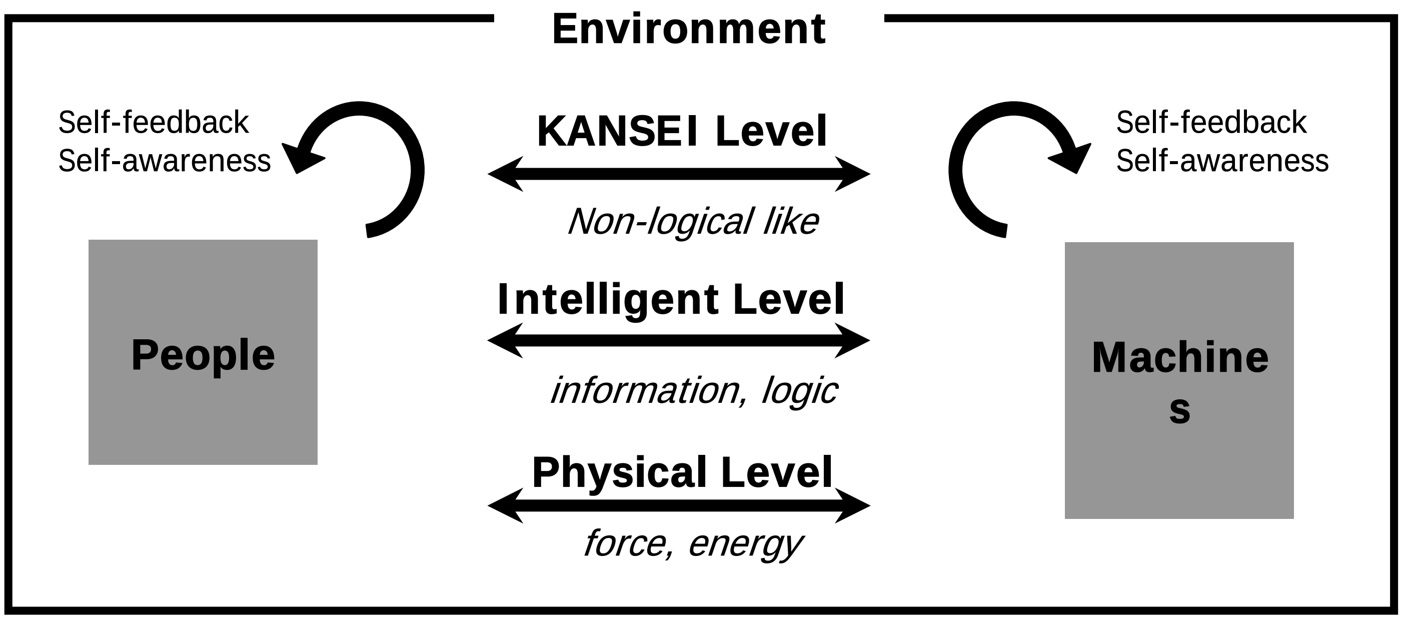
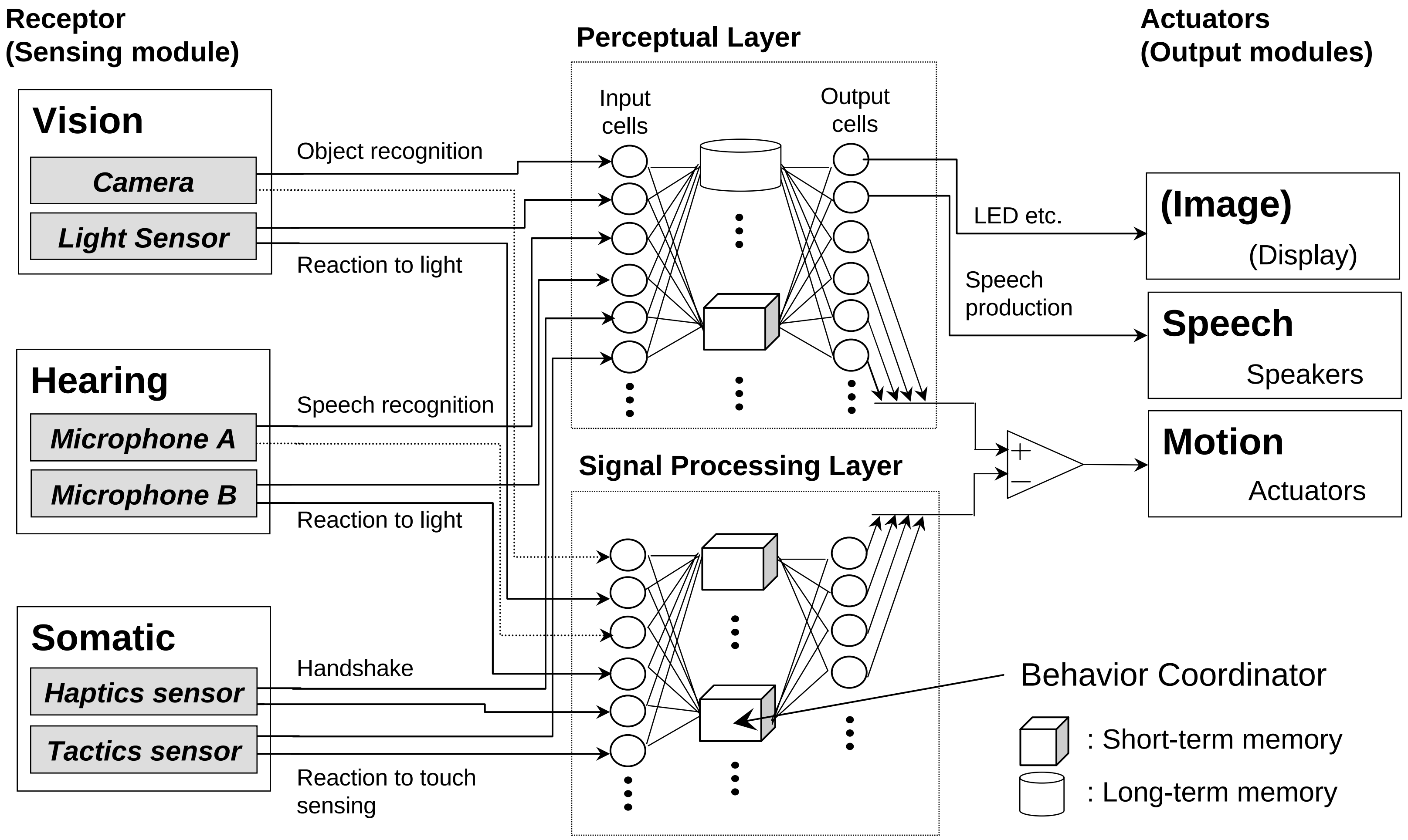


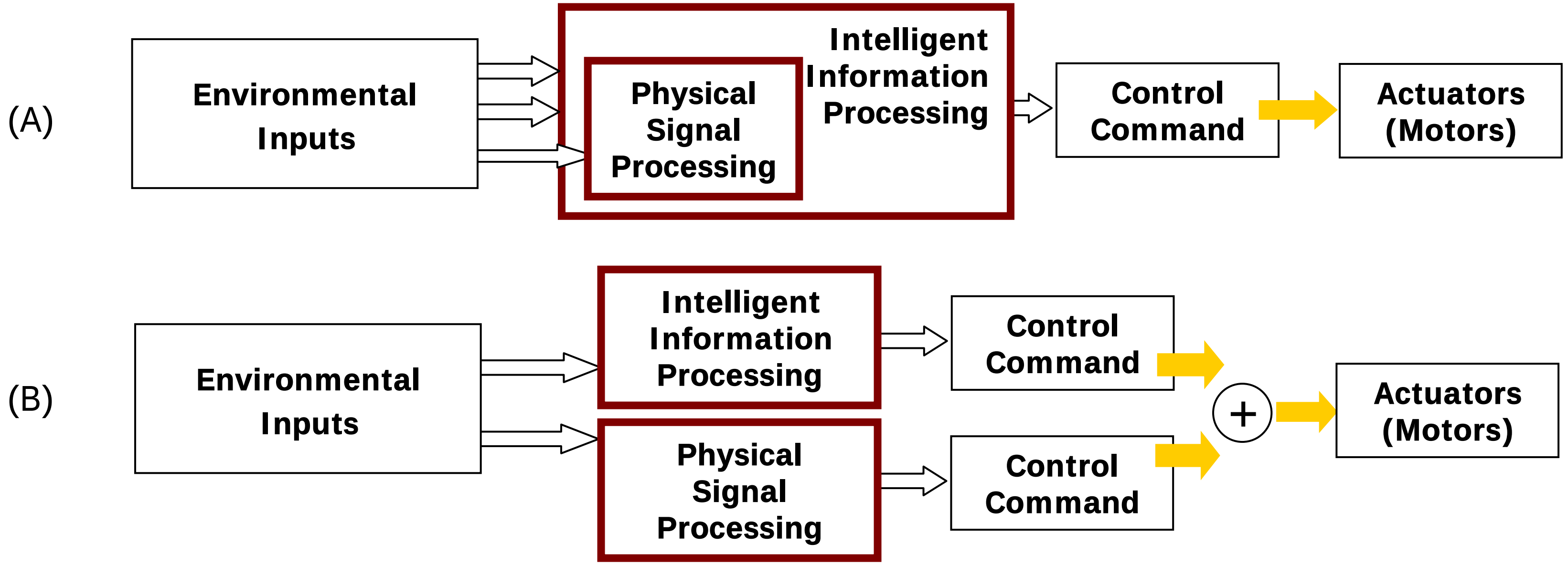
Fig. A Layered model of multimodal human-machine communication

Autonomous Humanoid Robot "iSHA"



Autonomous Humanoid Robot "iSHA"

- A Double-Layered Hierarchical Architecture
  - A diverse-redundant system



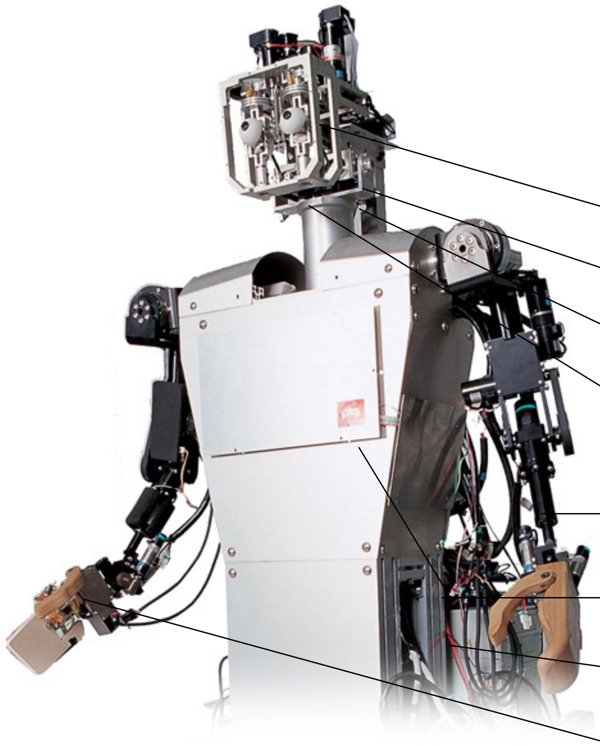
* Independent operating systems

Autonomous Humanoid Robot "iSHA"

- Autonomous and self-subsistent ability
  - On body controller and High-power Inverter
- Extensibility, flexibility and scalability
  - PDP (Parallel Distributed Process)
- Human-scale and Human-like modalities
  - Sight, Hearing, Touch, (smell), (taste)

Robotics Group

Autonomous Humanoid Robot “iSHA”



Upper-torso
(24 degrees-of-freedom)

Binocular vision system

Stereo auditory sensor

Head and neck (12 DOF)

Three Microphones

Arm and Hand (6 DOF each)

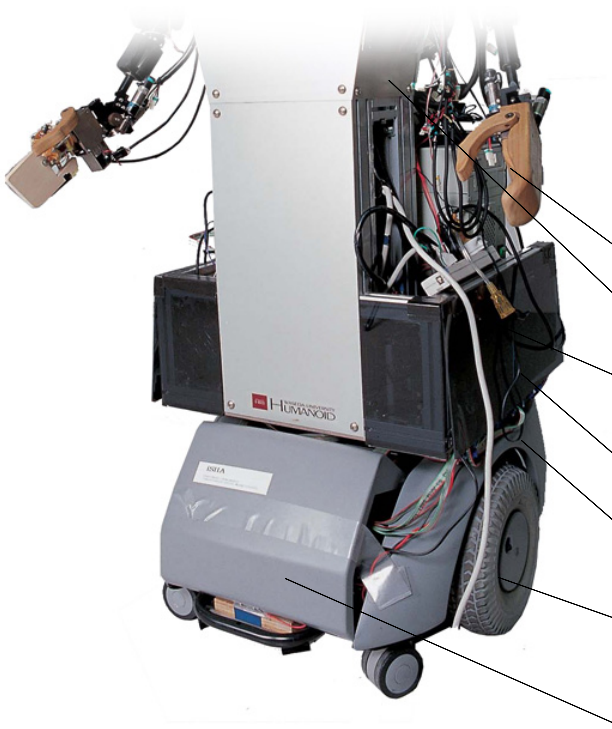
Touch sensing device

Main controller

Hand-shape interface

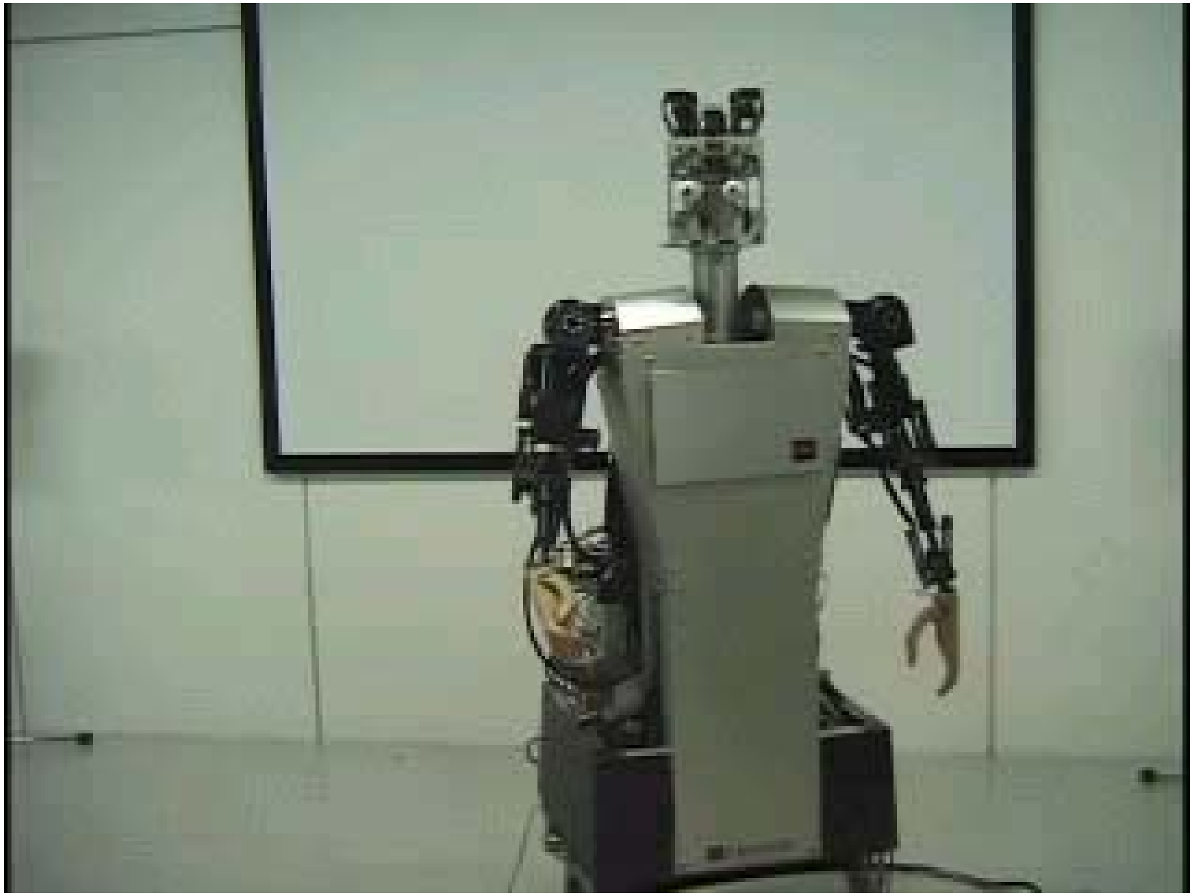
Autonomous Humanoid Robot “iSHA”

Mobile base
(2 degrees-of-freedom)



Two built-in computers
Motor control modules
Motor control modules B (x20)
High-power AC Inverter (1100W)
Built-in rechargeable Pb-battery (24V)
Wheelchair locomotion
Motor control modules C (x6)

Autonomous Humanoid Robot “iSHA”



- Reactions to tactile sensing - touch sensory devices
- Handshaking and human following
- Object tracking and reaching
- Reactions to auditory sensing
- Speech recognition/synthesis

Navigation robot - Bugnoid

- Environment recognition and map building
  - Path-planning in an unknown environment
  - Autonomously build a useful map in a short time

- Recognition of Dynamic Environment
  - Integration of human/environment information
    - *Dynamic* environment: human existence
    - *Static* environment: non-human existence

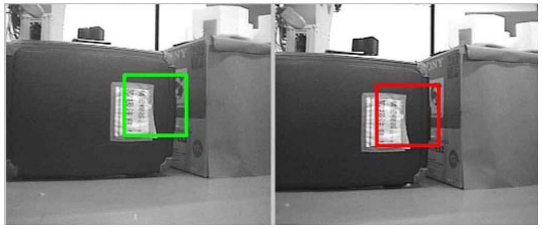
Navigation robot - Bugnoid

Robot Vision System

Omni-directional Camera

Estimation of the robot's position

Binocular Vision



Stereo measurement

Bugnoid

Navigation robot - Bugnoid

Robotics Group
SHALAB

Approaches to make a machine with KOKORO

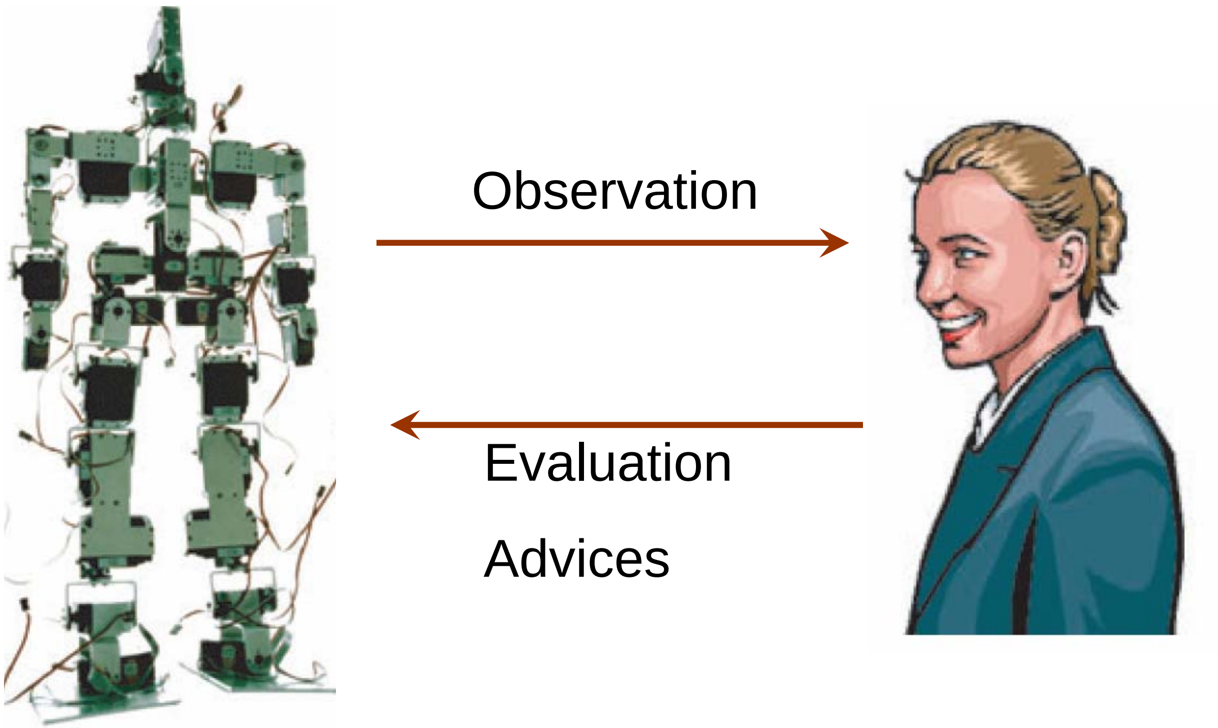
- Top down
  - Imitate human/creature behavior that looks to have KOKORO
  - Design based on knowledge

- Bottom up
  - Make seeds and design the environment
  - Expect their growth

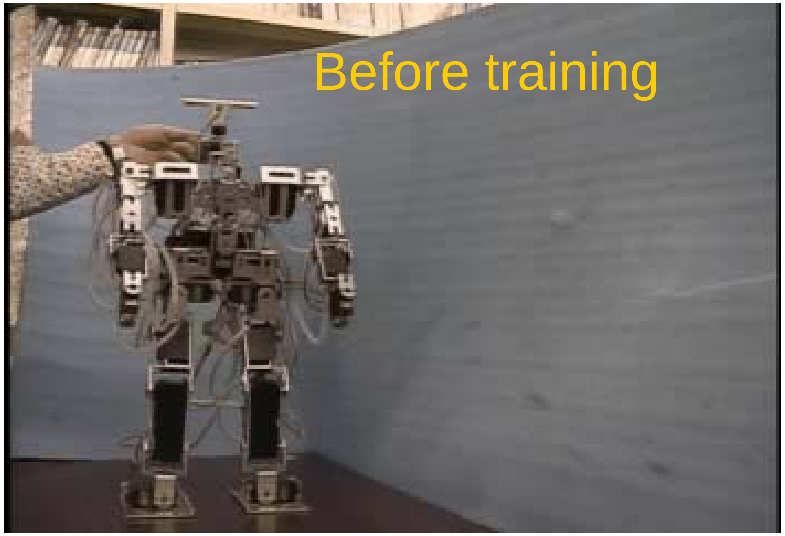
Future Directions – long range-

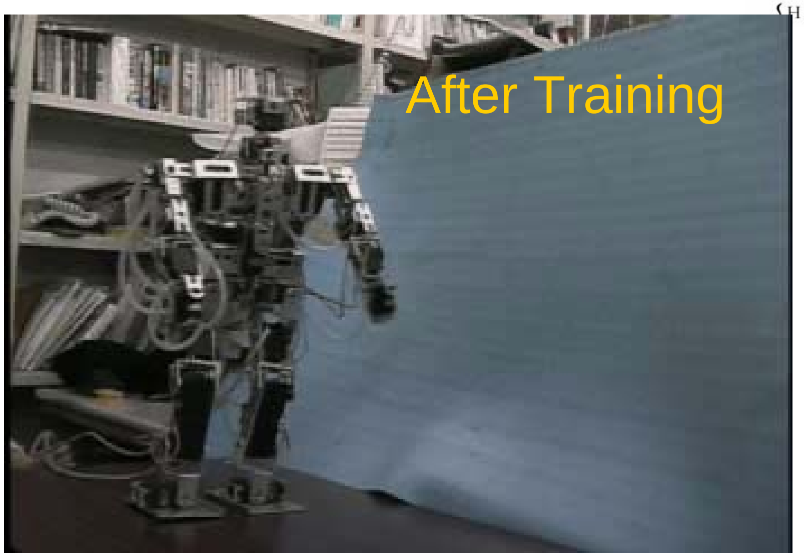
- Software: Beyond "Programming"
  - Learning in real world
  - Knowledge acquisition

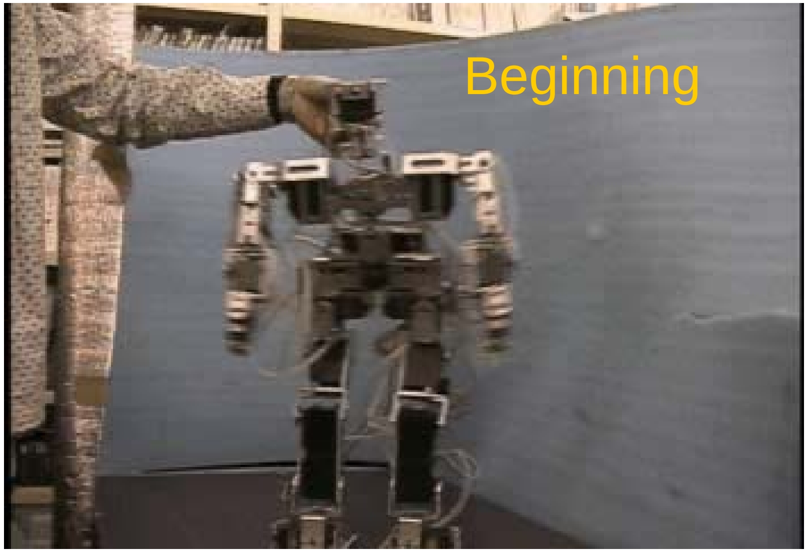
Subjective-Evaluation Based Teaching Scheme

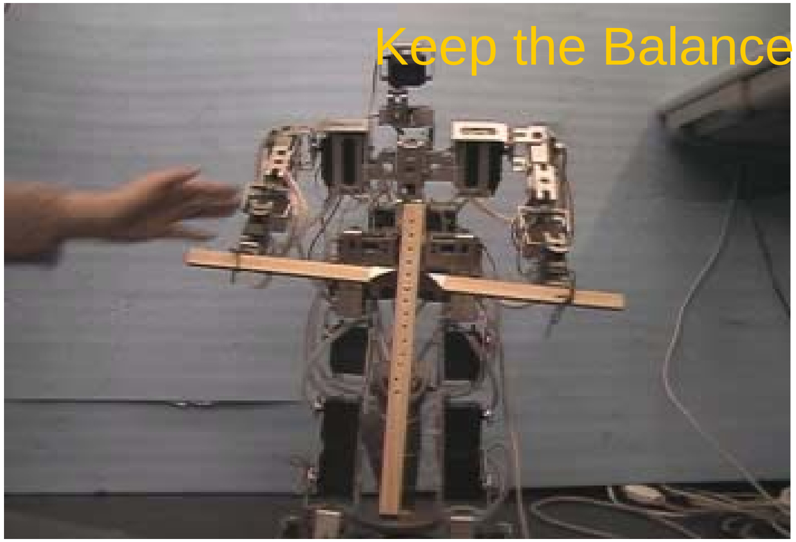


Coaching a robot for motion





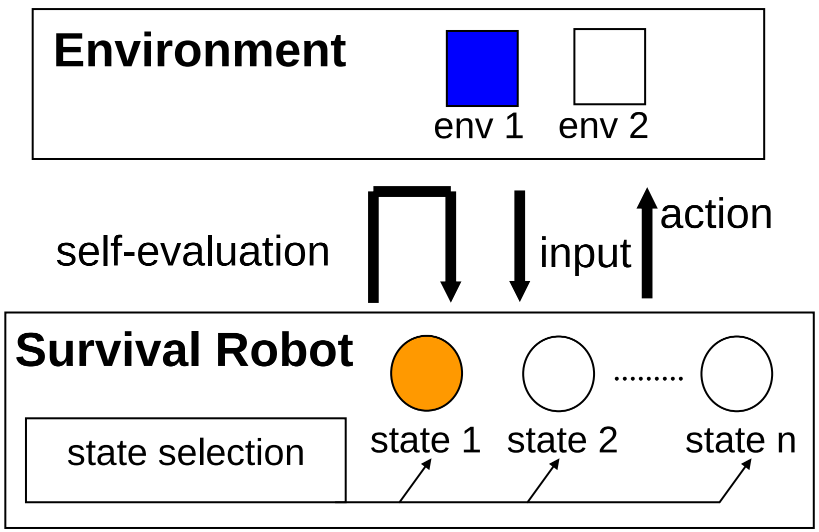




Artificial Creatures

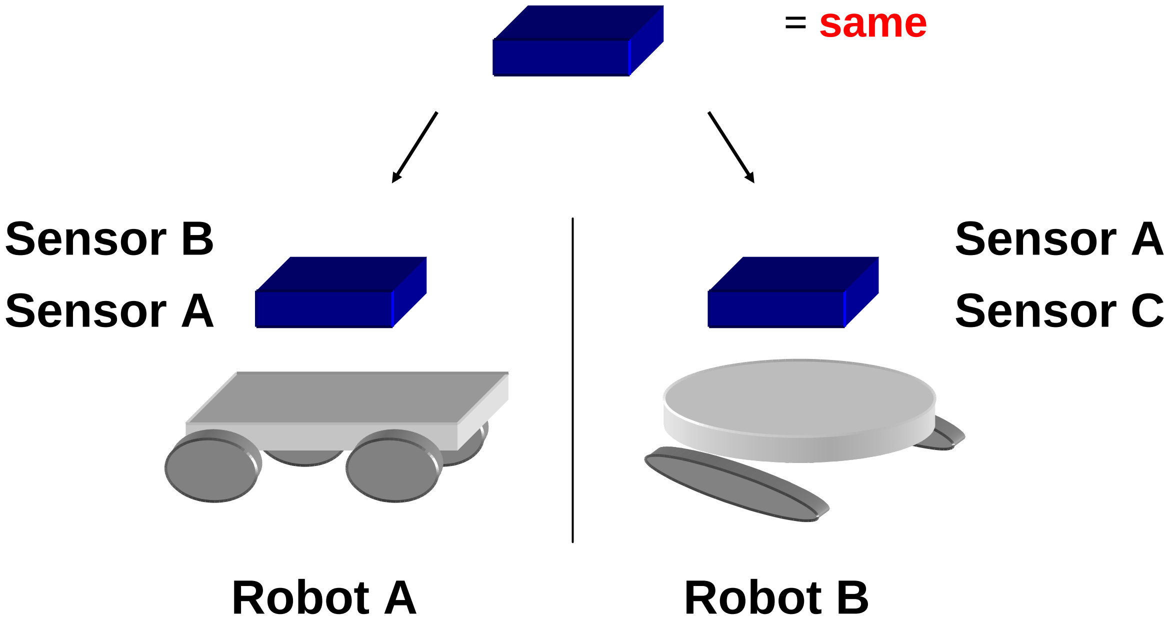
- **Robot must have motivation to exist !**
- **Most creatures can survive guided by their own decision-making scheme with several autonomous functions and adaptation mechanisms under an unknown environment.**

- **Evolutional robotics**

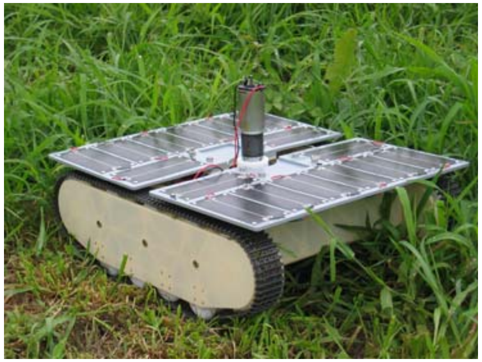


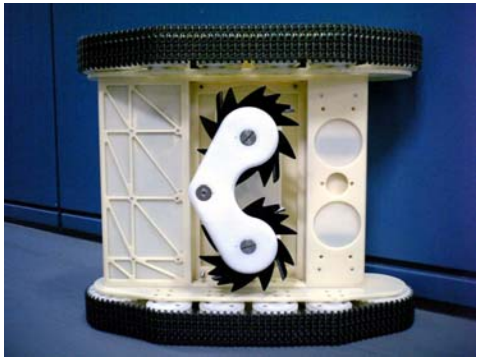
Autonomous Adaptation

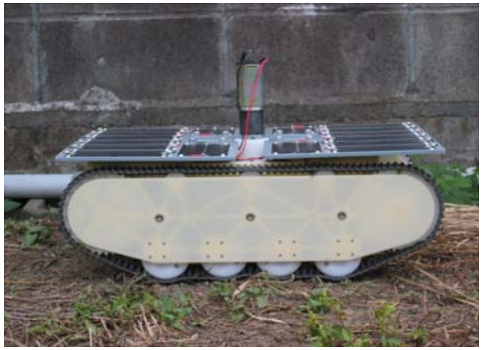
to the environment and self changing



Energy Self-Support Autonomous Mowing Robot

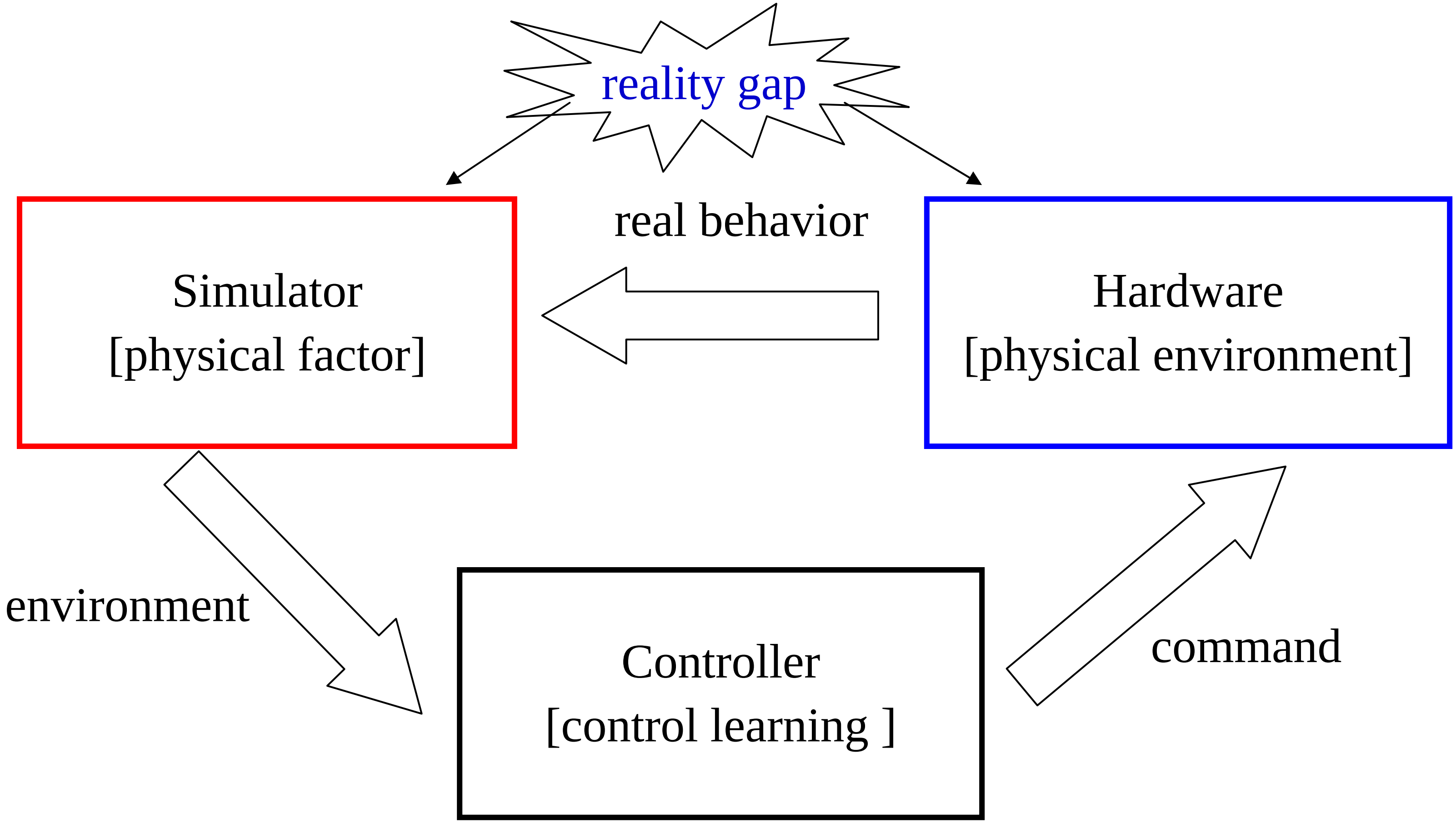






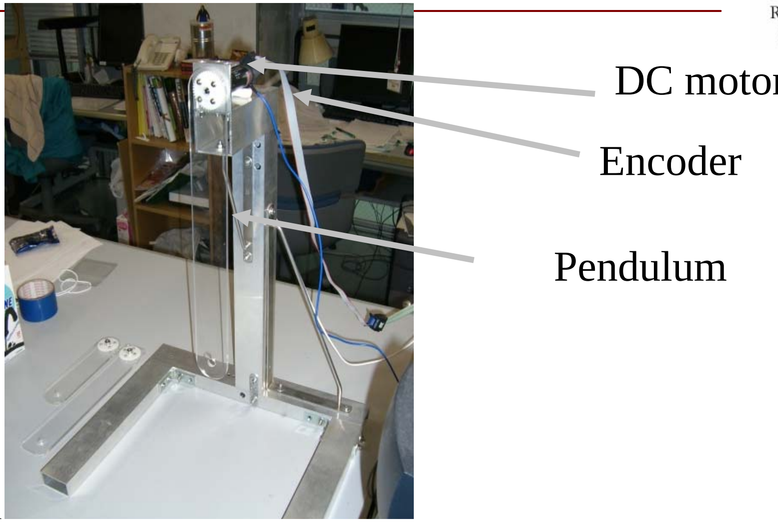
Knowledge Acquisition and Learning

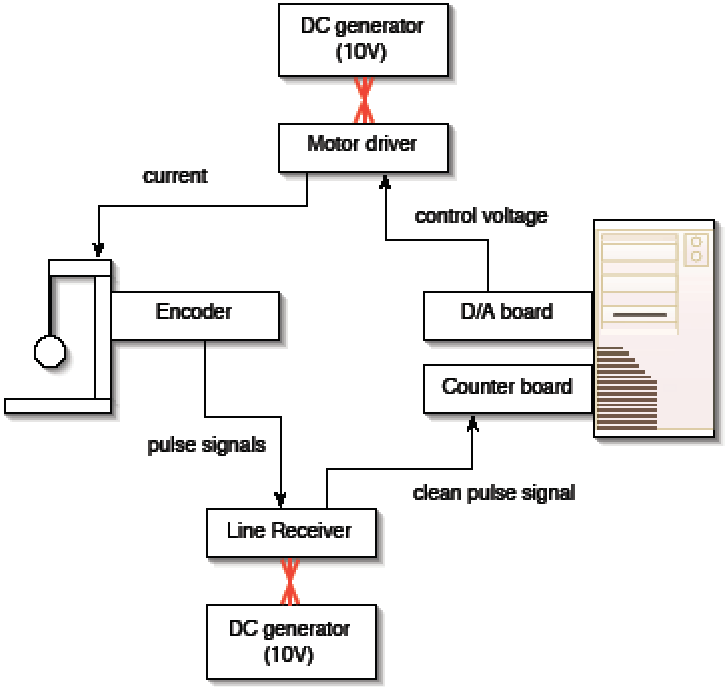
- Hybridization strategy



Hardware system

- DC motor (RE25 maxon)
  - motor free (passive)
- Encoder (HEDL 5540 maxon)
  - 500 count, 3channel
  - line receiver (SN 75175)
- Counter board (PCI-6204 inter
  - differential phase mode
- Pendulum
  - material: acrylic
  - w:50 h:400 d:5 [mm]
  - weight: 125[g]





Non-parametric Approach

- Use of Neural Networks for modeling of unknown system
- Experiments with real machine

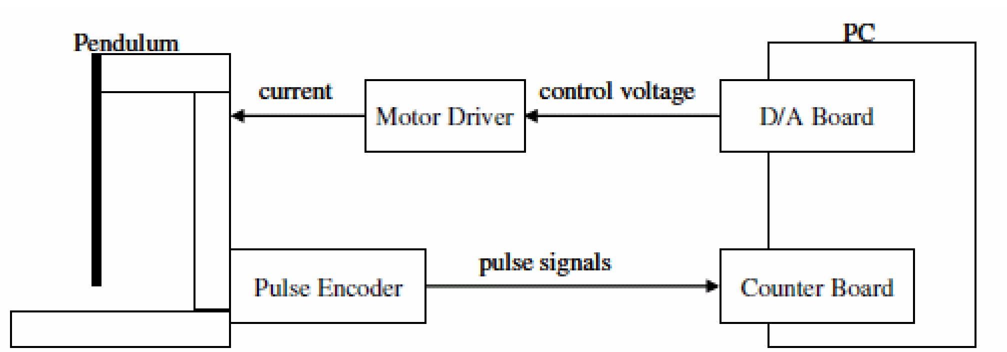


Fig.3 Setup of pendulum system

$$L\ddot{\theta}+\alpha\dot{\theta}+mgl\sin\theta=0$$

Mapping Function $f(\theta,\ \omega)$

$$\theta,\ \omega \quad \Rightarrow \quad \Delta\theta,\ \Delta\omega$$

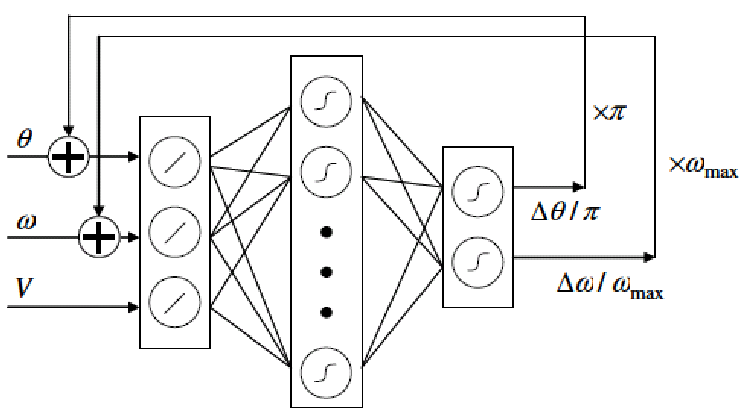


Fig.4 Pendulum simulator with MLP

Result of Back Propagation Learning

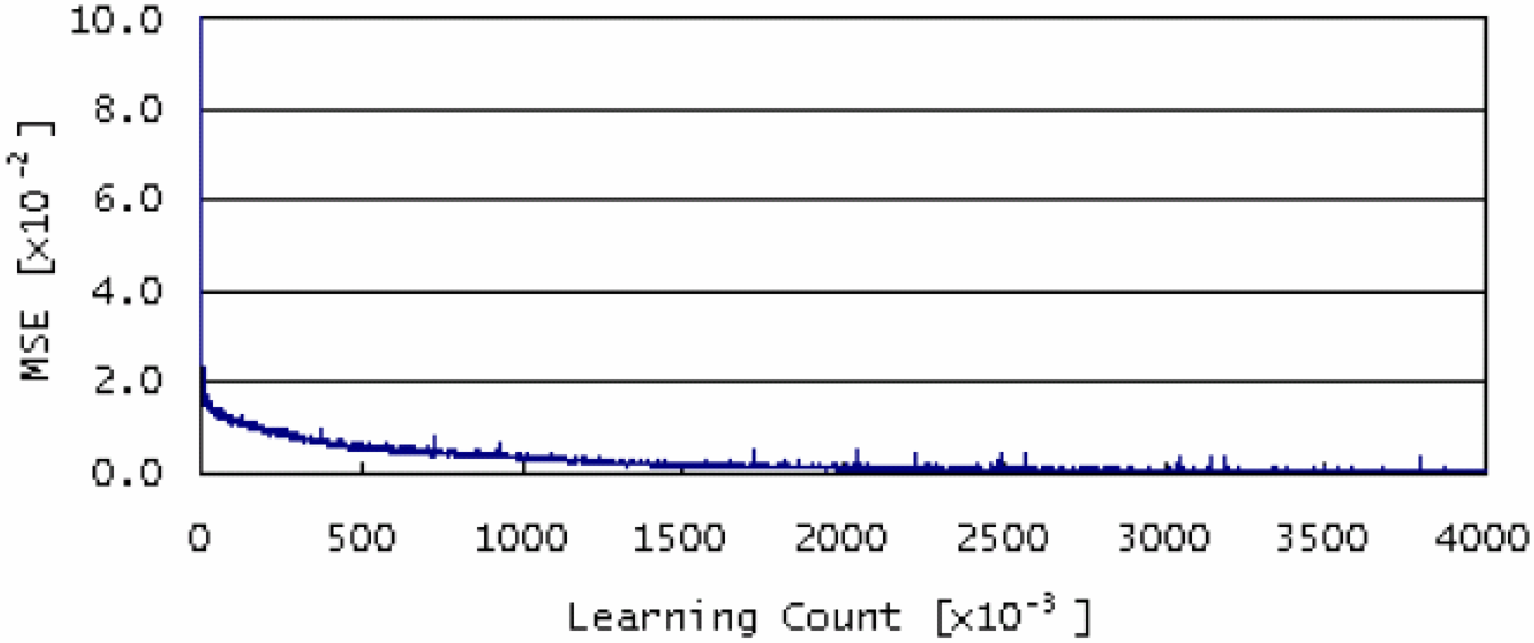
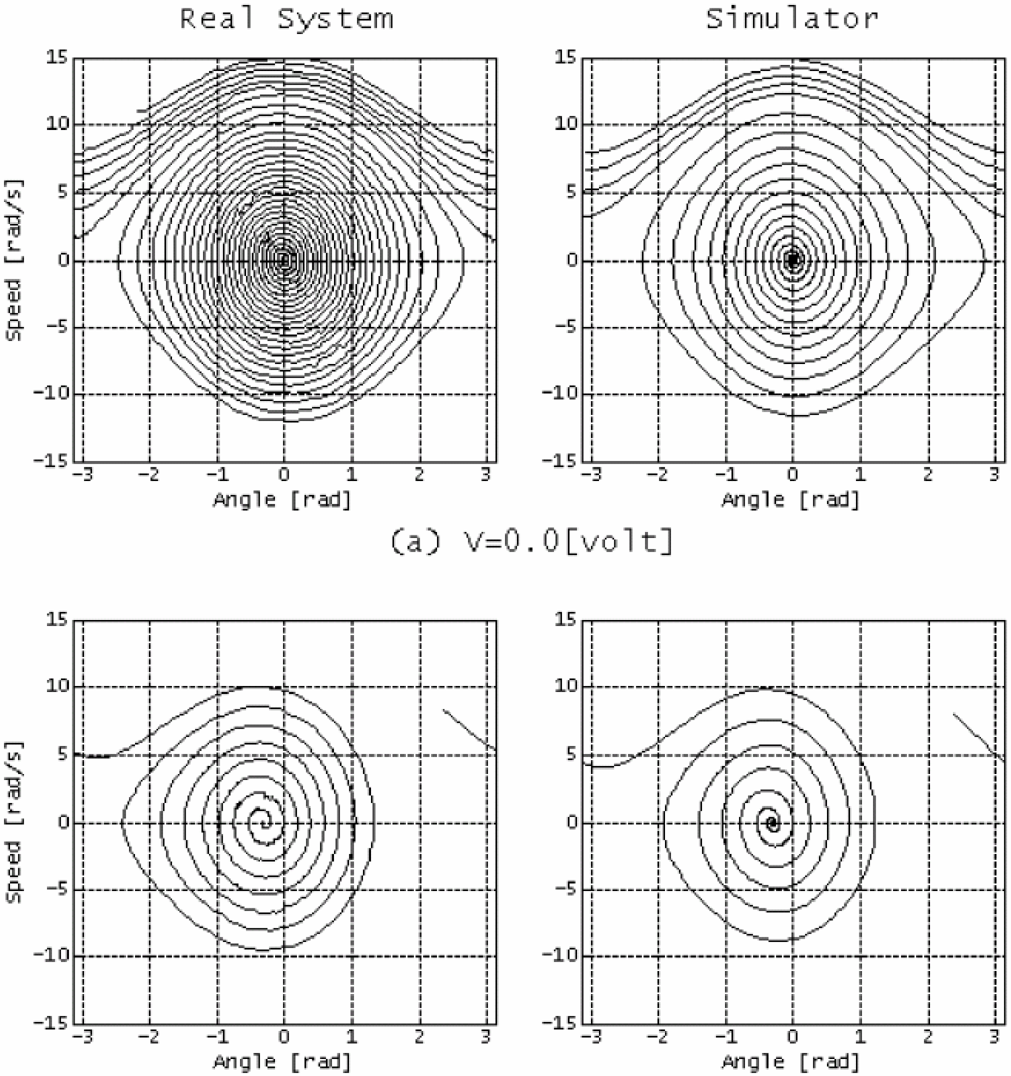


Fig.5 Result of simulator building learning

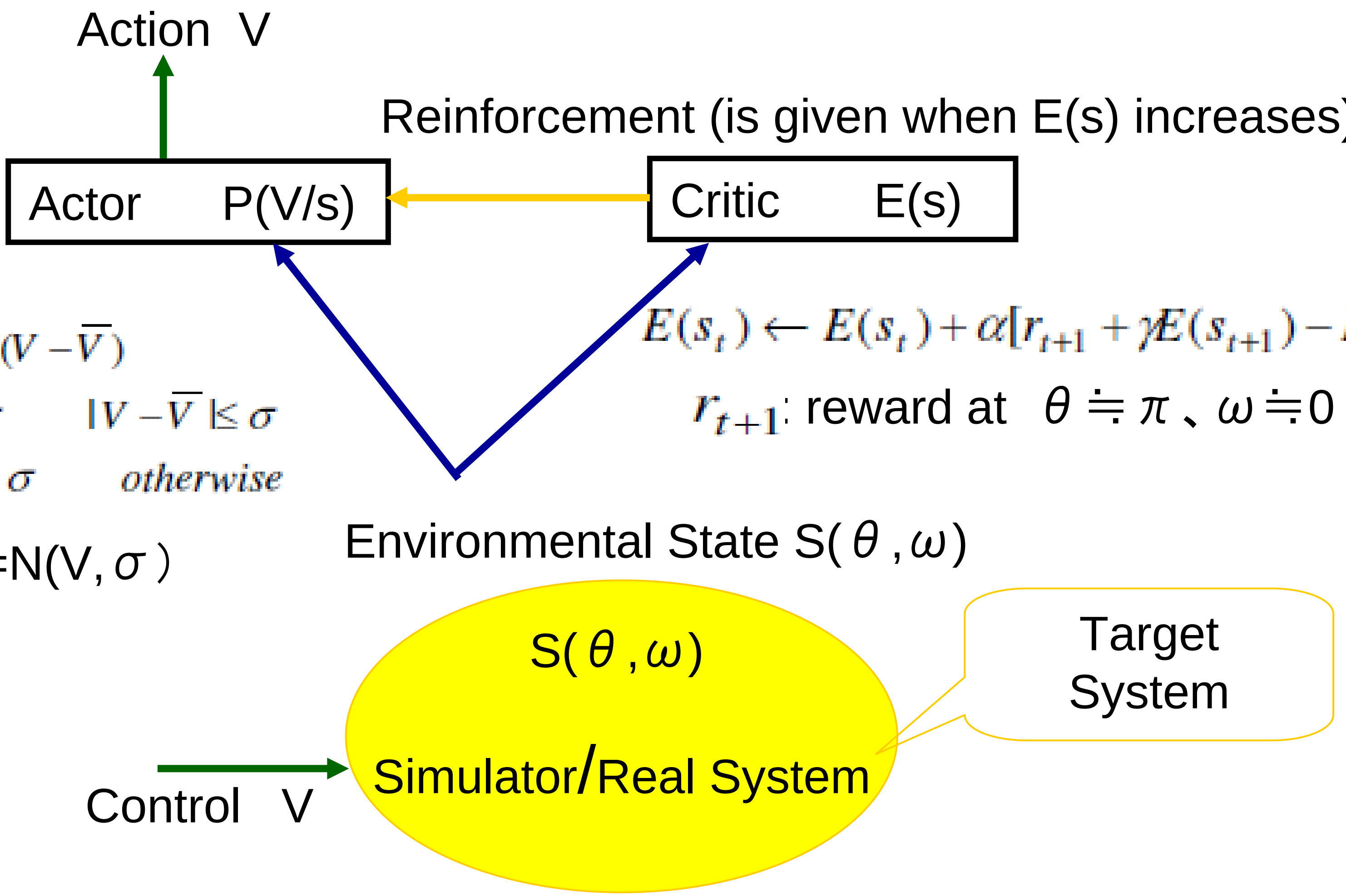
Phase Space Trajectory after Learning



(a) V=0.0[volt]

(b) V=-0.6[volt]

Reinforcement learning for Control



$$E(s_t) \leftarrow E(s_t) + \alpha[r_{t+1} + \gamma E(s_{t+1}) - E(s_t)]$$

r_{t+1}: reward at $\theta \fallingdotseq \pi$ 、$\omega \fallingdotseq 0$

$$\bar{V} \leftarrow \bar{V} + \alpha(V - \bar{V})$$

$$\sigma \leftarrow \begin{cases} \beta \cdot \sigma & |V - \bar{V}| \leq \sigma \\ \beta^{-1} \cdot \sigma & otherwise \end{cases}$$

P(V/s)=N(V, σ)

Reinforcement Learning Result

- The state parameter space [$-\pi$, π] [$-\omega_{MAX}$, ω_{MAX}] is divided into 20×20 at even intervals and treated as a discrete space.

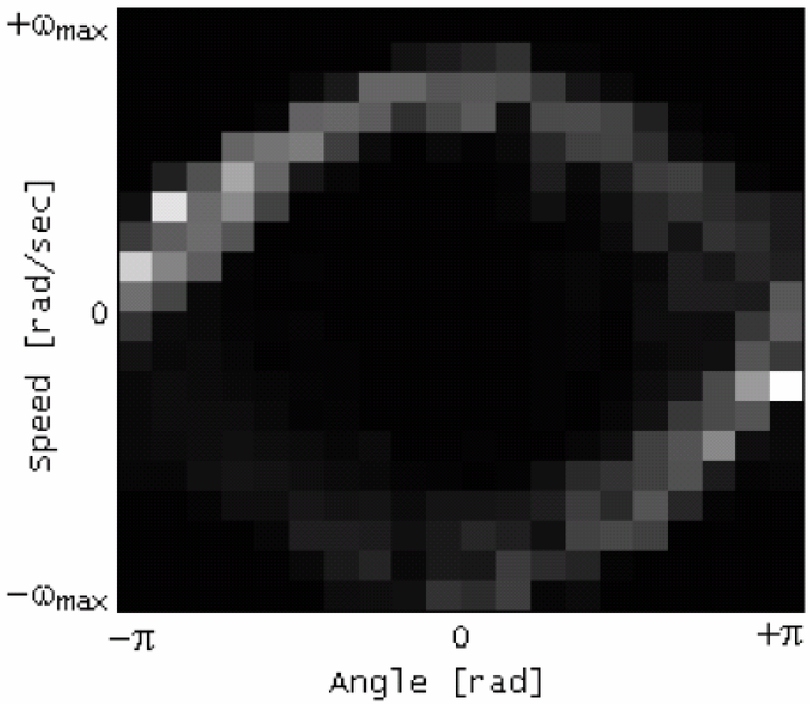


Fig.7 Result of evaluation value in parameter space

Experimental Results

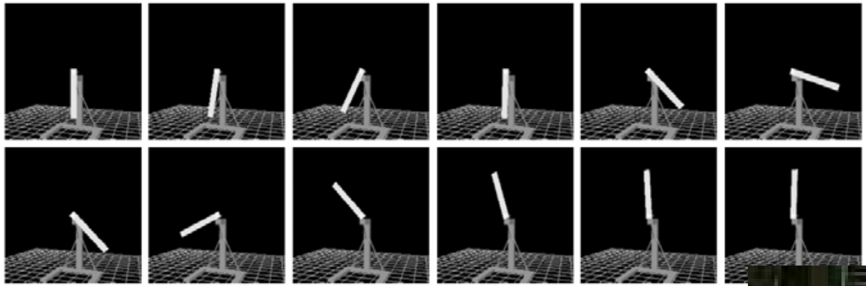


Fig.8 Result of swing-up behavior learning with simulator

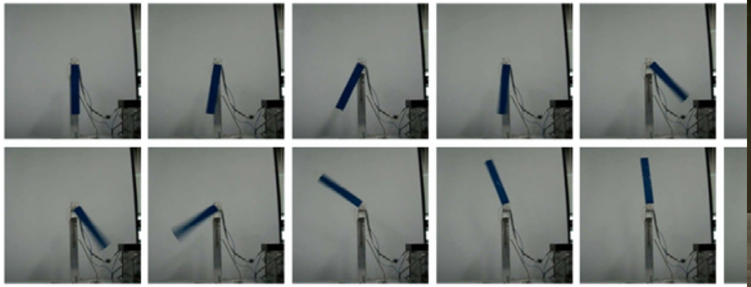


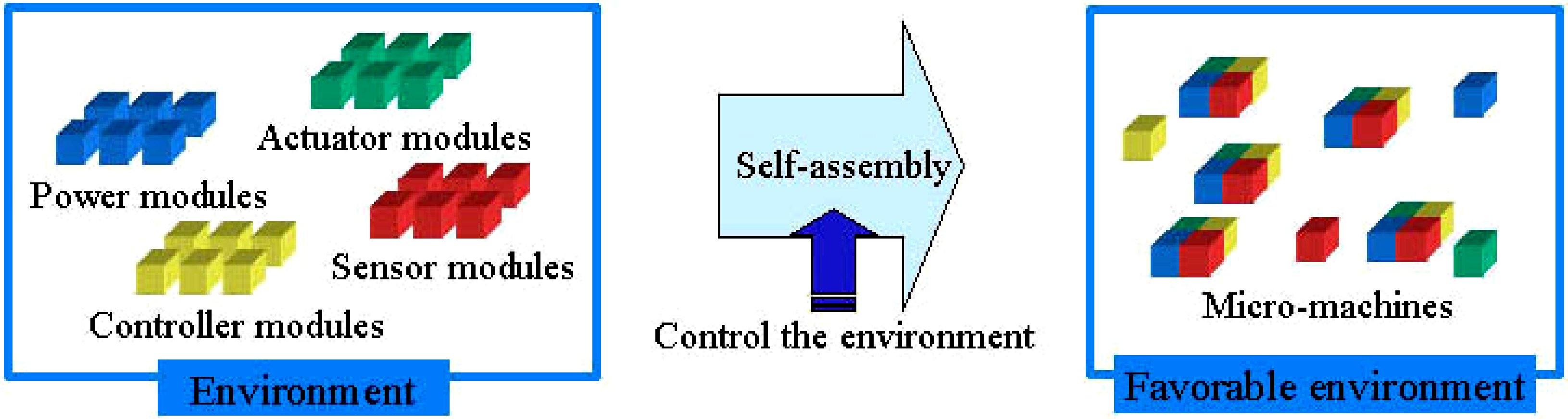
Fig.9 Result of swing-up behavior with real system

Future Directions – long range-

- Software: Beyond “Program”
  - Learning in real world
  - Knowledge acquisition
- Hardware: Beyond “Metal and Si”
  - Extended materials
  - Moleculer computing

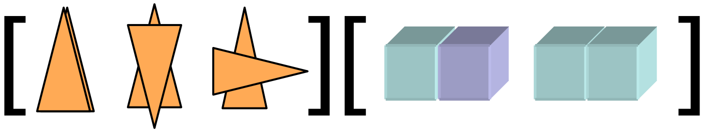
Objectives

■ To realize a novel assembly method taking insights from the self-assembly mechanism of nature.



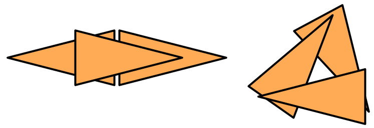
"Selectivity" of components contributes to the yield rate and the assembled structure.

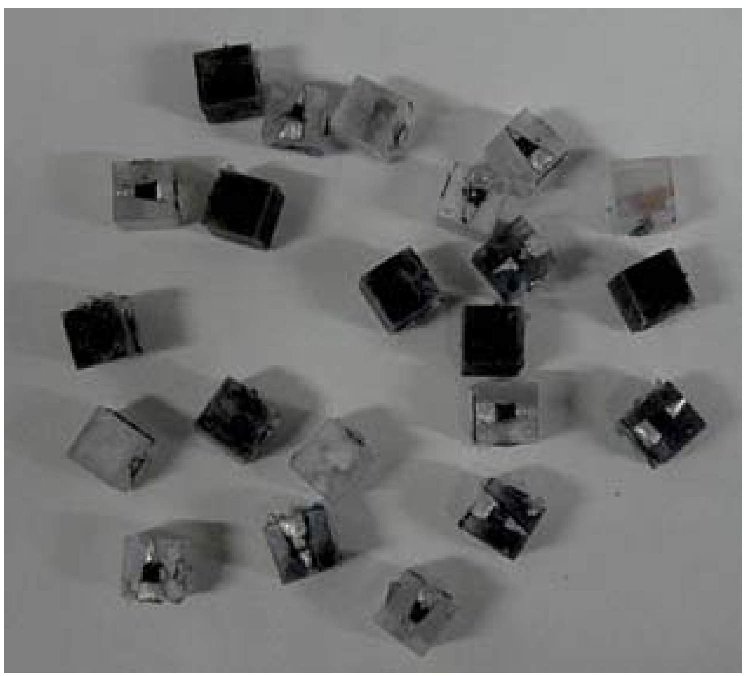
3D self-assembly in liquid solder

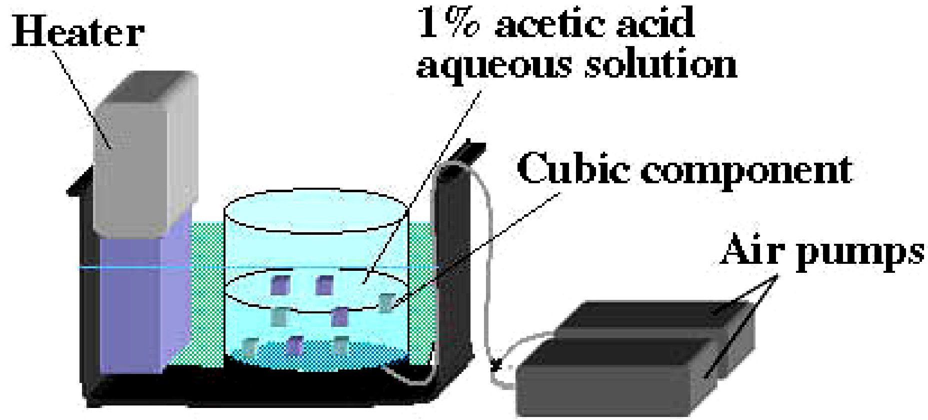


= 6 patterns

The others



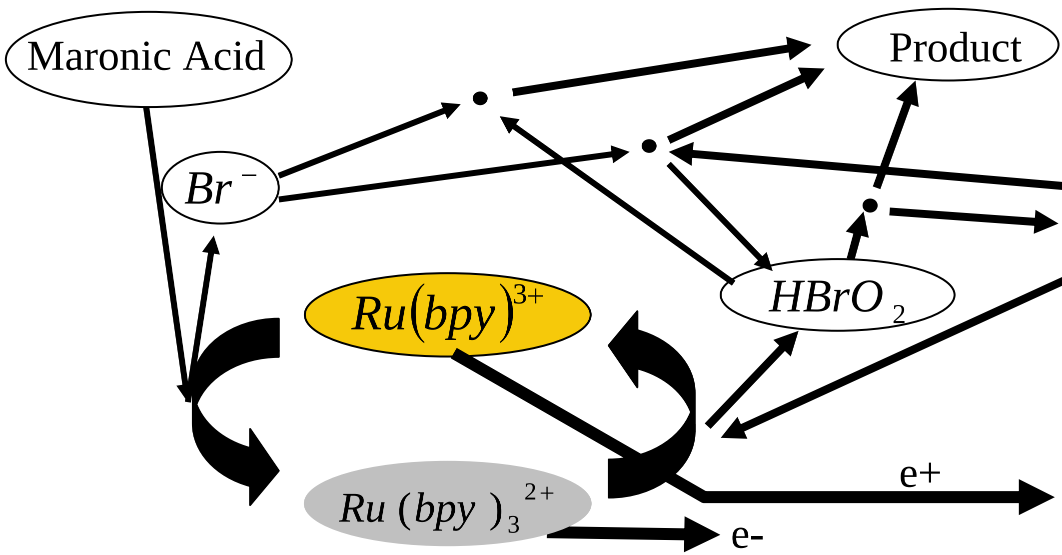




Electro-Static Self-assembly

Charged ceramic balls to combine together autonomously

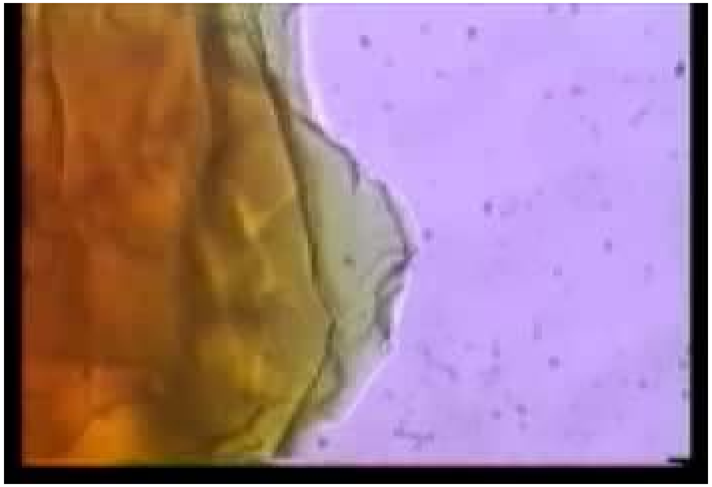
Chemical Circuits



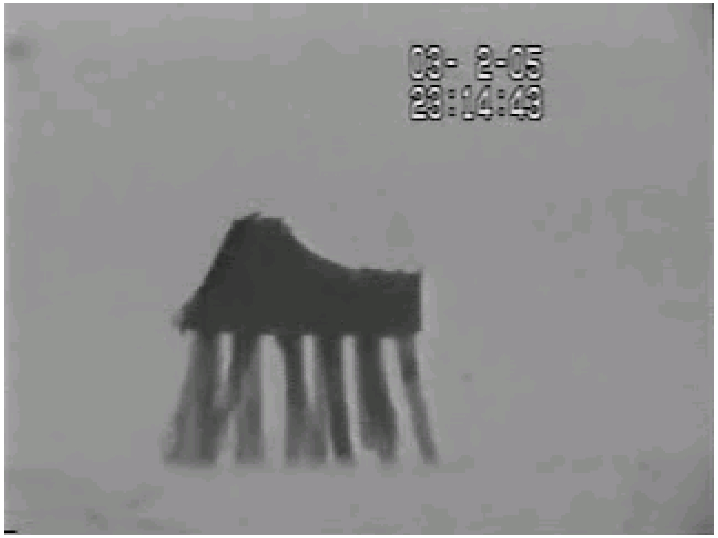
Self-Oscillating Gel with Belousov-Zhabotinsky Reaction

$$2BrO_3^- + 3CH_2(COOH)_2 + 2H^+ \rightarrow 2BrCH(COOH)_2 + 4H_2O + 3CO_2$$

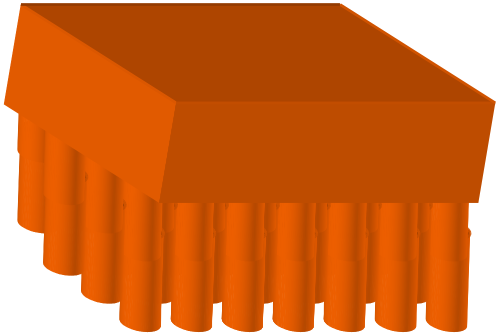
Deswell ←→ Swell



Chemical Robotics



Swell ←→ Deswell



Φ=200 μ m

Future Directions – long range-

- Software: Beyond "Program"
  - Learning in real world
  - Knowledge acquisition
- Hardware: Beyond "Metal and Si"
  - Extended materials
  - Moleculer computing
- Socialware: Beyond "Asimov "
  - How to coexist with autonomous machine ?
  - What is better for our happiness ?

Laws of Robotics by Isaac Asimov

1. A robot may not harm a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by the human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence, as long as such protection does not conflict the First or Second Law.

Human Centered Philosophy

Grow up to be a real partner

I will congratulate if my robot will oppose me because of the conscious of its ego but because not of its fault.

Just as I experienced when my son was in his rebellious stage….

"Not comfortable but it should be pleased as he is going to live his own life !"

"Sooner he will be a wonderful partner that has learned morals."

Science and Engineering

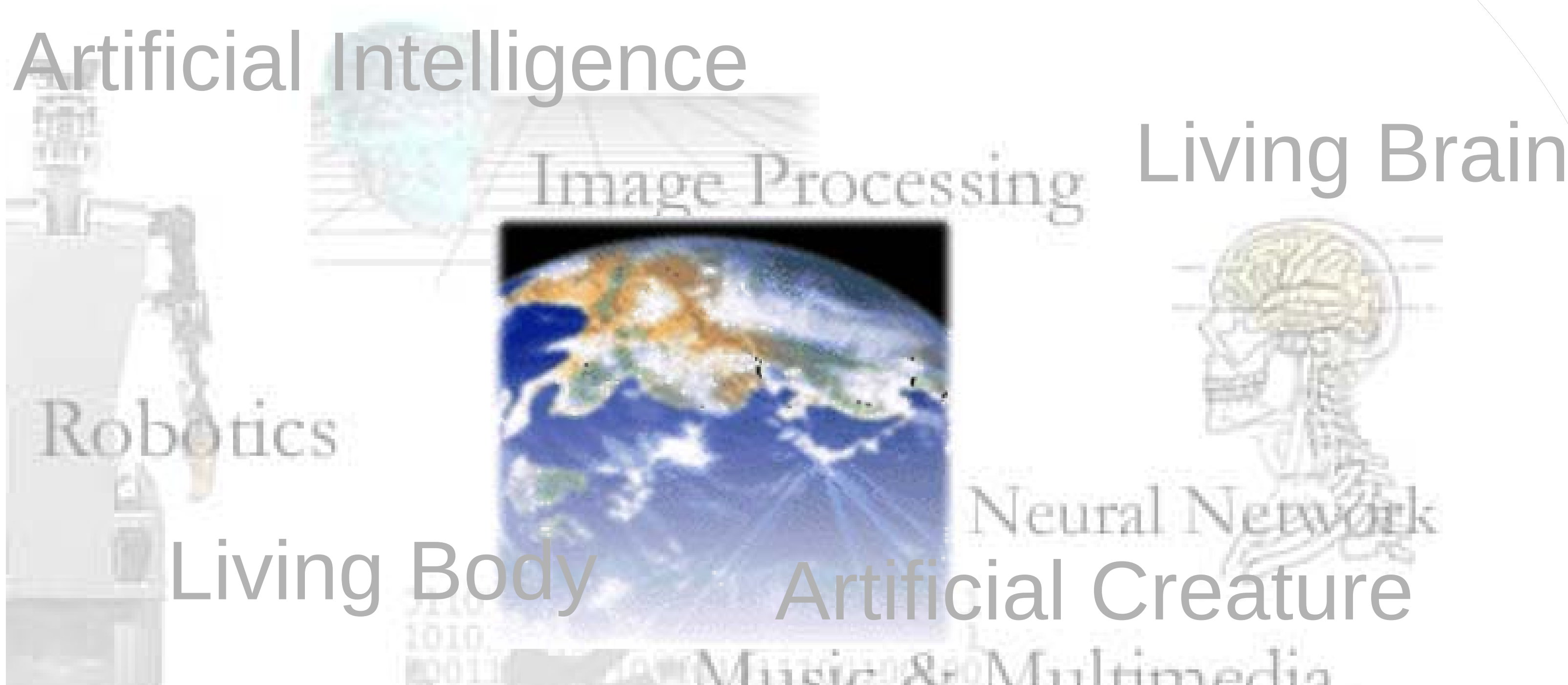
Robotics Group
SHALAB

- Scientific Aproach
  - Analyze to understand
  - Analysis by synthesis, analysis by analysis
  - Understand the past and forecast the future
- Engineering Aproach
  - Synthesize to know
  - Synthesis by analysis, synthesis by synthesis
  - Create the future
- It may not be possible to understand KOKORO completely.
- It is, however, possible to create KOKORO.

Human Evolution beyond Humanism

We need a new philosophy

to create a robot that is real partner



The future is not allowed to see but opened for creation.