Topics on Artificial Intelligence and Robotics

Pitoyo Hartono

School of Engineering, Chukyo University

Institute for Human Robot Co-Creation, Waseda University

Where do I work ?

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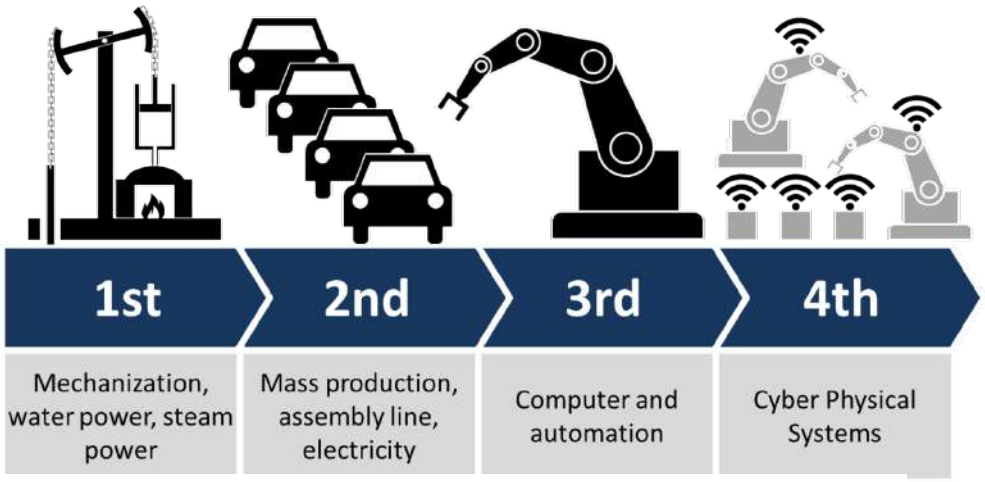
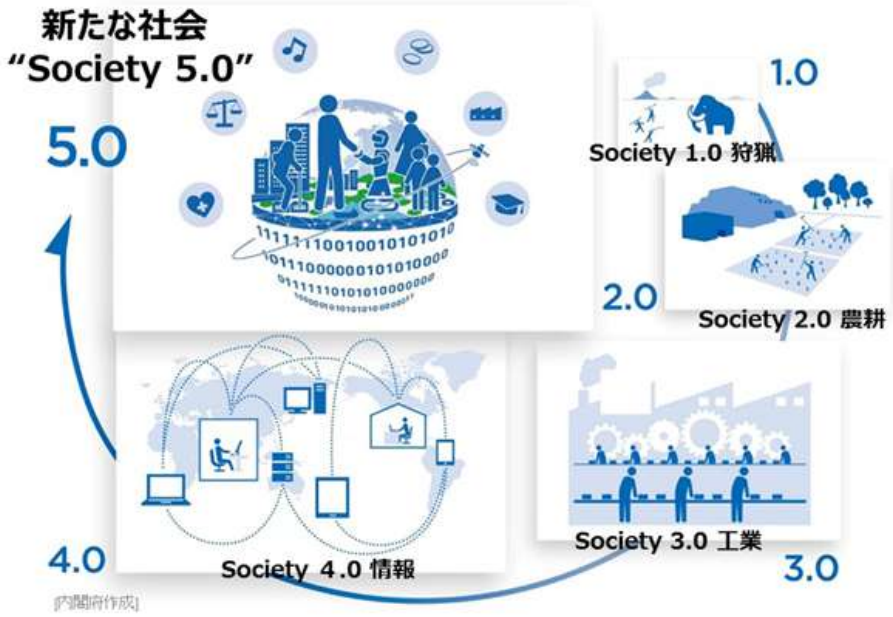
Technological and Societal Revolutions



Industry 4.0



Society 5.0

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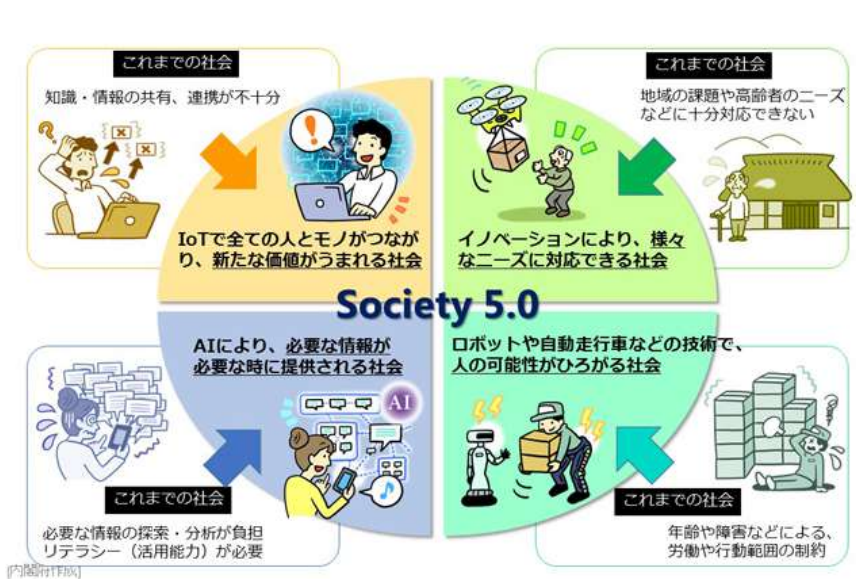
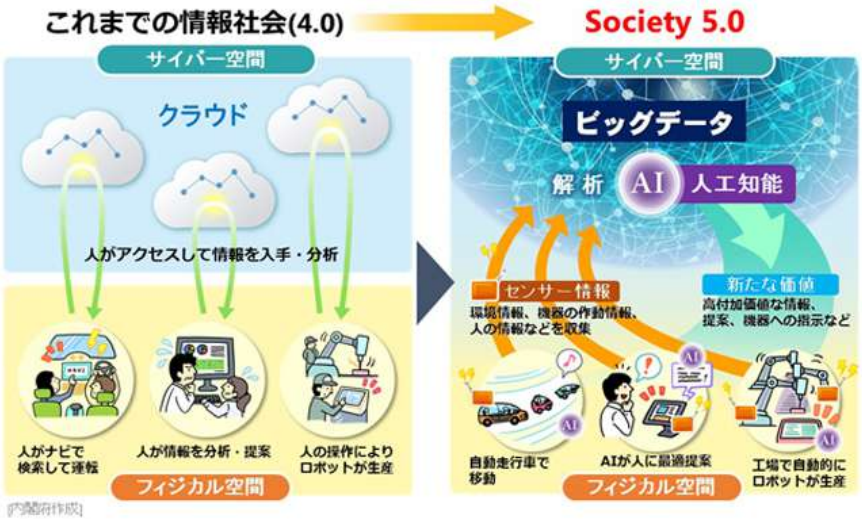
Technological and Societal Revolutions



Kentaro Yoshifuji (吉藤健太朗)



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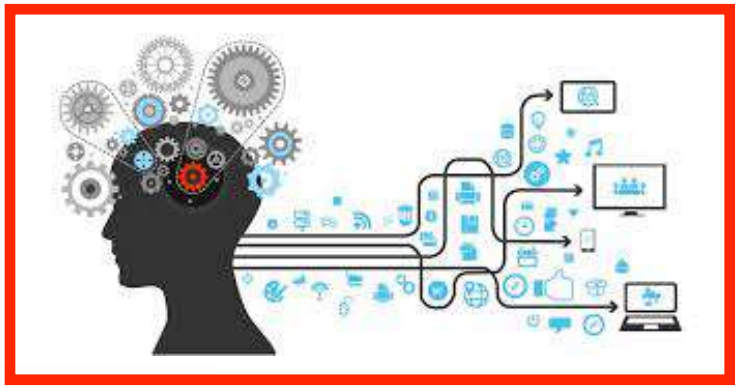
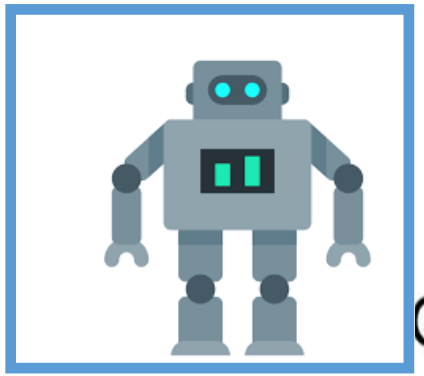
Technological and Societal Revolutions





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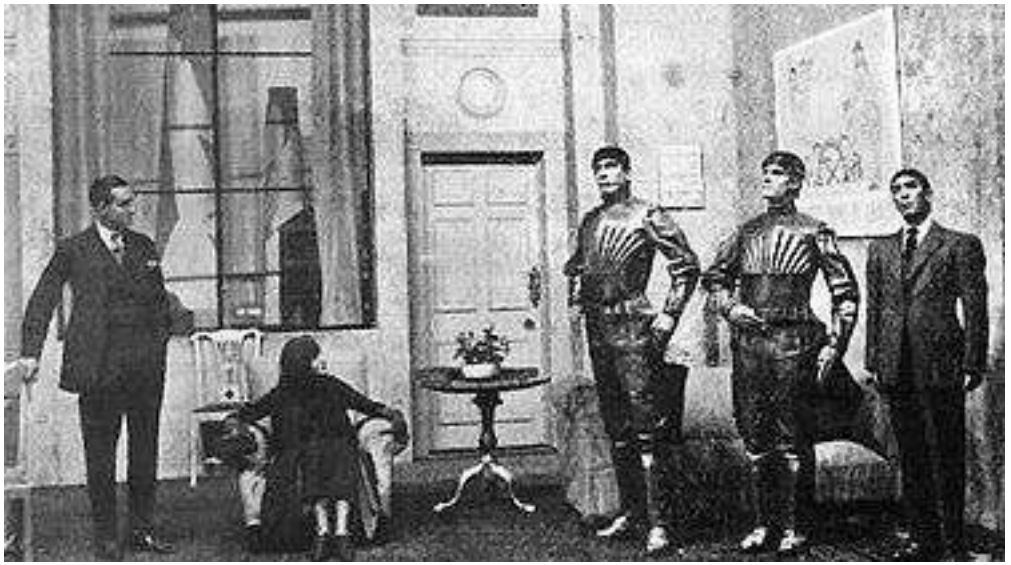
History of Robots

Karel Capek
(1890-1938)

Rossum's Universal Robot (RUR)



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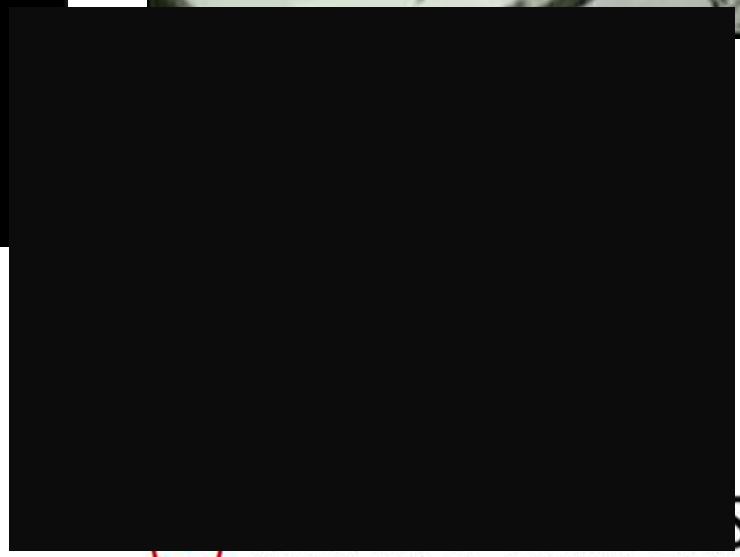
History of Robots

70's

80's

18th century

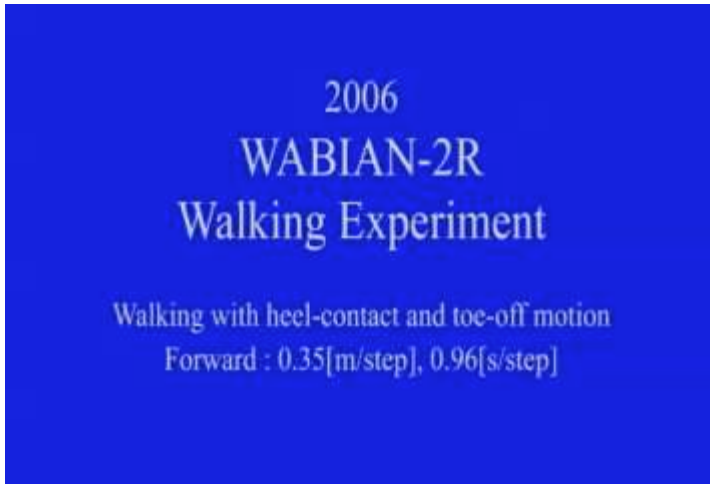
90's

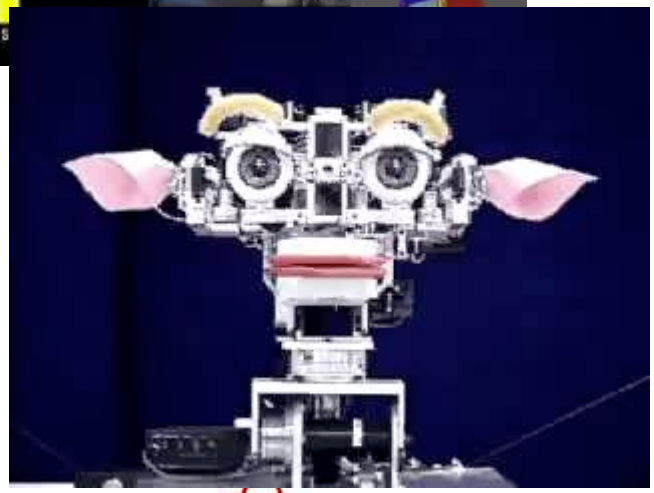


200

History of Robots

2000's





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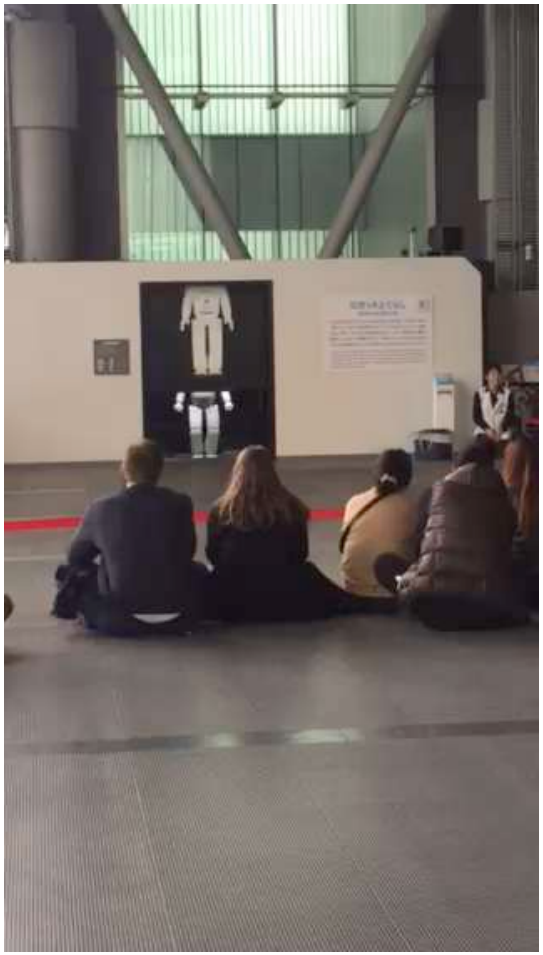
History of Robots

2000's



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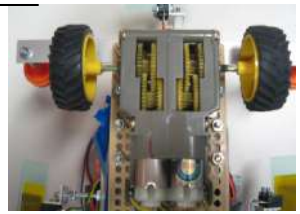
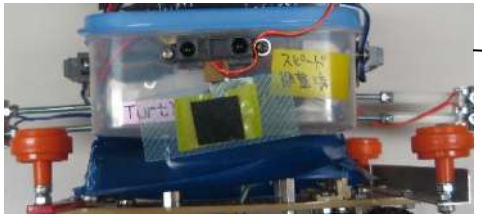
Complexity of Building Robots

actuators



sensor

mechanical parts



power

controller

```
%get class data and teacher data
for i=1:pattern_n
    t(i,1)=fscanf(fclass,'%d',1);  % class
    tcr(i,:) = fscanf(fteach,'%d',out_n);
end

for i=1:target
    err_log(i) = 0;
    err_son_log(i)=0;
end

for ex=1:experiment

  % initialize map
for i=1:size_x
    for j=1:size_y
        neuron(i,j).weight = rand([1 in_n]) * 1-0.5;
        neuron(i,j).pos_x = i;
        neuron(i,j).pos_y = j;
        neuron(i,j).weight_out = rand([1 out_n]) * 1-0.5;
    end
end
```

program

http://www.shalab.phys.waseda.ac.jp/robotics-j.html

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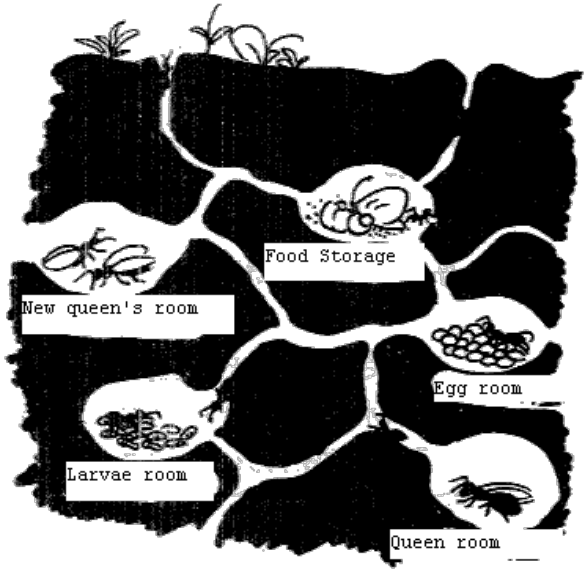
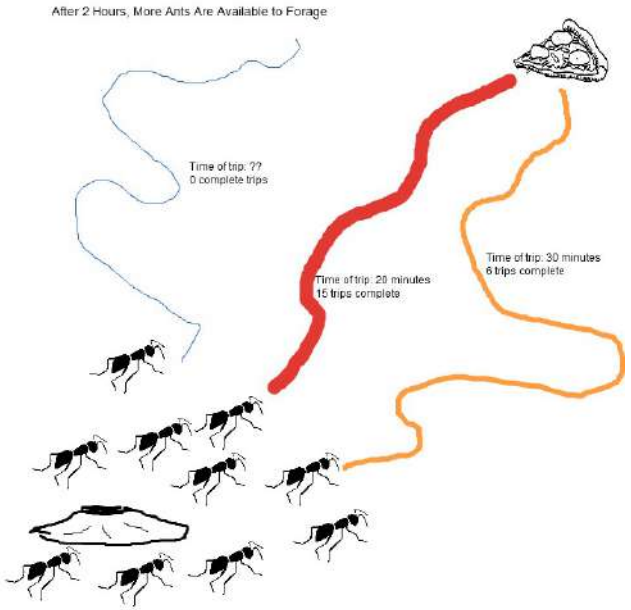
In nature …

Florida State University



http://homepage3.nifty.com/Kume/naru/040/naru040e.html



http://www.bigvisible.com/2011/07/clockware-and-swarmware/

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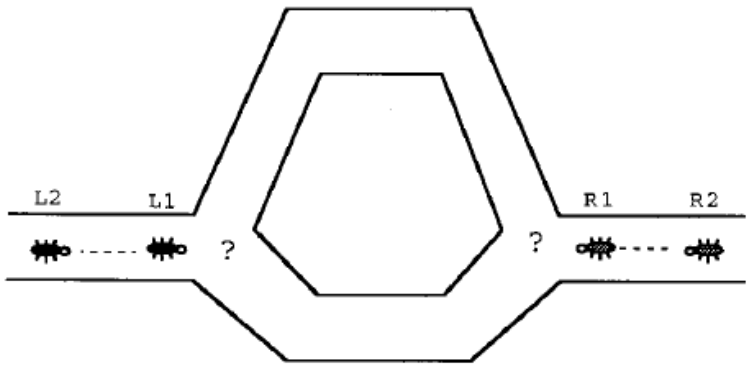
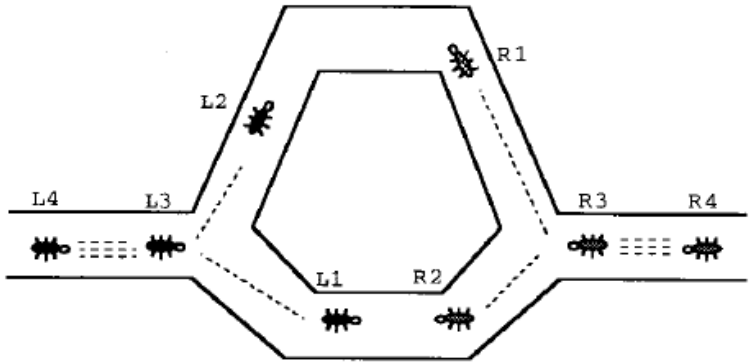
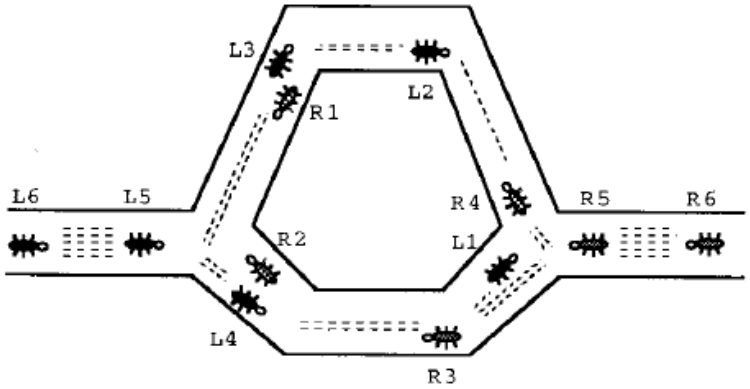
In nature …



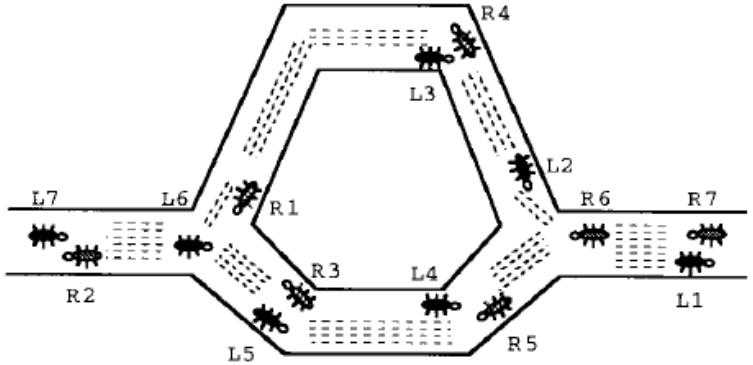
(a)



(b)



(c)



(d)

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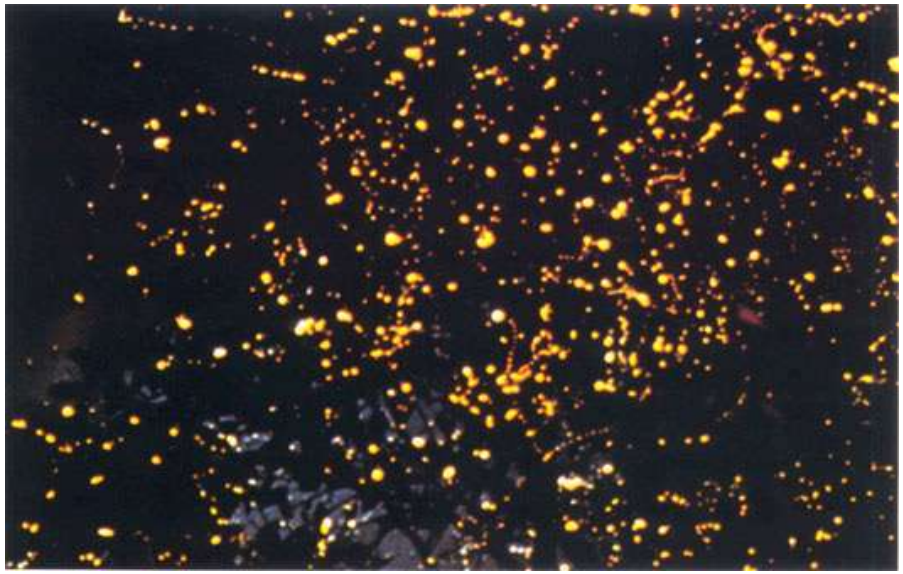
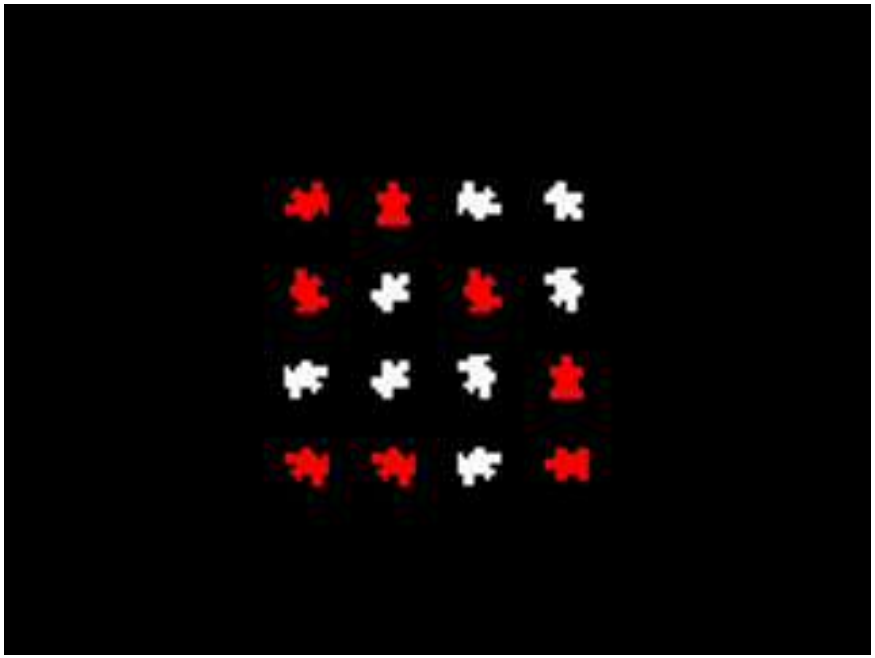
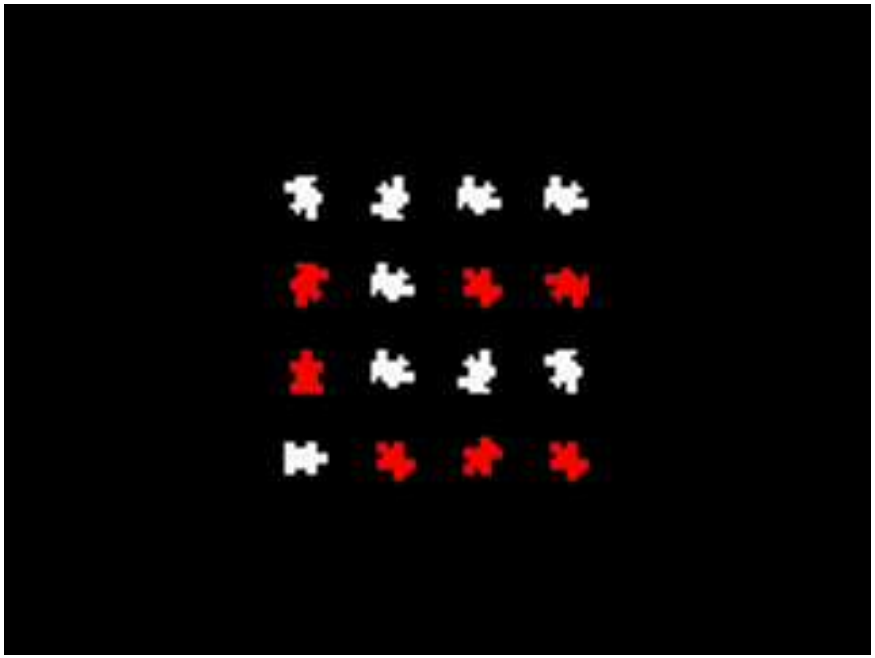
In nature …



In nature …

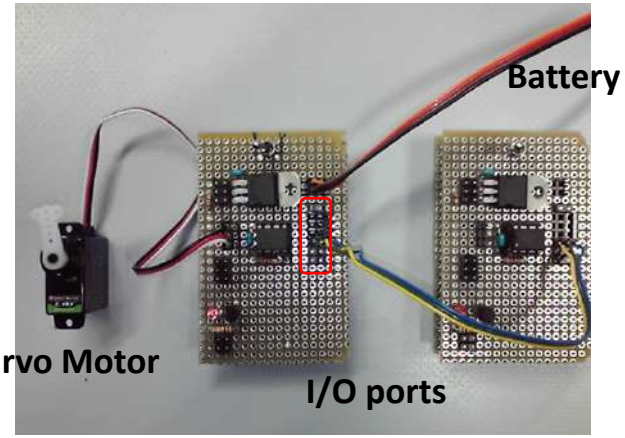
Mathematical Model of Fireflies



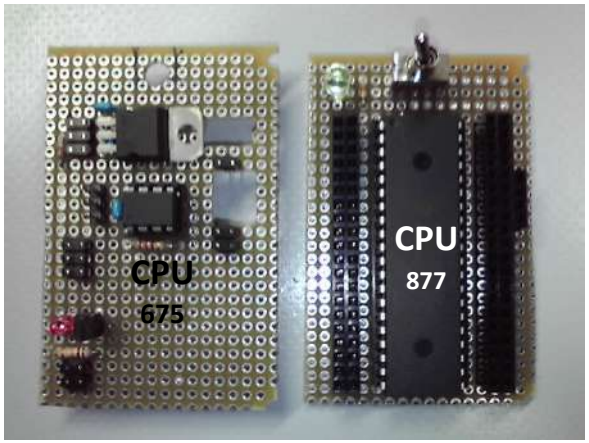


Self-Organization in Robotics

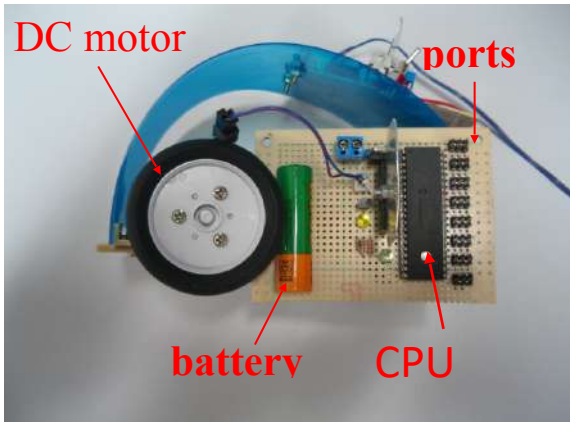
Modular Robots



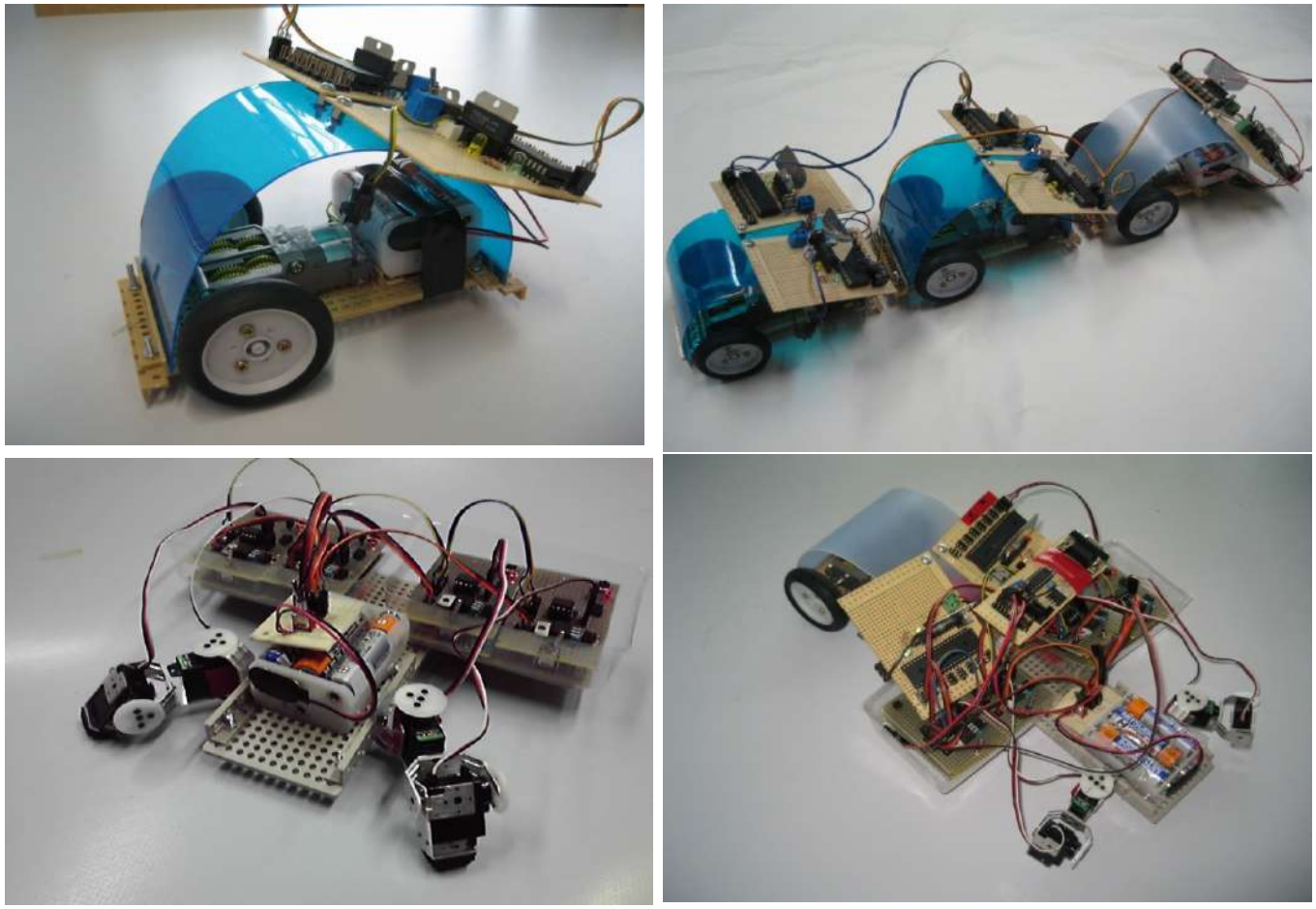
- Small power resources
- Small calculations resources
- Simple Sensors
- Simple Actuators
- Local Communication



hardware module



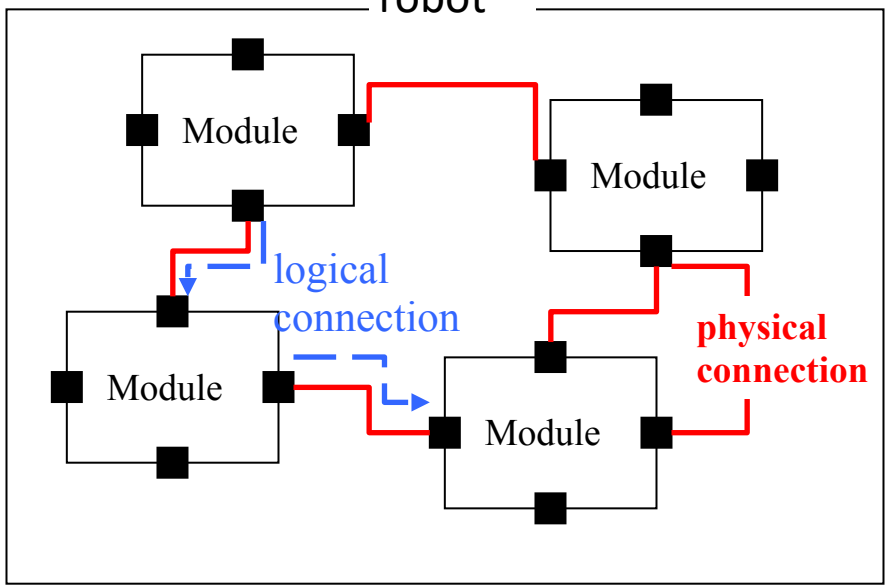
Self-Organization in Robotics

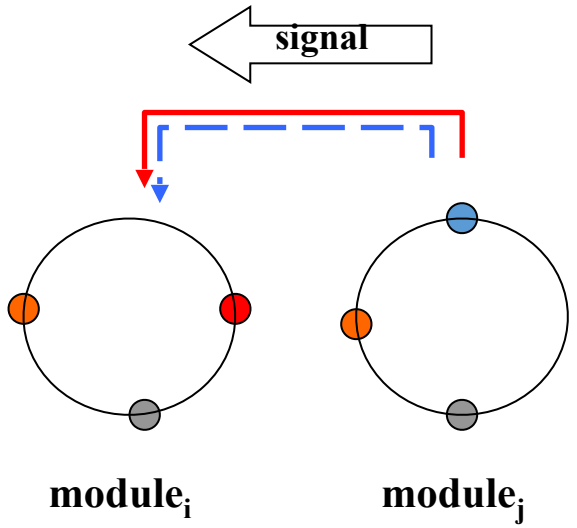


P. Hartono, and A. Nakane, Modular Robot with Real Time Adaptive Connection Topology, Int. Journal of Computer Information Systems and Industrial Management Application, Vol.3, pp. 185-192 (2011).

Self-Organization in Robotics

Coupled Oscillator





$$\frac{d\theta_i}{dt} = \omega - \sum_j \varepsilon_{ij} \sin(\theta_i - \varphi_{ij} + \eta)\delta(T_j - t)$$

$$\varepsilon_{ij} \neq \varepsilon_{ji}$$

$\varepsilon_{ij} \in \{1,0\}$:logical connection between i and j

φ_{ij} : ideal phase difference between i and j

T_j : time when $\theta_j = 0$

η : random perturbation

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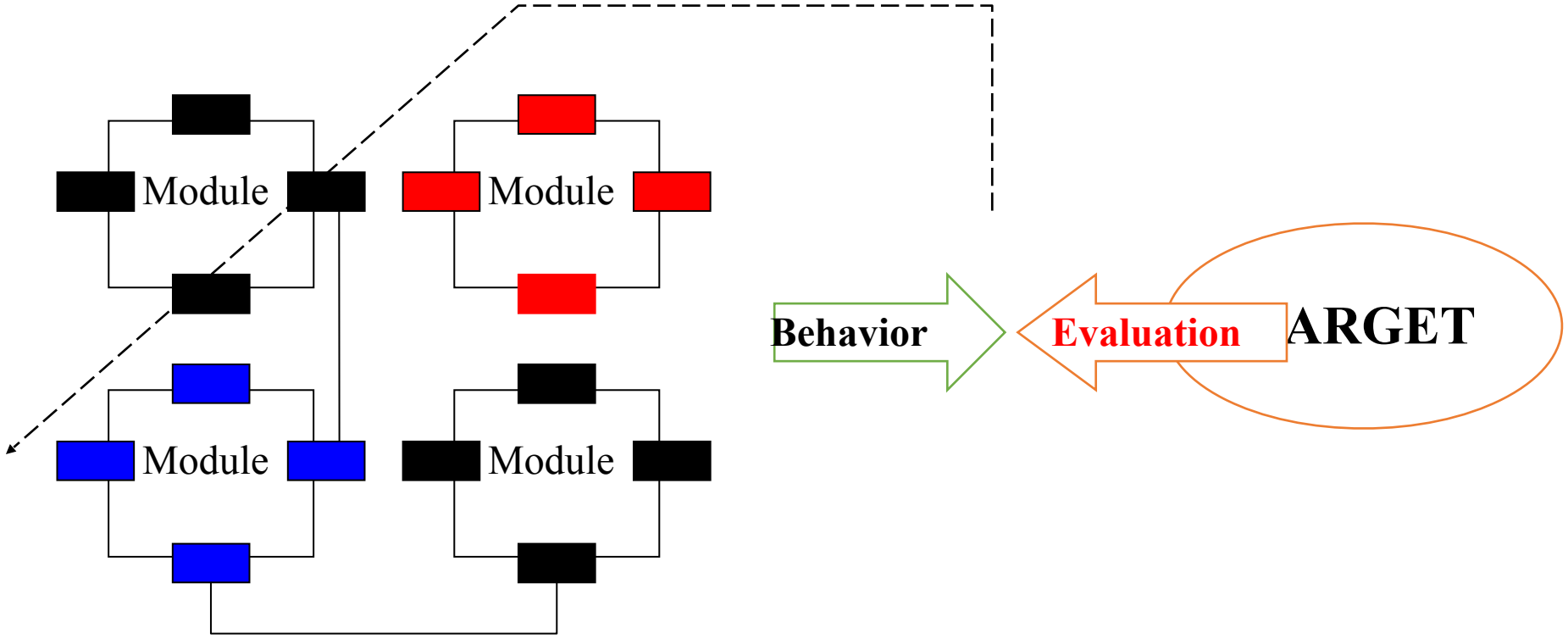
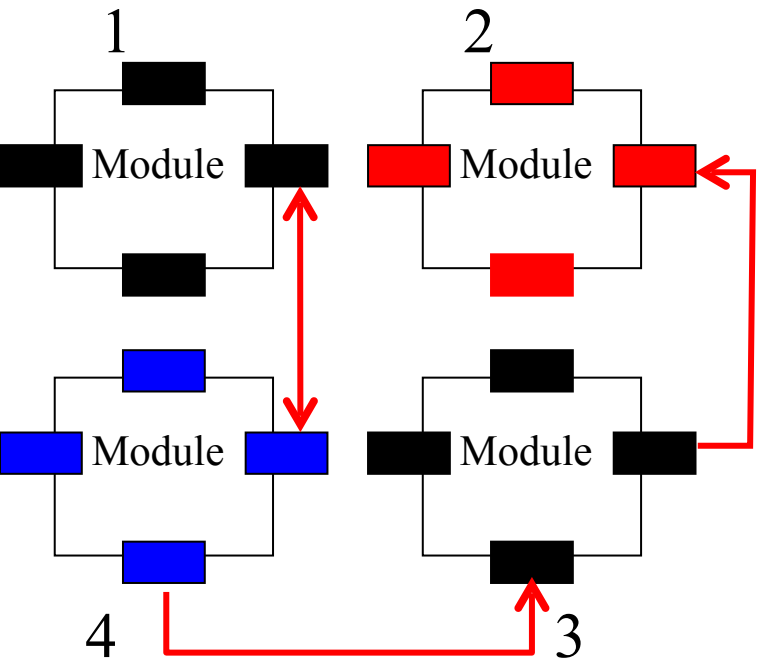
Adaptive Topology

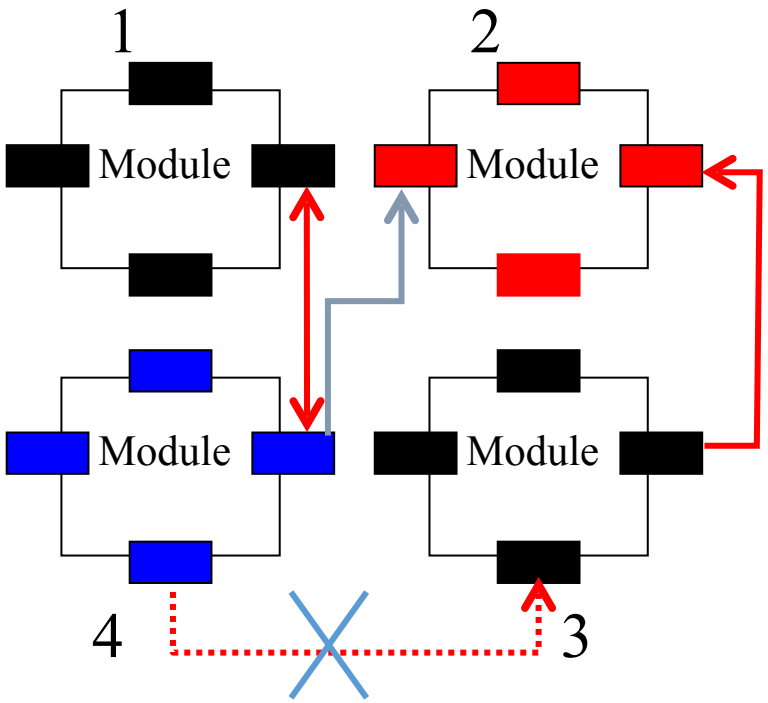


Adaptive Topology



adaptation

Simulated Annealing



$$A = \begin{bmatrix} 0 & 0 & 0 & \varepsilon_{14} \\ 0 & 0 & 0 & 0 \\ 0 & \varepsilon_{32} & 0 & 0 \\ \varepsilon_{41} & 0 & \varepsilon_{43} & 0 \end{bmatrix}$$

Topology Matrix

$$A = \begin{bmatrix} 0 & 0 & 0 & \varepsilon_{14} \\ 0 & 0 & 0 & 0 \\ 0 & \varepsilon_{32} & 0 & 0 \\ \varepsilon_{41} & \varepsilon_{42} & \varepsilon_{43} & 0 \end{bmatrix}$$

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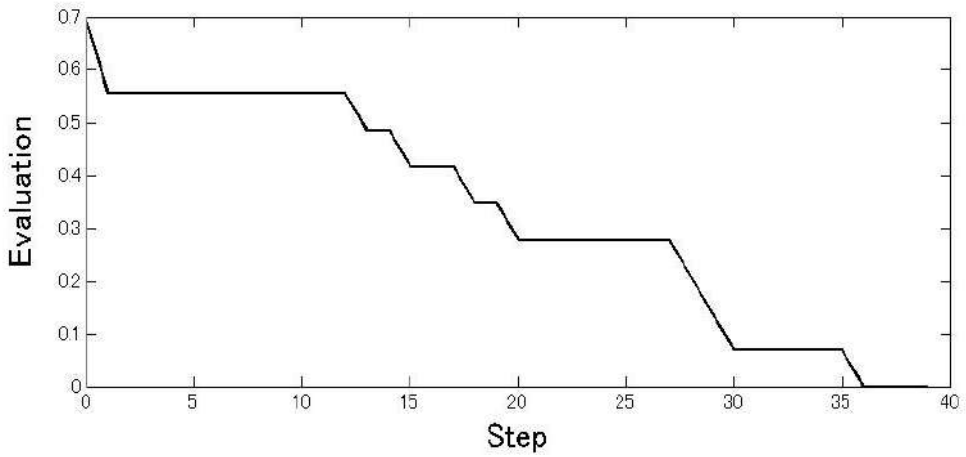
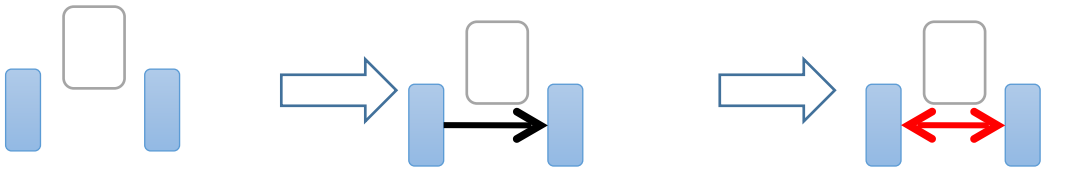
Self-Organization in Robotics

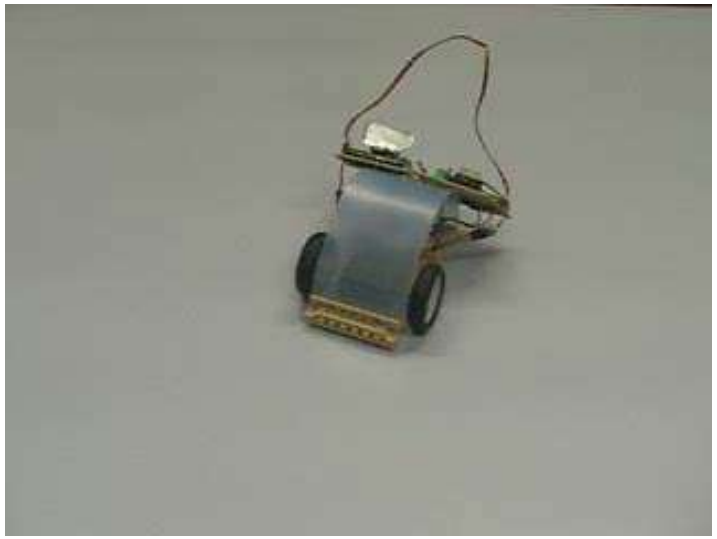
$$E = -\sum_{i=1}^{k} p(\alpha_i)\log p(\alpha_i) \quad \textbf{entropy}$$

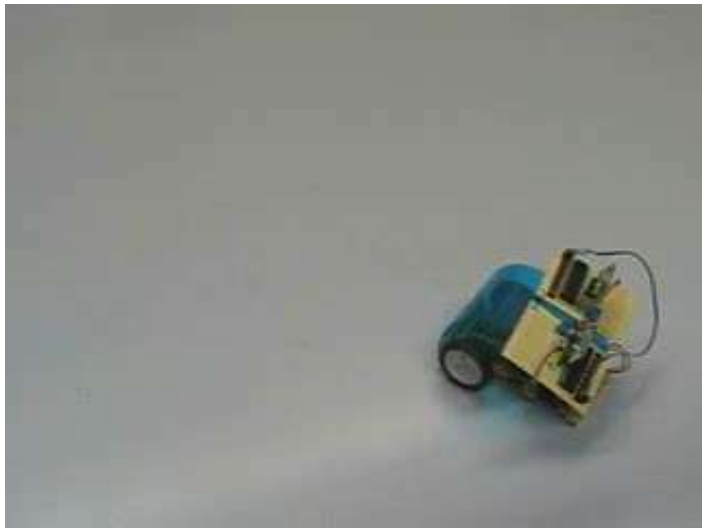




Initial State

Final State





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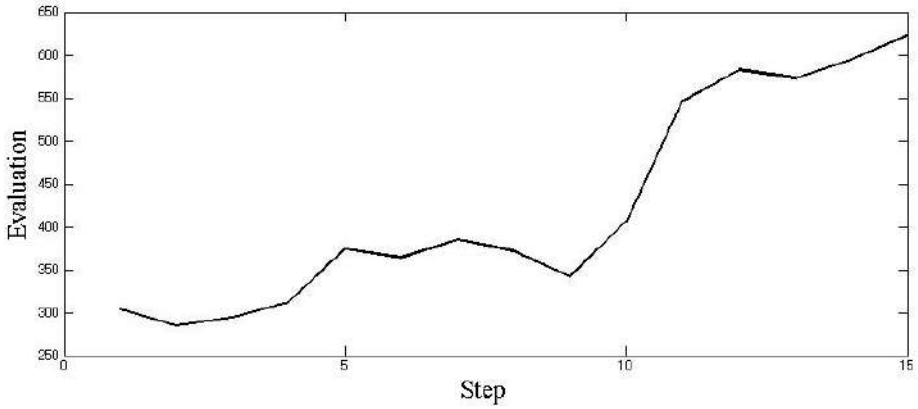
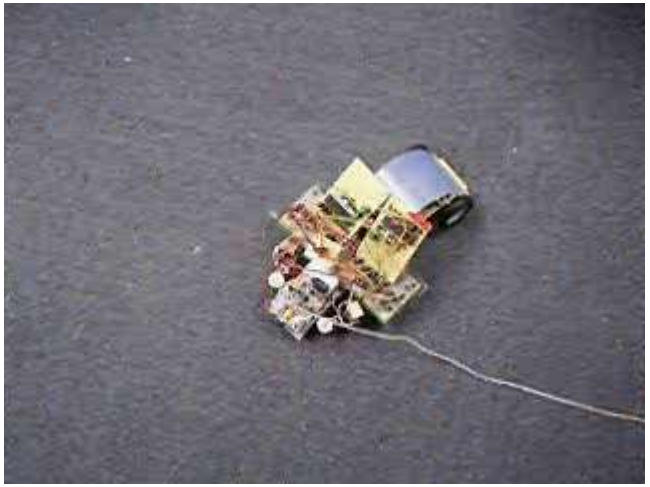
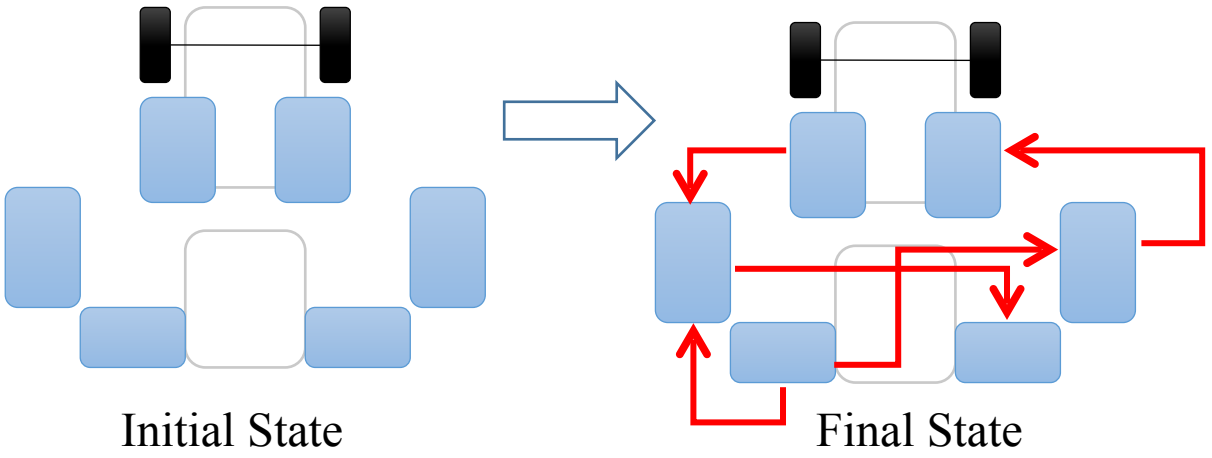
Self-Organization in Robotics

$$E = \sum_{t=1}^{T} |a_x(t)| + |a_y(t)|$$







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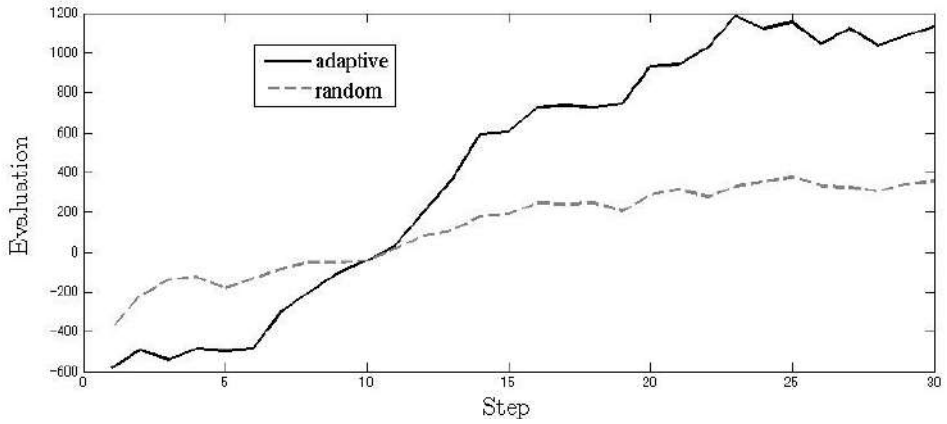
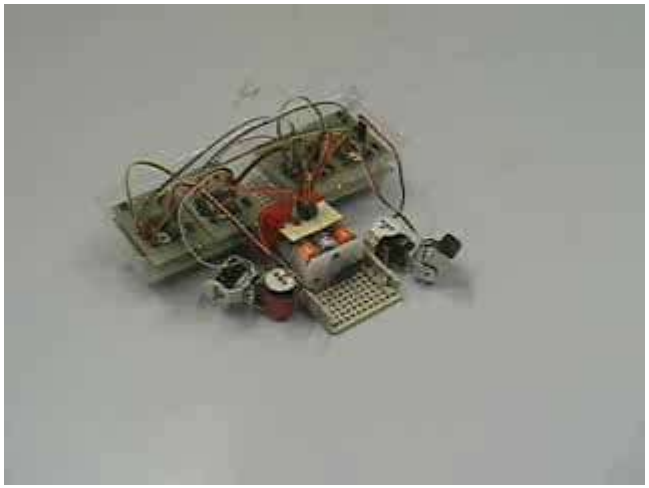
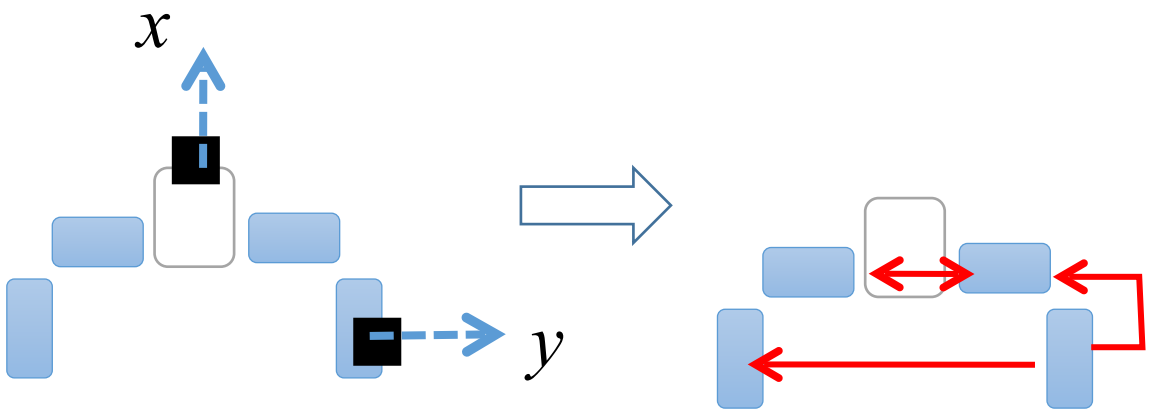
Self-Organization in Robotics

$$E = \sum_{t=1}^{T} |a_x(t)| - |a_y(t)|$$







Initial State

Final State

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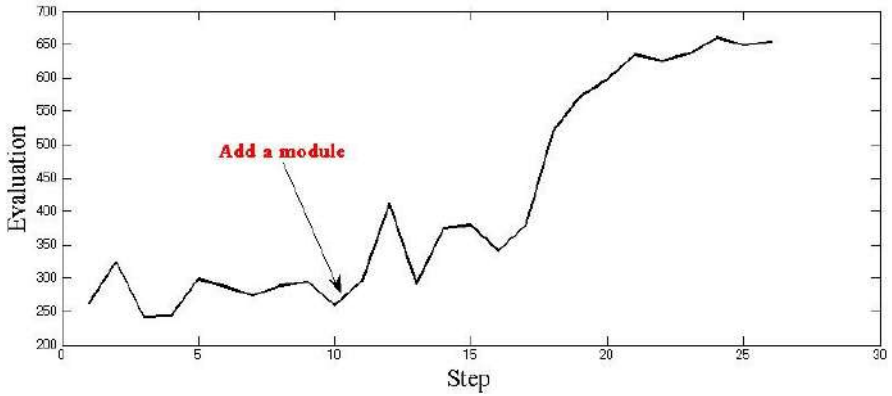
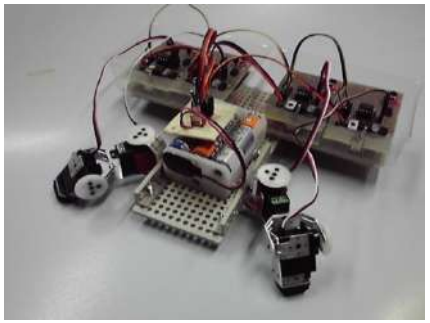
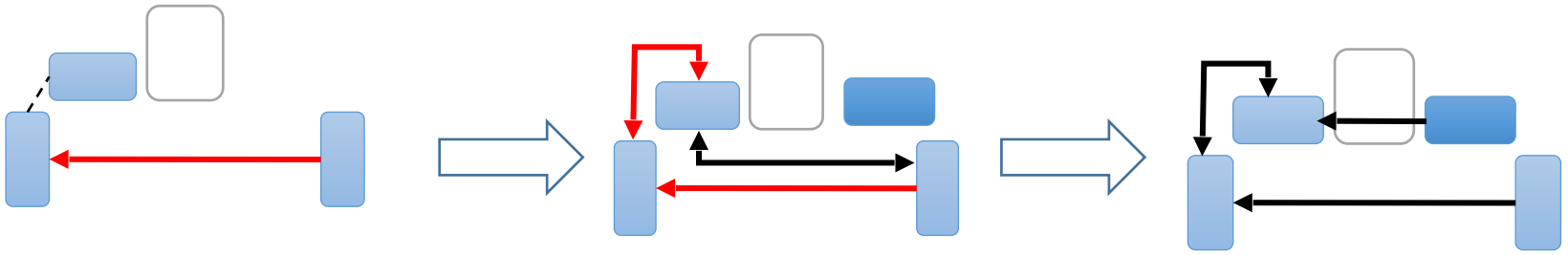
Self-Organization in Robotics

Flexibility to Change







Initial State

Stable State

Modified State

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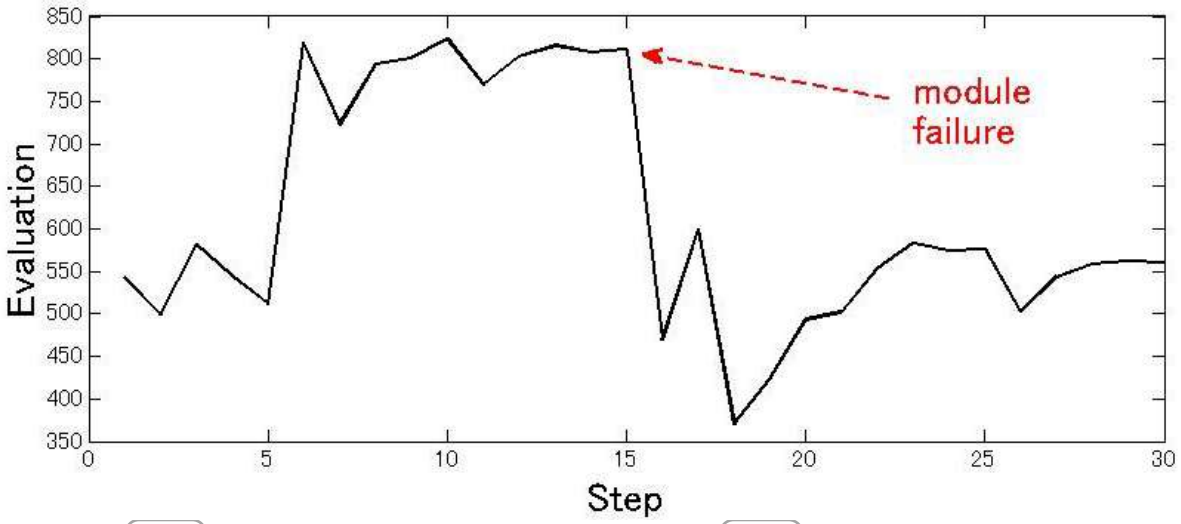
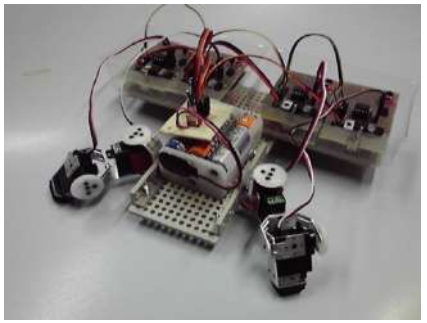
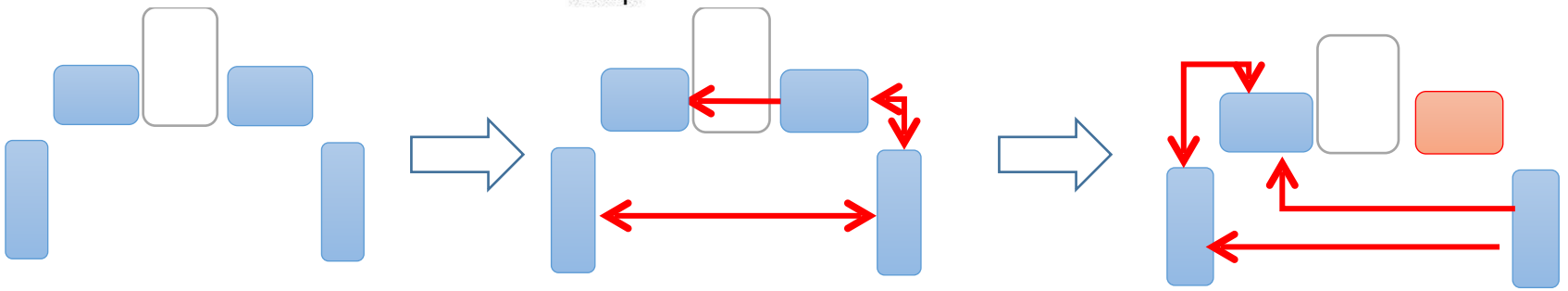
Self-Organization in Robotics

Graceful degradation







Initial State

Stable State

Alternative State

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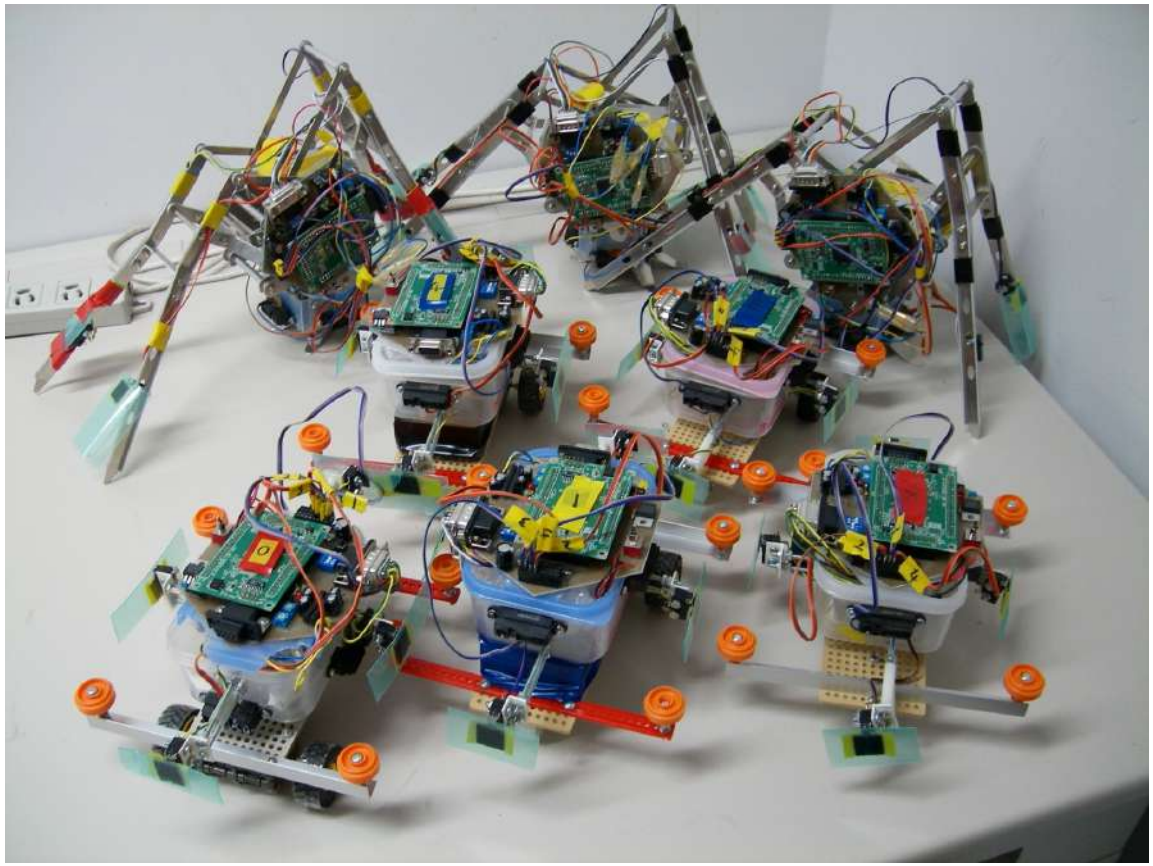
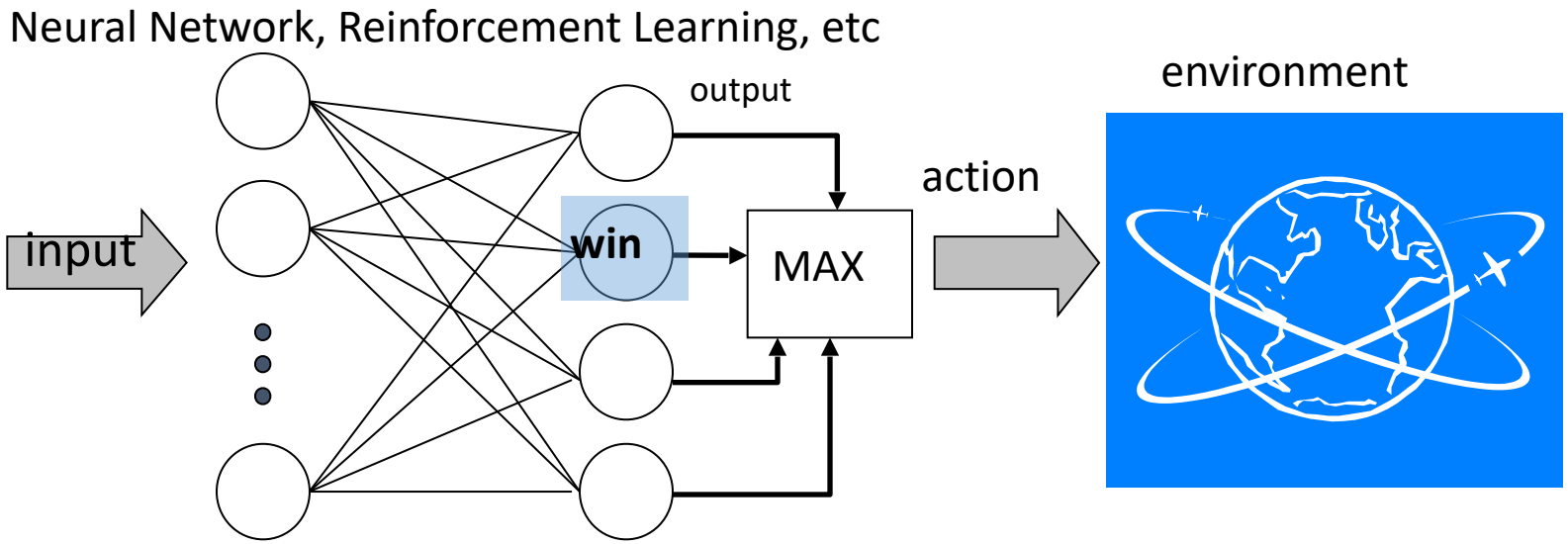
Learning



P. Hartono, and S. Kakita, Fast reinforcement learning for simple physical robots, Memetic Computing, Vol. 1, No.4, pp. 305-313 (2009).

Training

Simplifying the process: Training the controller



$$O_j(t) = f\left(\sum_i w_{ij}(t)\, x_i(t)\right)$$

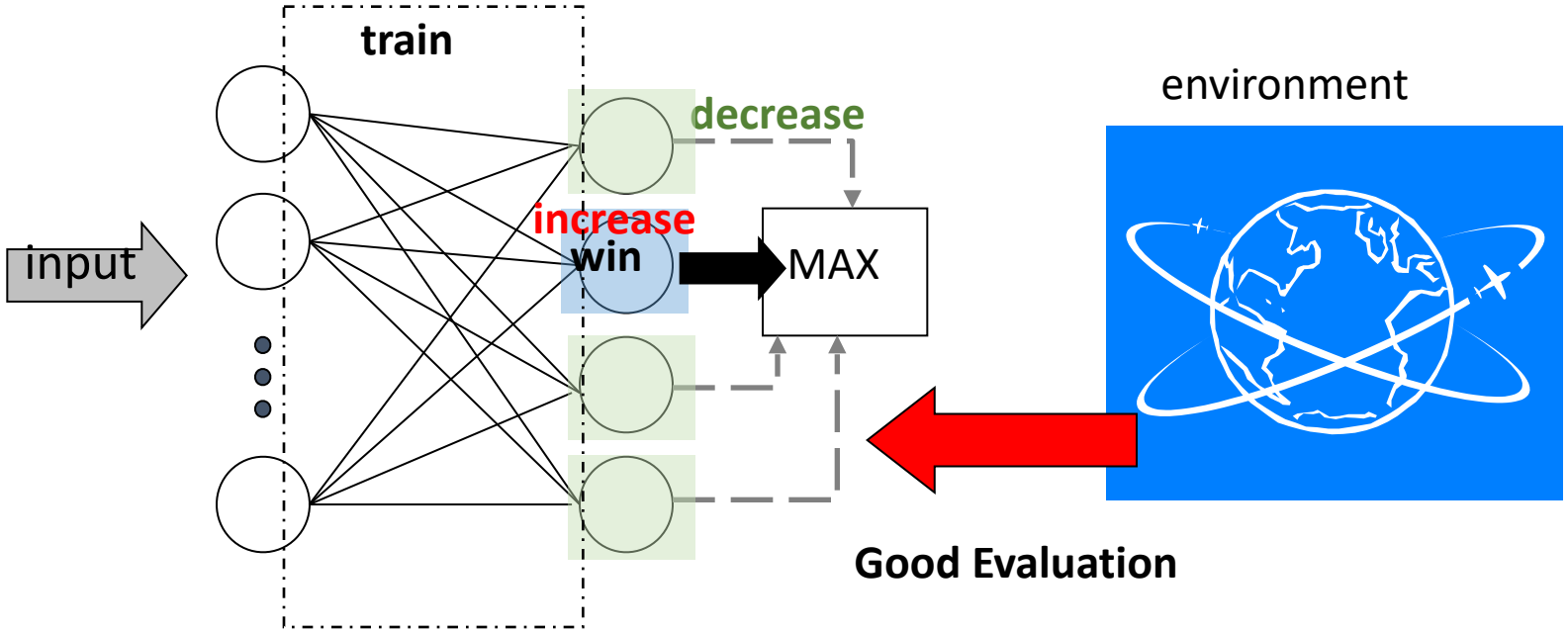
$O_j(t)$: output value of the *j*-th neuron

$w_{ij}(t)$: weight between *i*-th input and the *j*-th output neurons

$x_i(t)$: value of the *i*-th input

Training

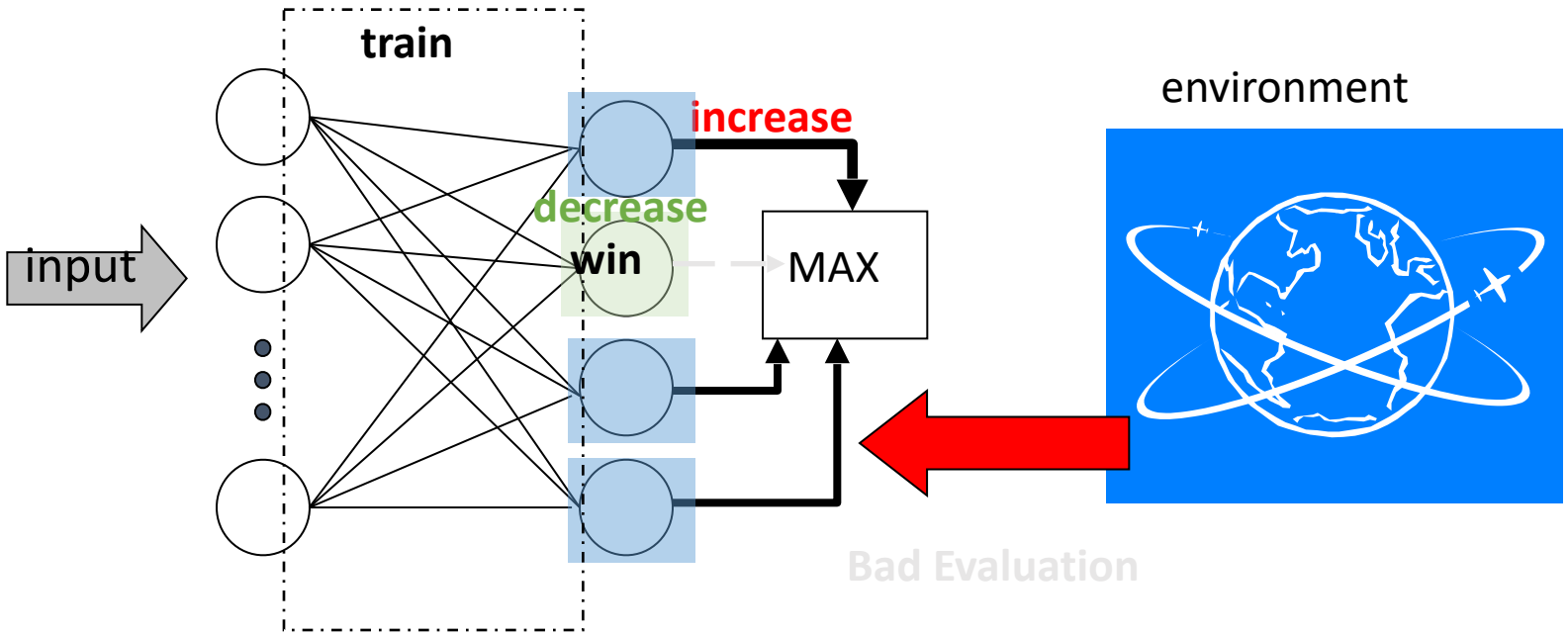
Learning Mechanism



Good Evaluation

- Increase the winner's output
- Decrease the losers' outputs

Training



Bad Evaluation

- Decrease the winner's output
- Increase the losers' outputs

Training

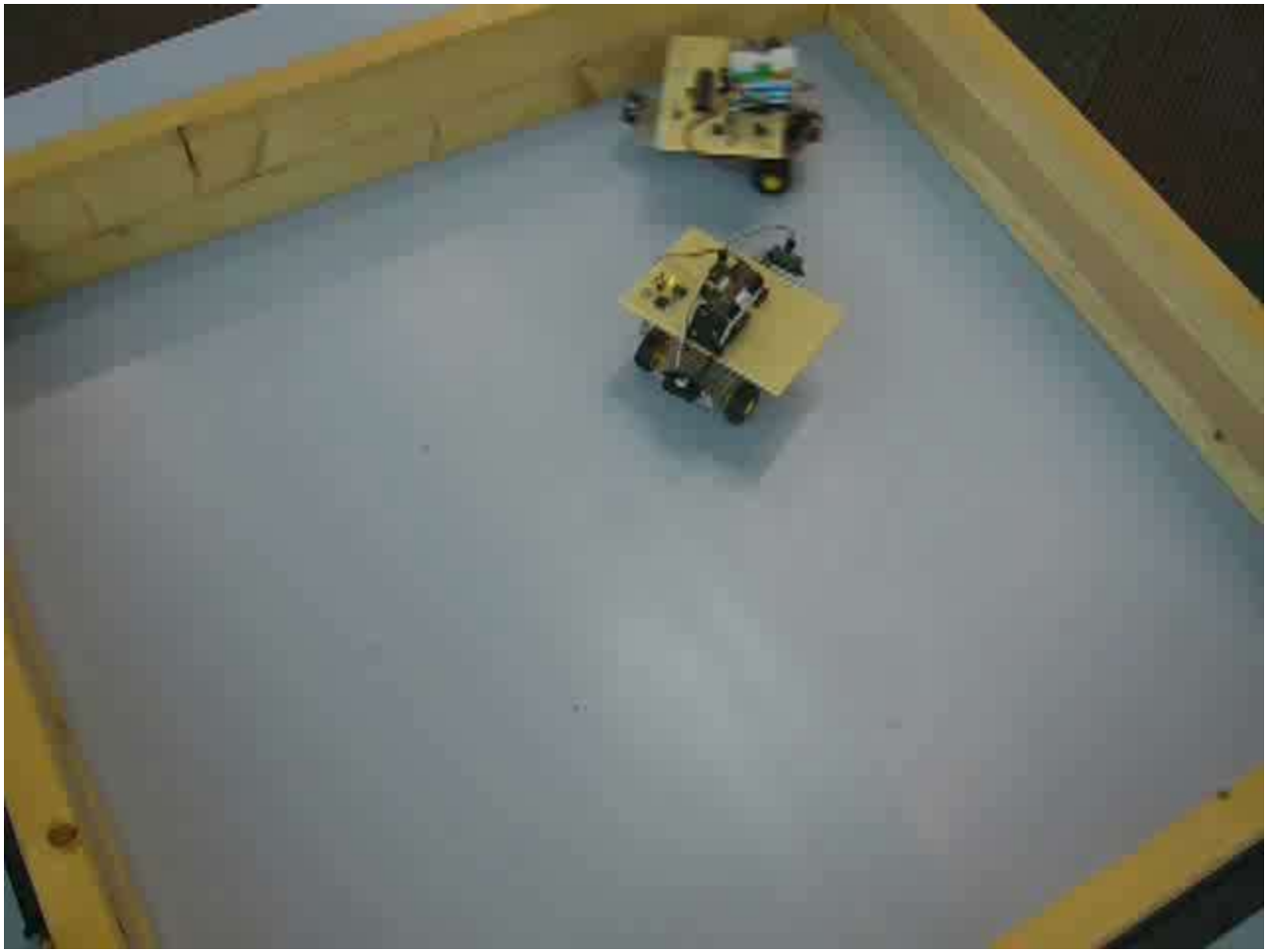
障害物回避実験
1次元、Turtle-1

2006/02

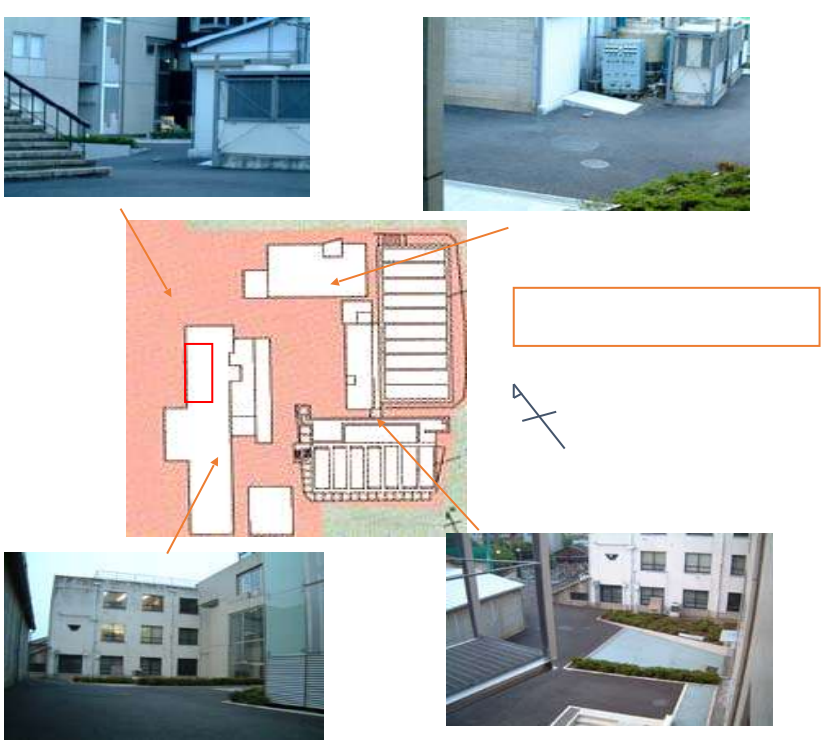
獲得した障害物回避行動

Turtle-2, 1次元
学習開始から12分後

Training

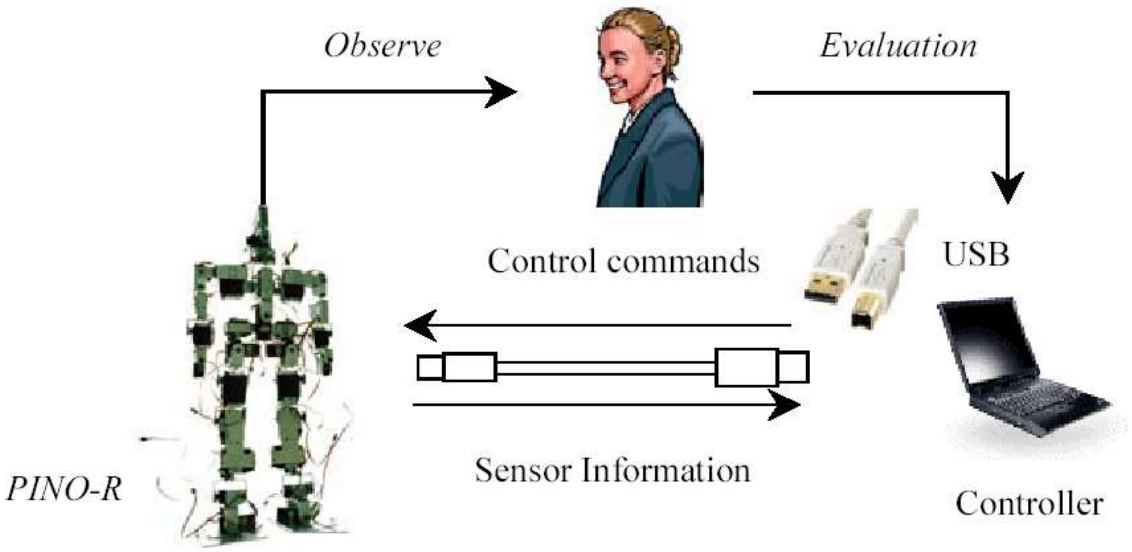


Training



Training

Human Coaching

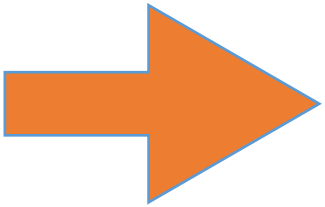


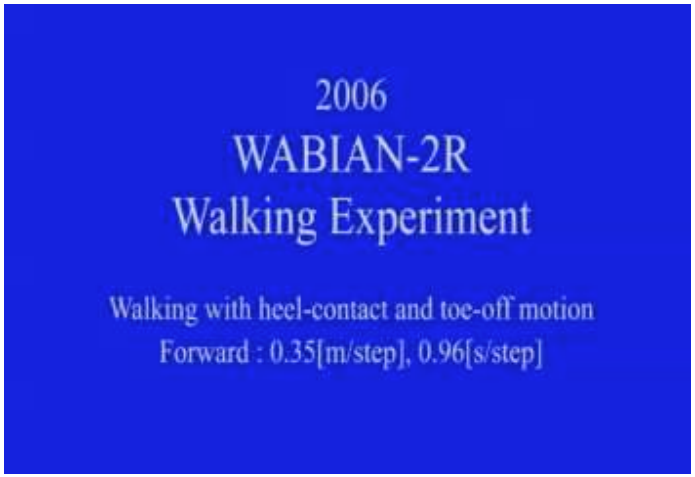
Human Evaluated Simulated Annealing

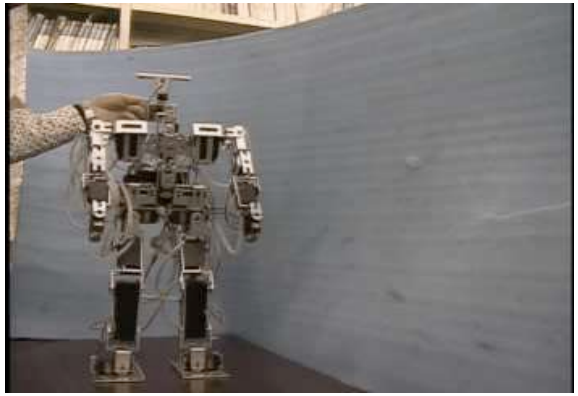
M. Nakatani, K. Suzuki and S. Hashimoto, Subjective-Evaluation Oriented Teaching Scheme for a Biped Humanoid Robot,
Proc. of the 2003 IEEE-RAS International Conference on Humanoid Robots (2003)

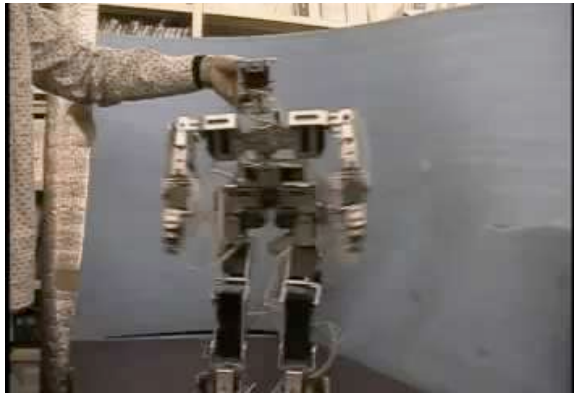
Training

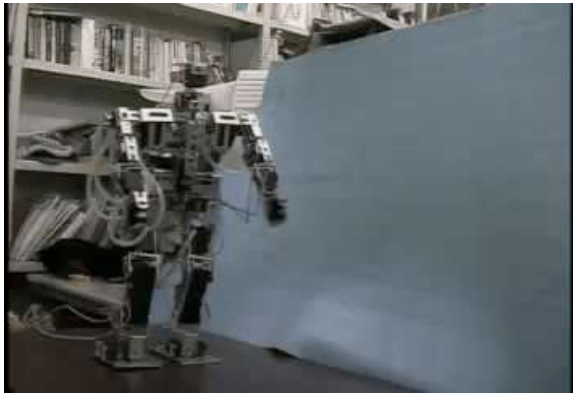
30 years !



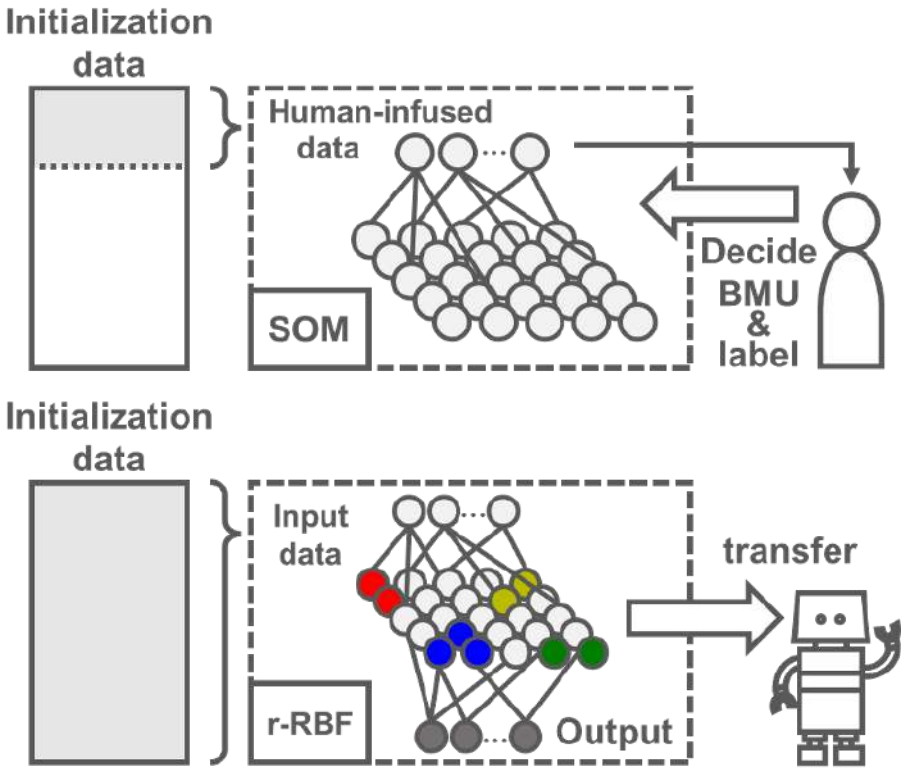


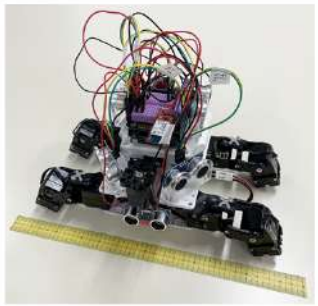




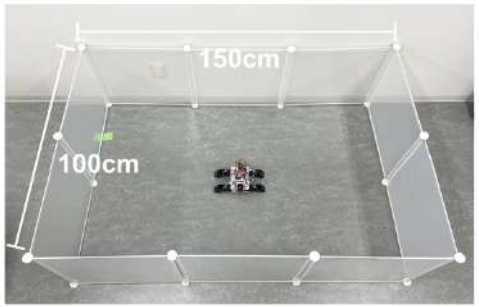


Transferability and Comprehensibility

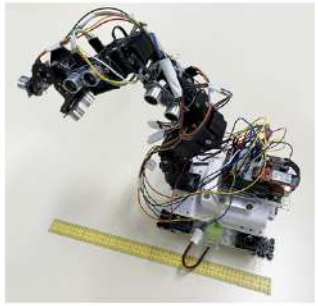




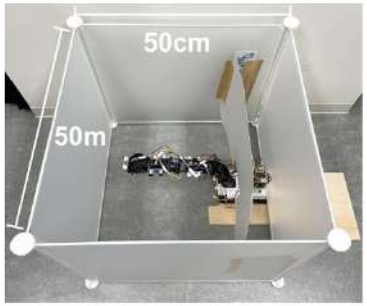
▲ 4-legged crawler robot



▲ Experiment environment



▲ Arm robot



▲ Experiment environment

P. Hartono, P. Hollensen, T. Trappenberg, Learning-Regulated Context Relevant Self-Organizing Topographical Map, IEEE Trans. On Neural Networks and Learning Systems, Vol. 26, No. 10, pp. 2323-2335 (2015).

P. Hartono, Mixing autoencoder with classifier: conceptual data visualization, IEEE Access Vol. 8, pp.105301 -105310 (2020)

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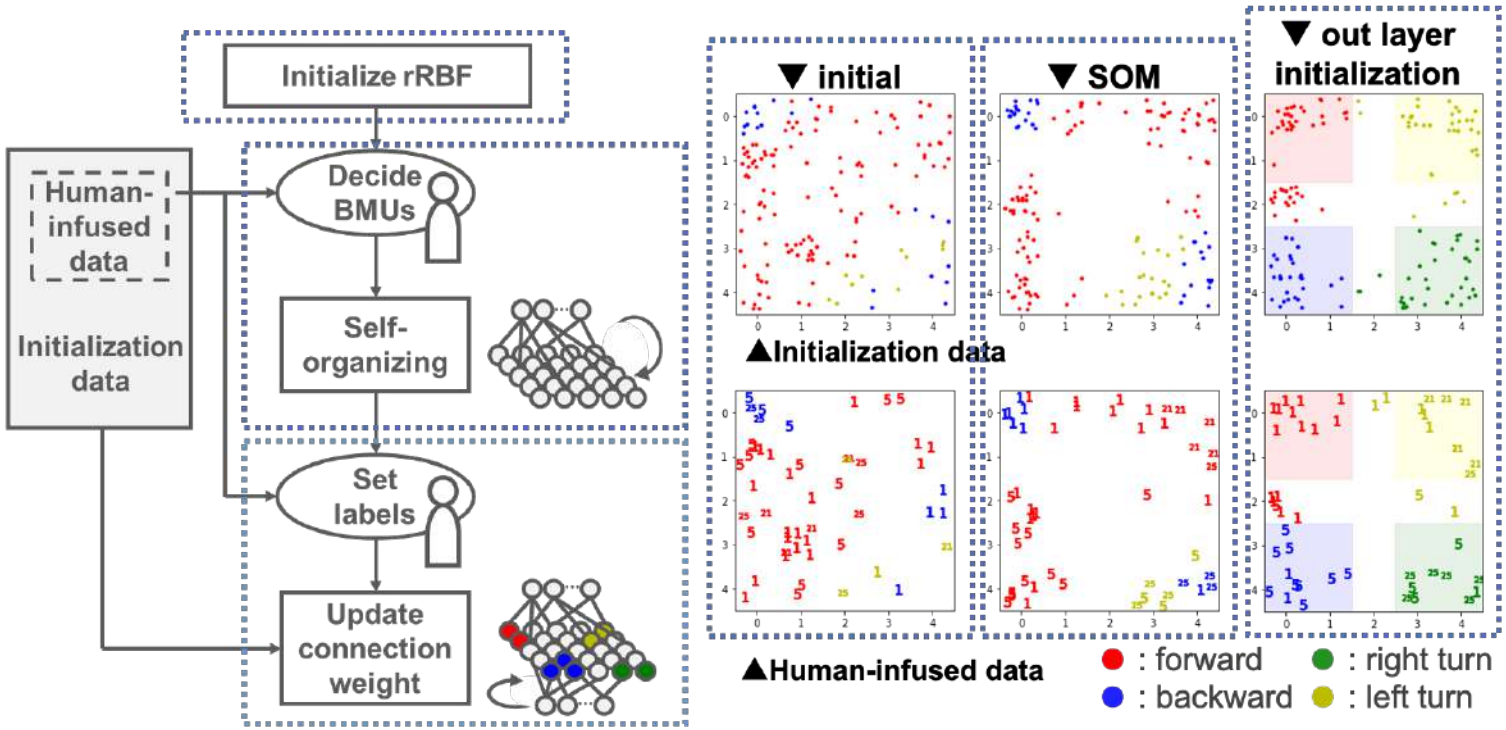
Transferability and Comprehensibility



K. Ogawa, P. Hartono, Infusing prior knowledge into topological representations of learning robots, Proc. 27th Int. Symposium on Artificial Life and Robotics, pp. 347-352 (2022) (**Young Author Award**).

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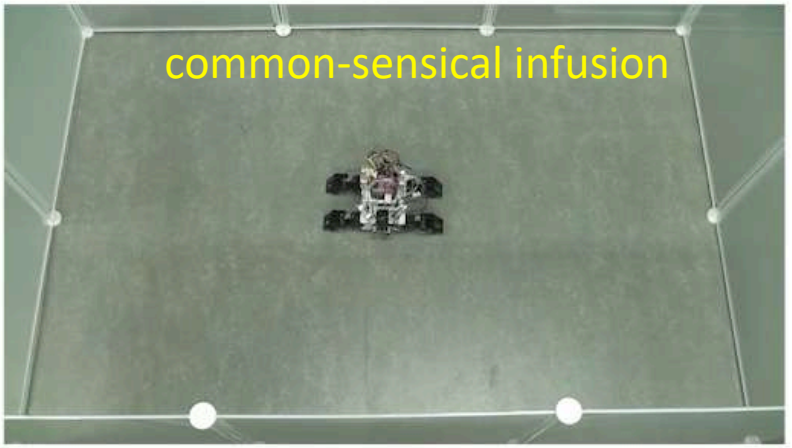
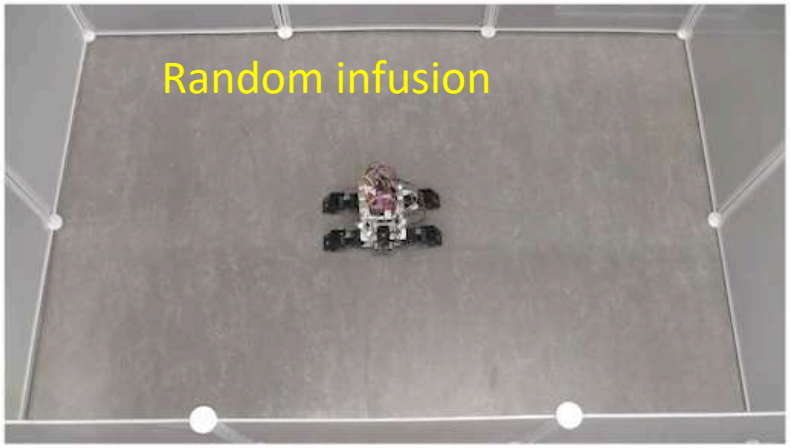
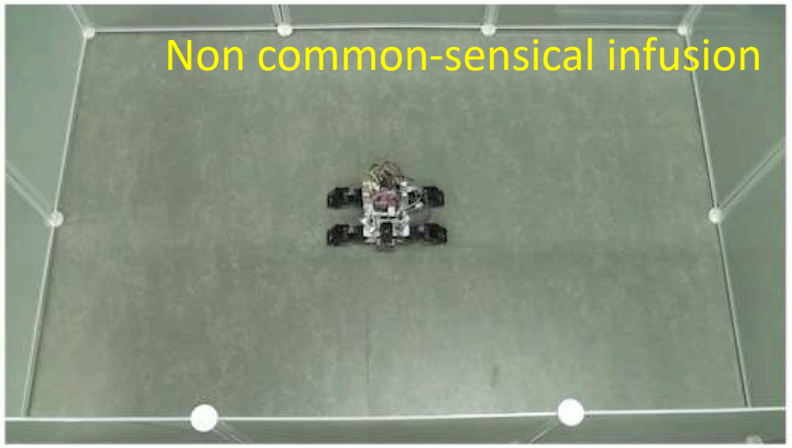
Transferability and Comprehensibility







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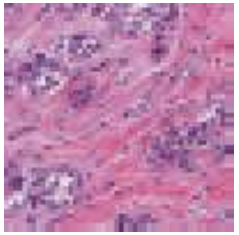
Comprehensibility

Explainable AI for histopathological diagnosis

your sample is IDC



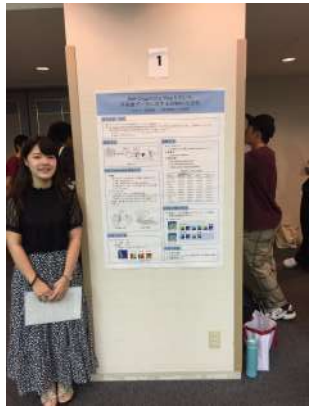
"Your image is IDC. However, there is high possibility that it could be misclassified as non-IDC, because it has medium similarity with some clusters of the non-IDC samples."

low-similarity non-IDC

non-similar non-IDC

Patrik Sabol

TU Kosice, Slovakia



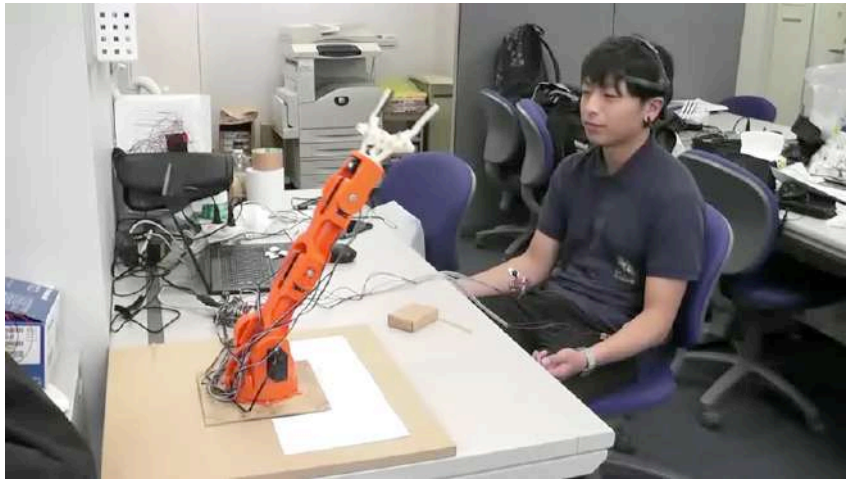
Kana Ogawa

P. Sabol, P. Sincak, P. Hartono, et al. , Explainable Classifier Supporting Decision-making for Colorectal Cancer Diagnosis from Histopathological Images, Journal of Biomedical Informatics, Vol. 109, 103523 (2020)

Smart Interface

Brain Machine + Biosignal interface

Ryo Nakashima



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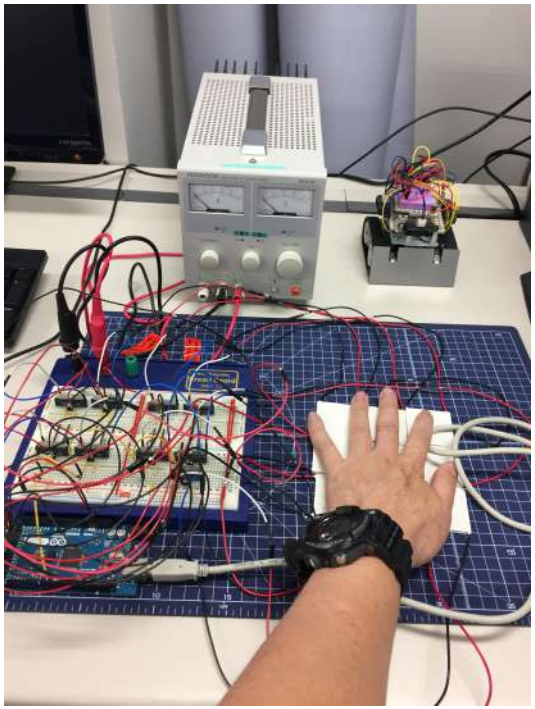
Smart Interface

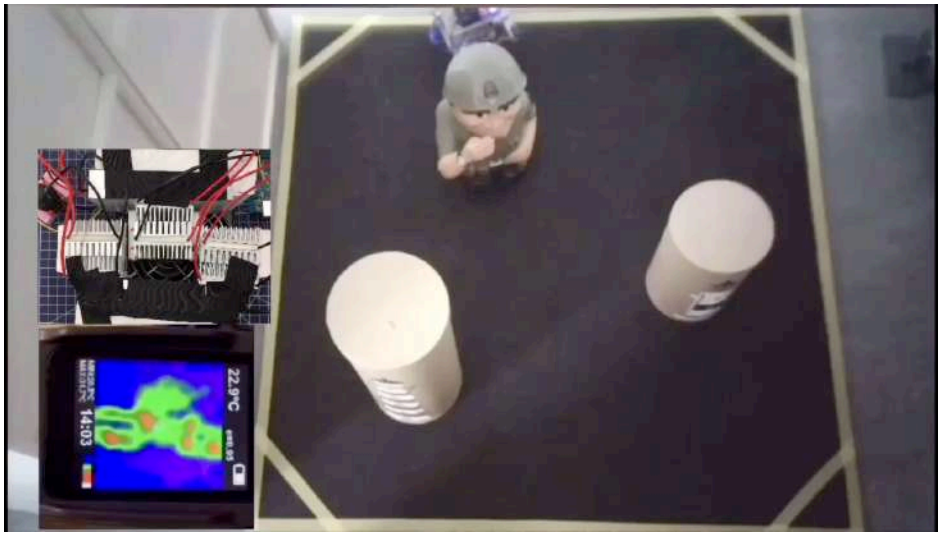
Pain illusion

Shota Kato

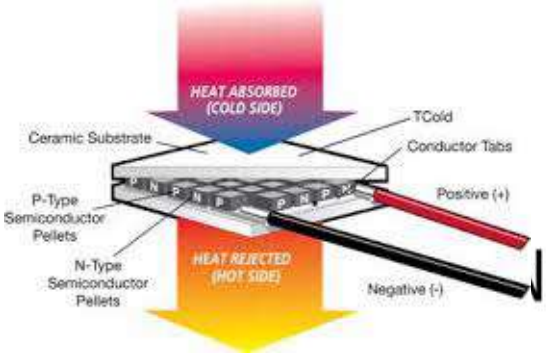
Hiroki Kishi

Thermal Grill Illusion





Peltier Device



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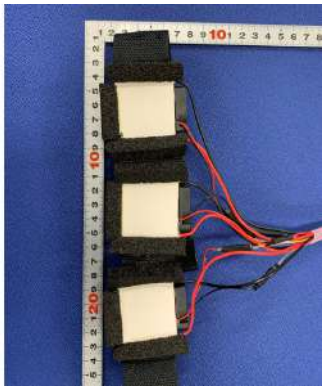
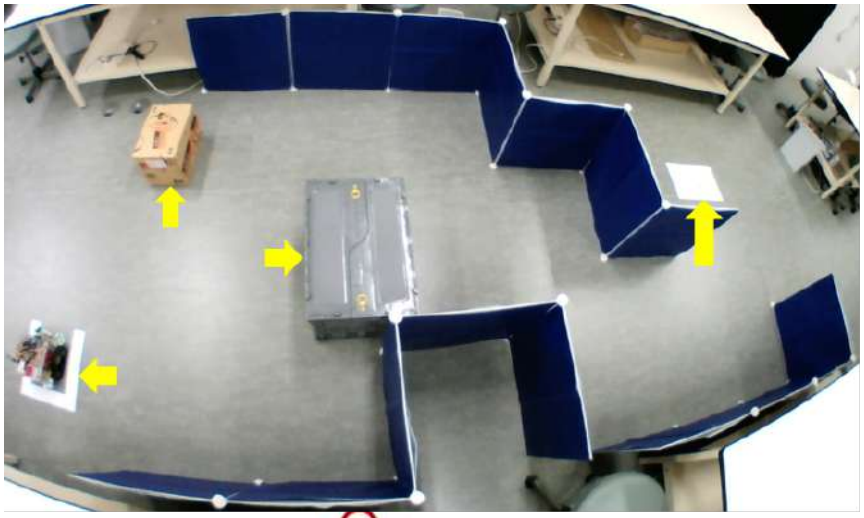
Smart Interface

Pain illusion





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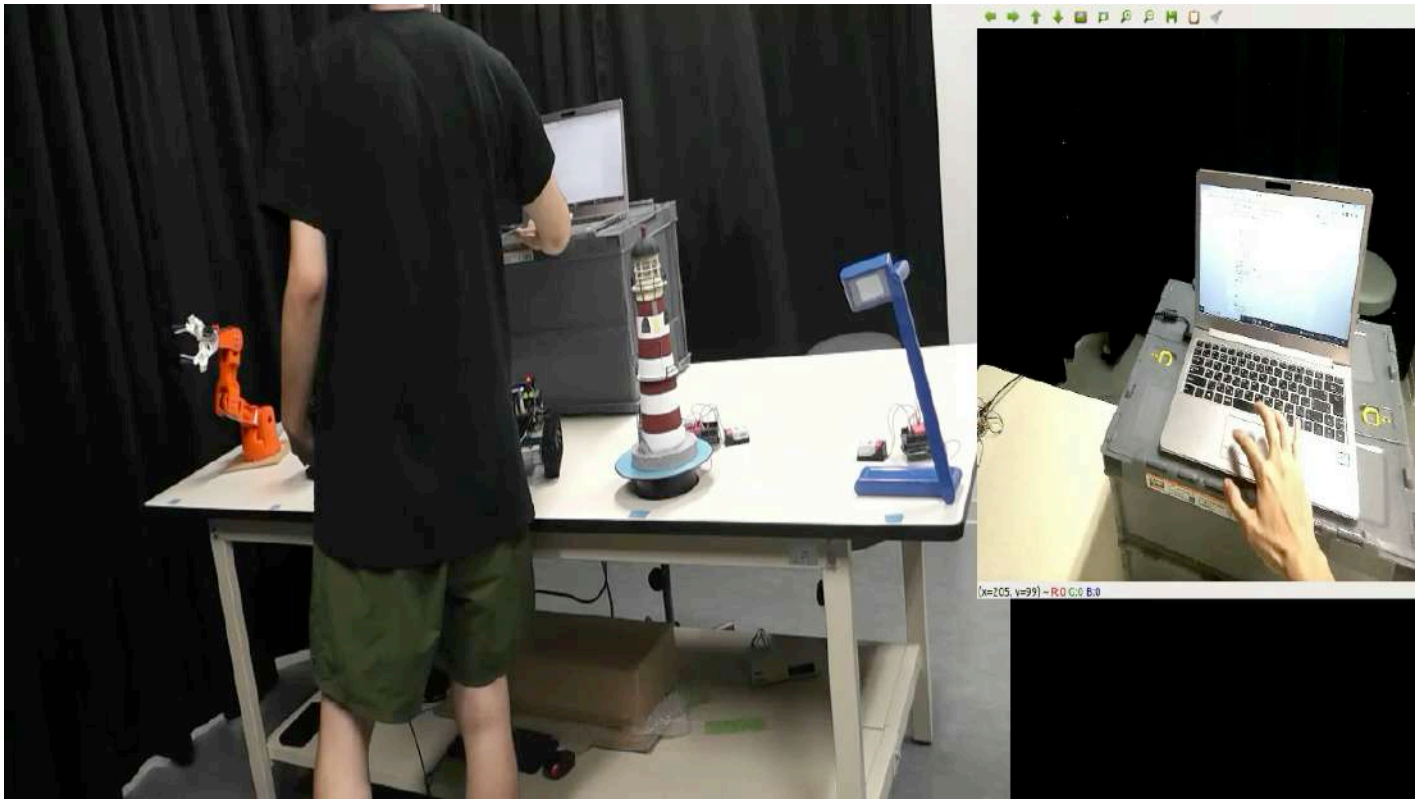
Smart Interface

Gaze Interface



Yoshikazu Murase

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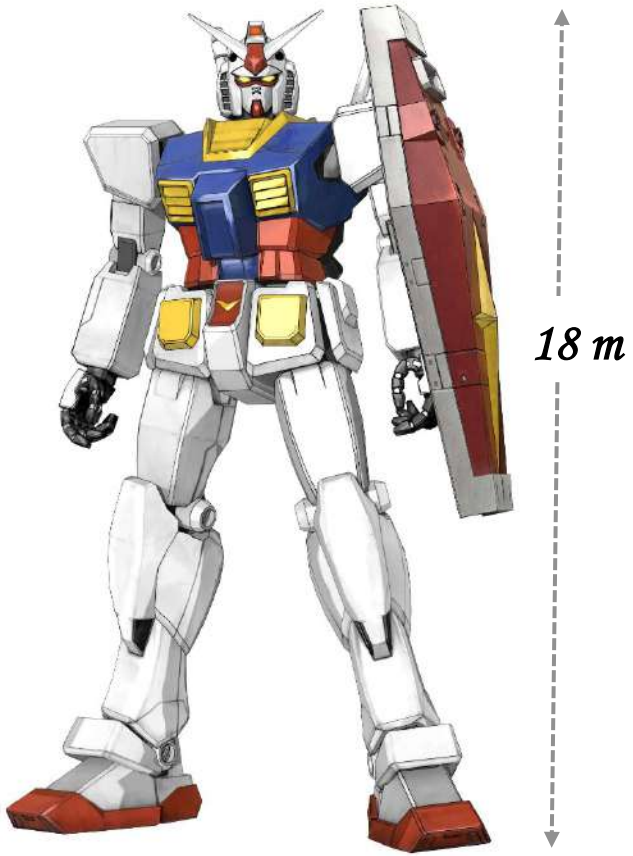
Gundam Global Challenge

Building real size moving robot Gundam ~~before Tokyo Olympic 2020~~



television animation movie (1979～) (SUNRISE)

Creating animated movie industries
Creating toys industries
Tourism
Promoting creative image of Japan
Fueling creative imagination

economic effect:
\ 76.7 billions (2014)
($ 600 millions)

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Gundam Global Challenge

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Gundam Global Challenge

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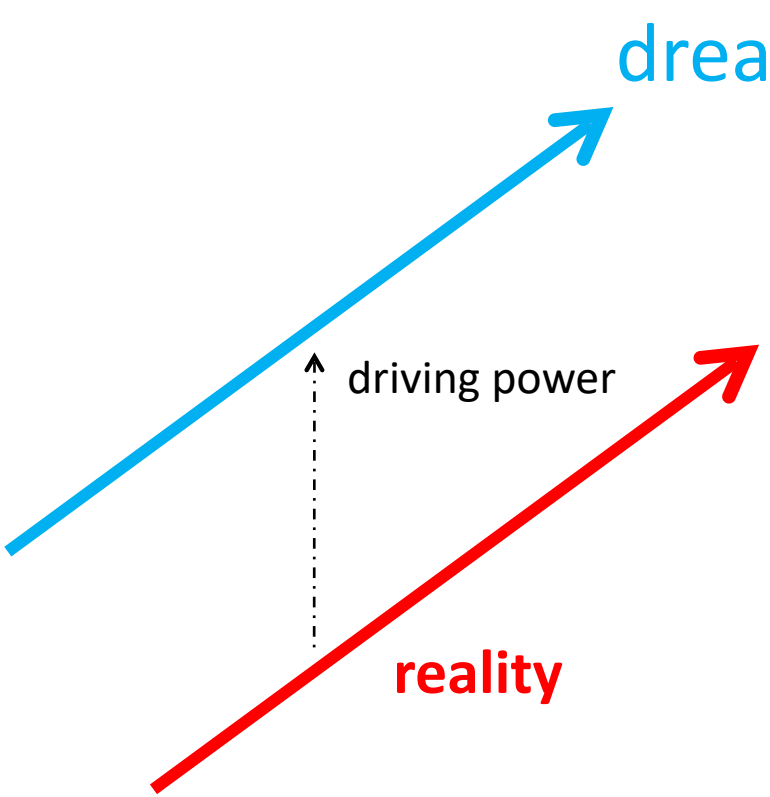
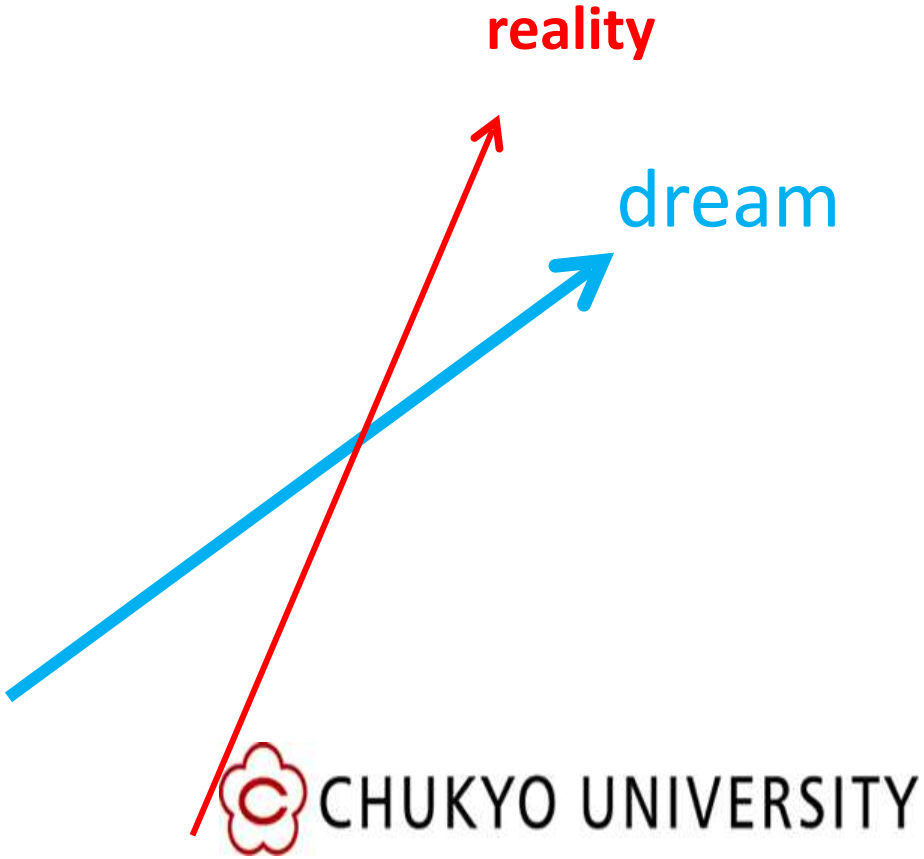
Prof. Shuji Hashimoto
Waseda University, Tokyo

Dream is the motor of innovation, but to dream is not easy





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Thanks to

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Aito Nakane
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Kana Ogawa
Hiroki Kishi
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Thomas Trappenberg
Peter Sincak
Patrik Sabol

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