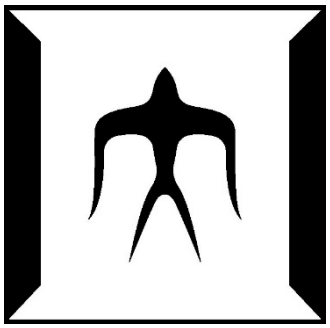
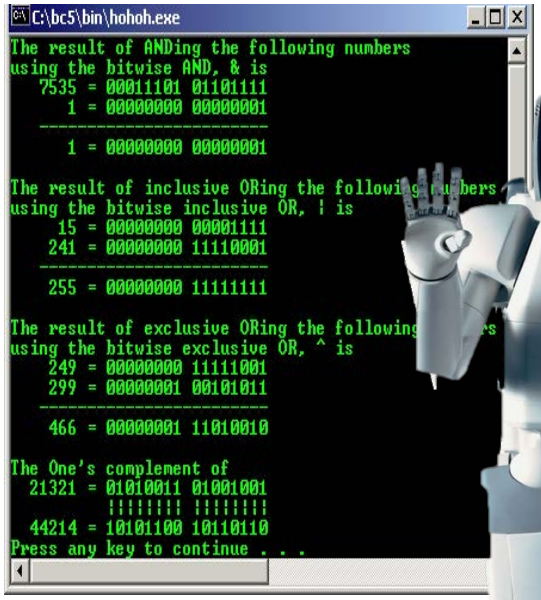
SOINN : An Artificial Brain



Osamu Hasegawa

Motivation

hard-cording



Confined environment

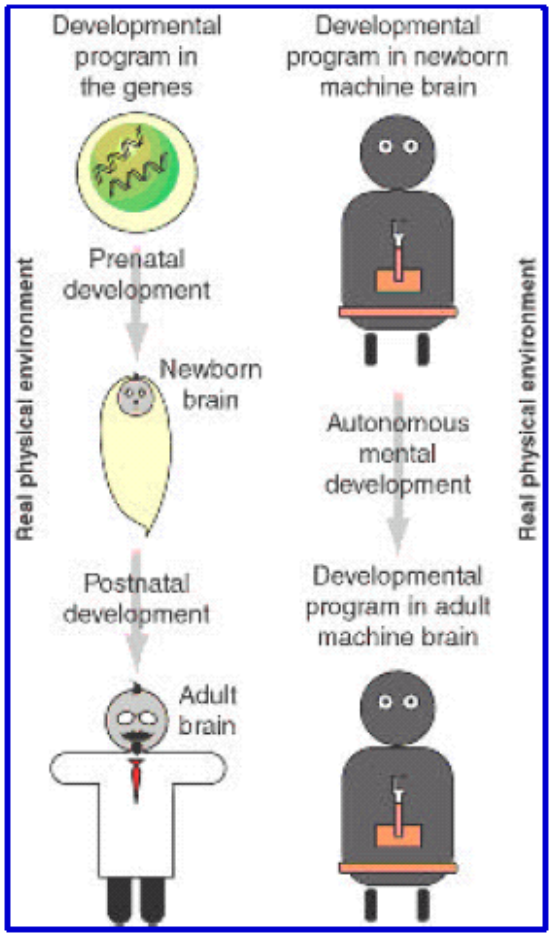
operator

We need to develop a robot which …

1. Understand a voice command
2. Learn autonomously from the Internet, if needed
3. Generate the procedure and accomplish the task.

Autonomous Mental Development

Weng, J., et. al. (2001). Autonomous mental development by robots and animals., *Science*, 291, 599-600.



DIFFERENCES BETWEEN ROBOT PROGRAMS

Properties	Traditional	Developmental
Not task specific	No	Yes
Tasks are unknown	No	Yes
Generates a representation of an unknown task	No	Yes
Animal-like online learning	No	Yes
Open-ended learning	No	Yes

Big Data

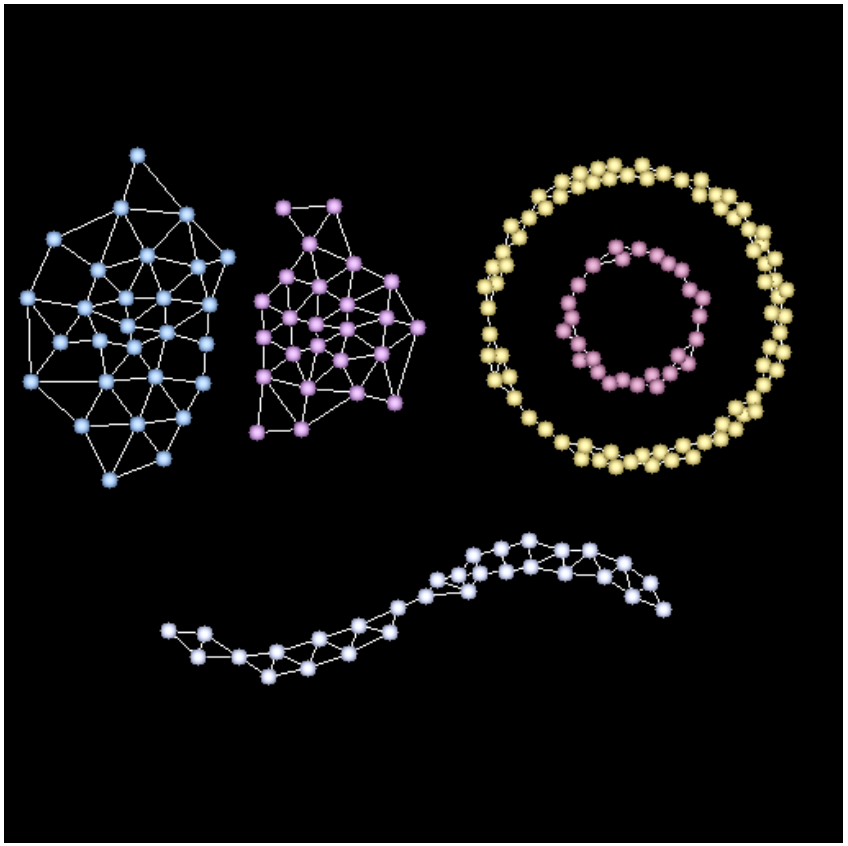
- “Infoplosion” is underway globally on daily basis. Data accumulation volume is enormous.
- Computers and robots in addition to human beings should use these data for learning, associating, reasoning, knowledge-transferring and forecasting.
- We want to eliminate irrelevant noise automatically.
- SOINN does it!

Major Advantages of SOINN :

1. SOINN user does not need to define a mathematical model for learning.

2. SOINN can automatically eliminate noise.

Self-organizing Incremental Neural Network (SOINN)

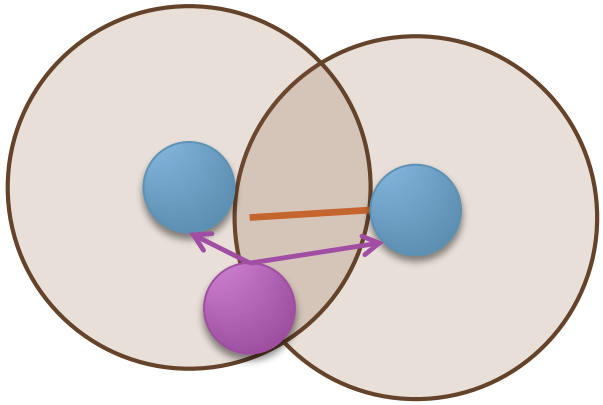


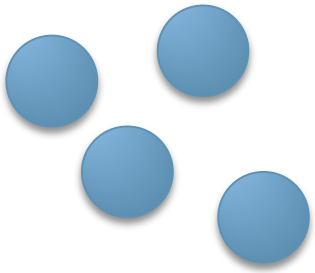
Noise is eliminated.

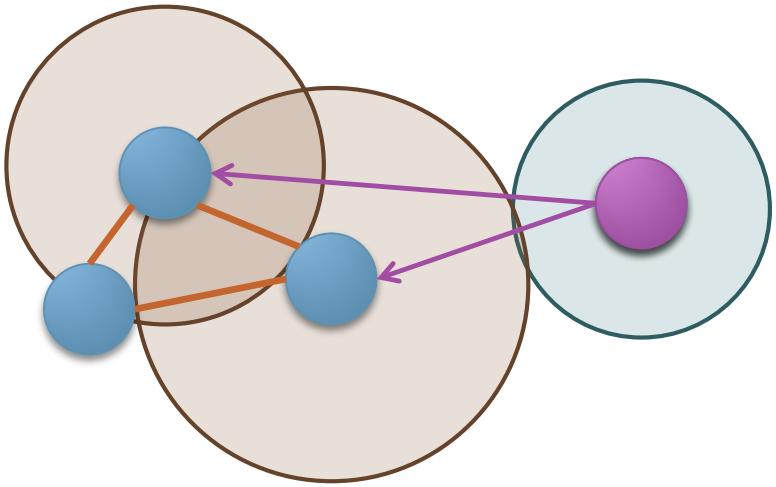
Pattern is recognized.

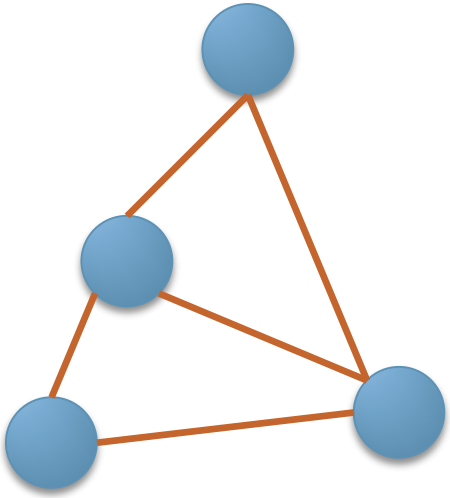
SOINN applet demo

SOINN Algorithm









SOINN has vast possibilities

- SOINN is algorithm: it works with any language:
  C, C++, C#, JAVA, GP-GPU, Matlab

- SOINN works with any hardware:
  - Google Glass, Cellular phone, smart phone, personal computer, embedded system, etc.

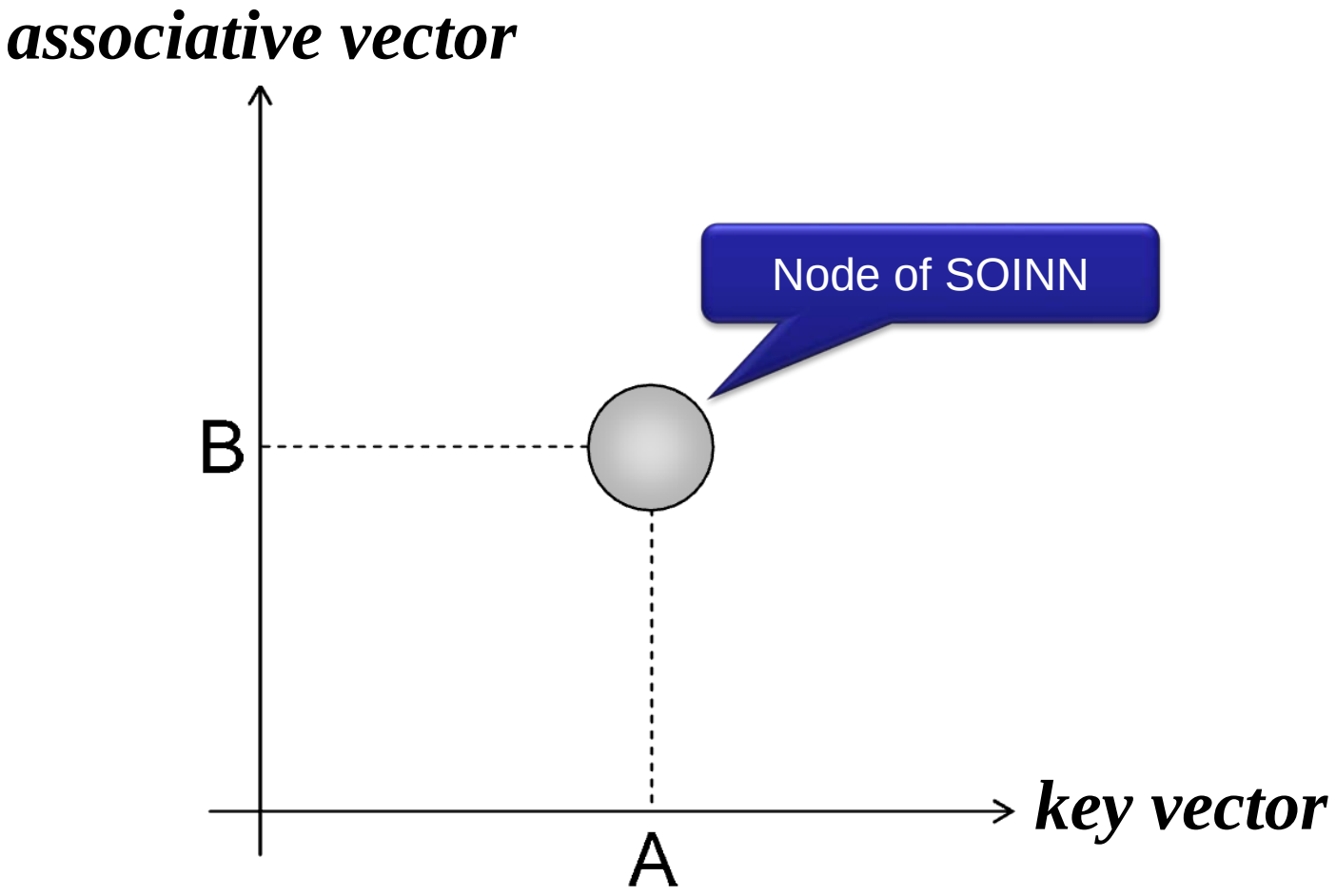
- SOINN works best with internet :
  - Google Drive, finance, distribution, climate/environment, education, medicine, etc.

SOIAM

- SOIAM: SOINN for Associative Memory
- Learn a pair of vectors (a key and an associative vector)
- Realize the association between the above pair
- One-to-many and many-to-many association

Example of one-to-many association

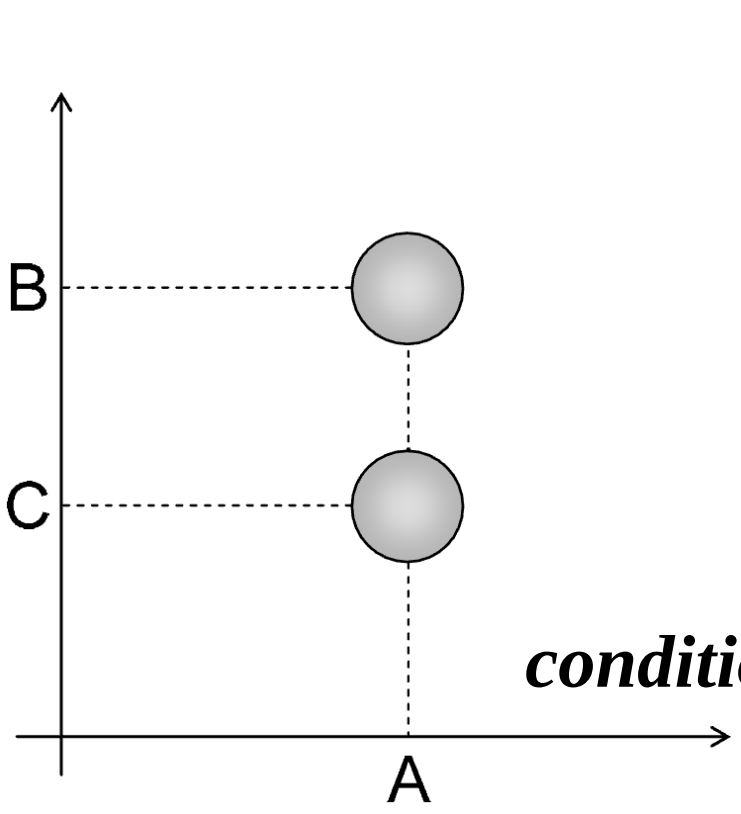
SOIAM (conceptual diagram)



SOINN-PBR

- SOINN-PBR: SOINN for Pattern-Based Reasoning
- Realize reasoning with the pattern-based if-then rules of propositional logic
  - Furthermore, realize deductive inference by using the known pattern-based if-then rules
- Extend SOIAM to learn the pattern-based if-then rules

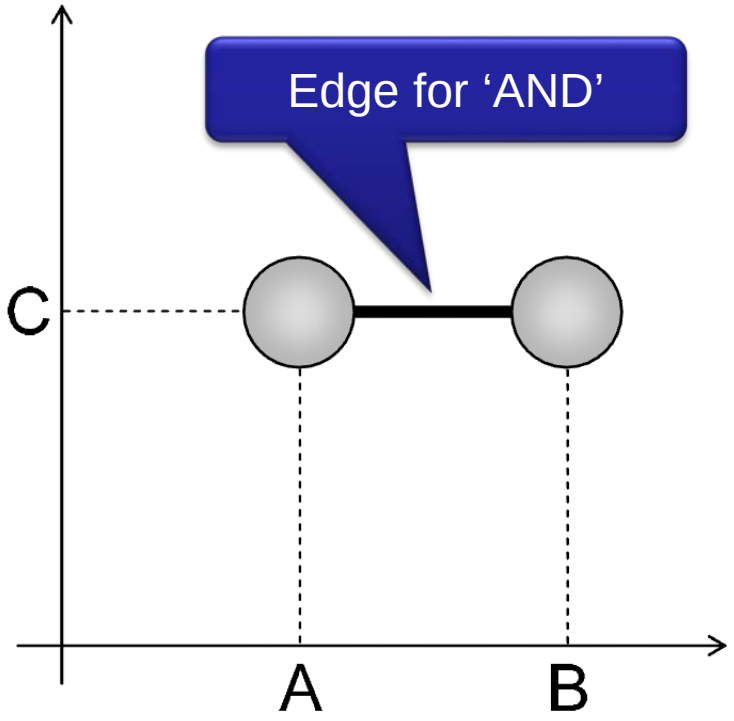
SOINN-PBR(conceptual diagram)



$A \rightarrow B \vee C$

conditional rule

sequential rule



$A \wedge B \rightarrow C$

SOINN for Real-world Robots

UNGUIDED ROBOT NAVIGATION USING CONTINUOUS ACTION SPACE

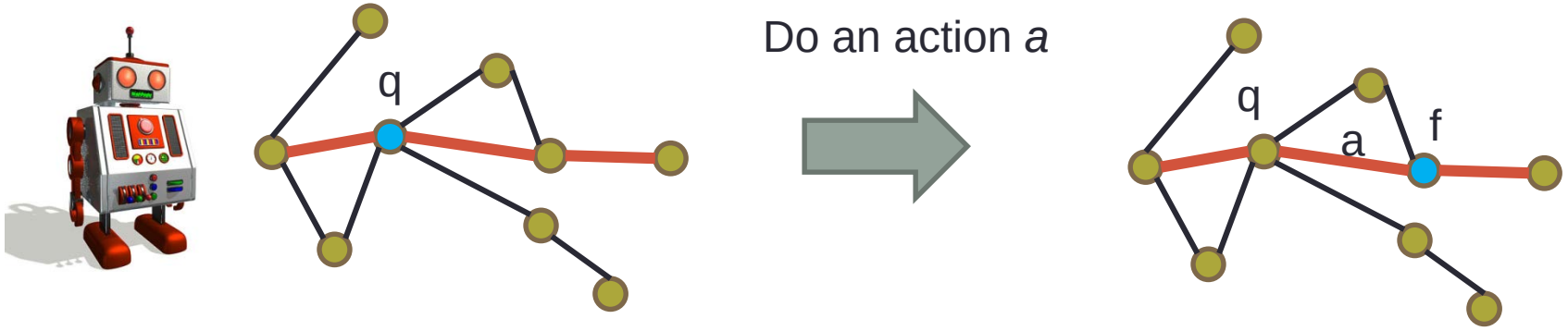
Sirinart Tangruamsub, Manabu Tsuboyama,
Aram Kawewong and Osamu Hasegawa

If-then Rules

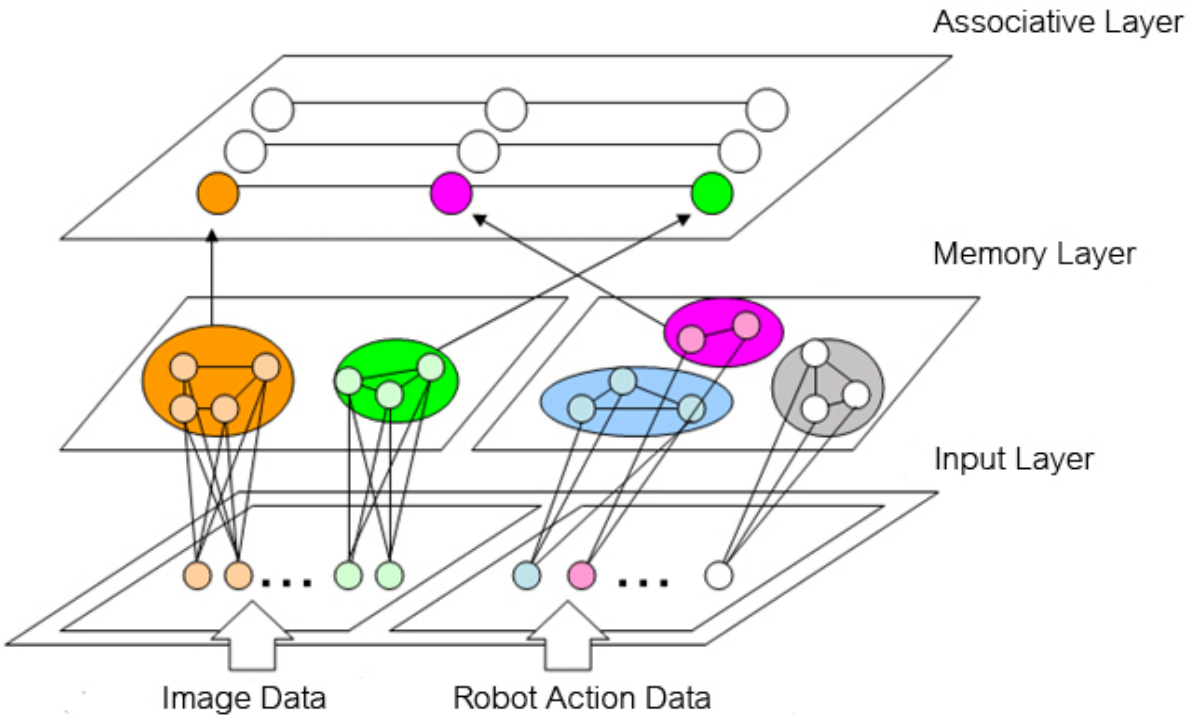
- Use for searching path fragments (from start to goal).

$$q \wedge a \longrightarrow f$$

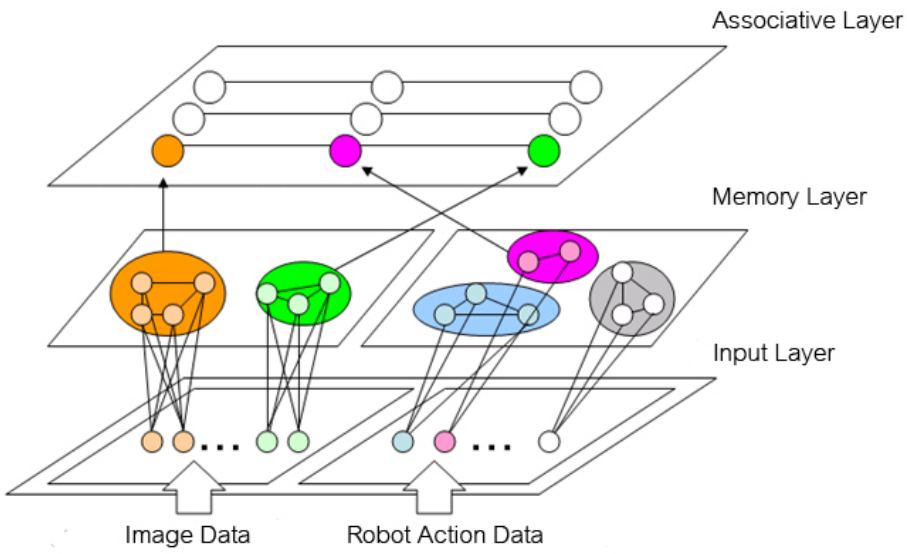
- where
  - *q* = ‘from-position’ or ‘current position’
  - *a* = ‘robot action’
  - *f* = ‘to-position’



SOINN Architecture



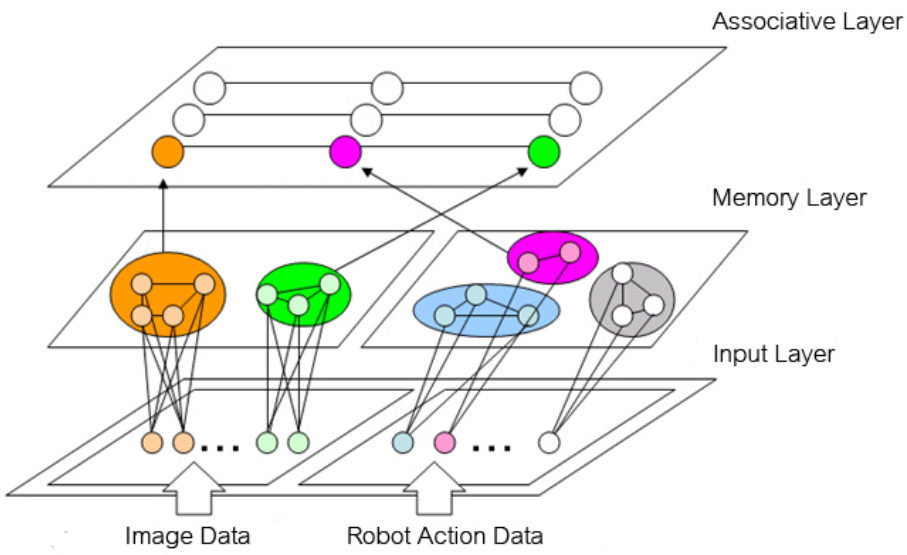
SOINN Architecture



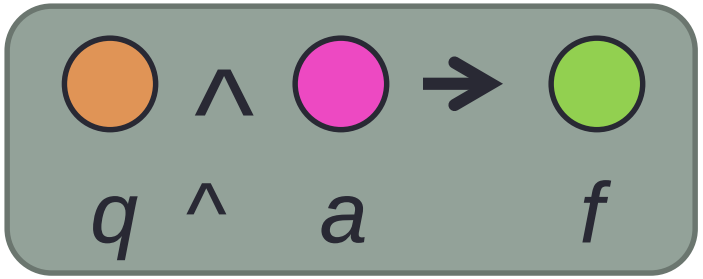
- Input Layer
- Role:
  - Receive data from robot
- We separated this layer into 2 parts
  - Image data (*q*,*f*)
  - Robot action data

- Memory Layer
- Role:
  - Memorize the data pattern from the input layer

SOINN Architecture

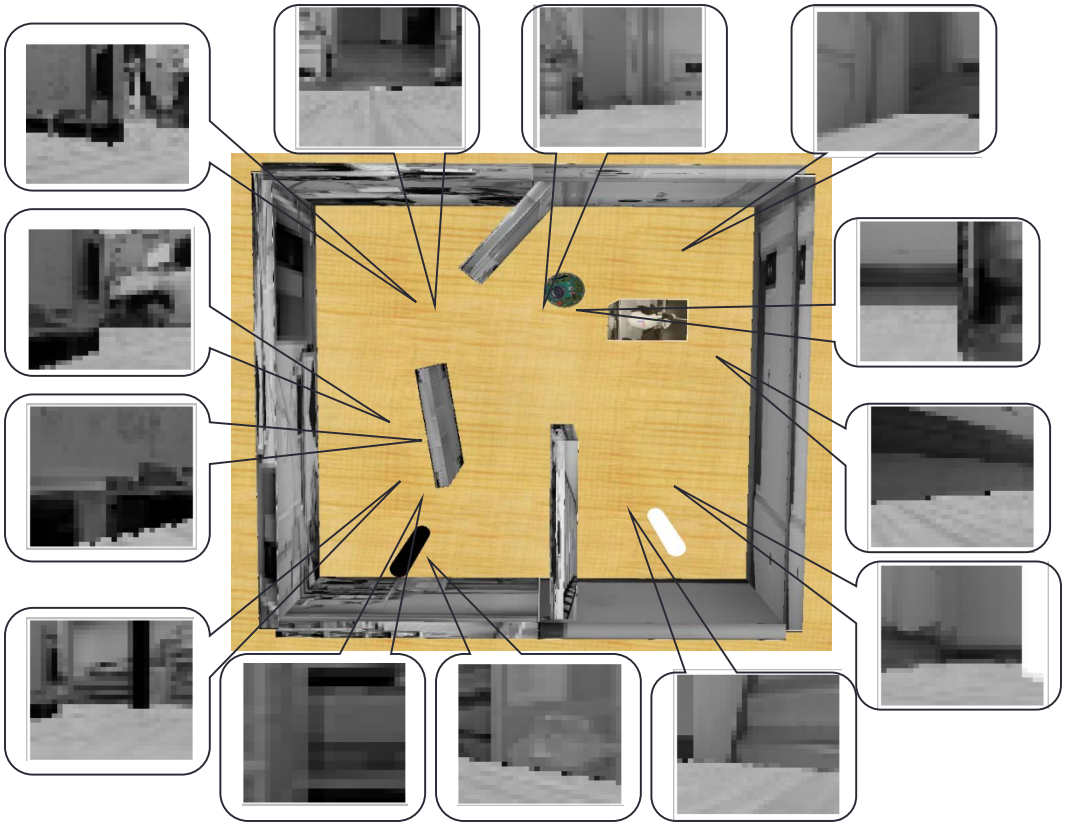


- Associative Layer
- Role:
  - Shows the relation ship between image data and action data (if-then rules).



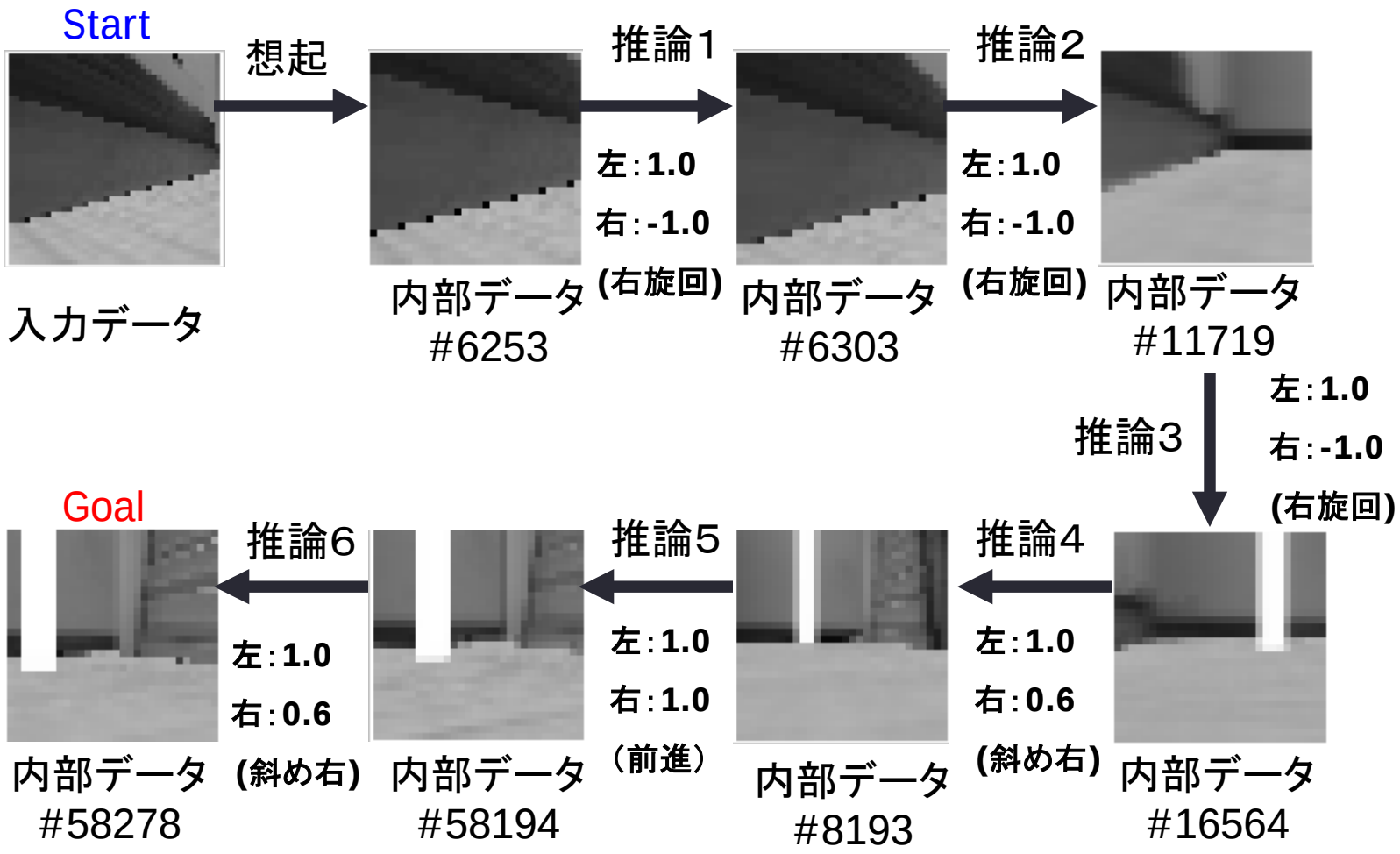
Experiment 1

- Robots automatically learns the associations between images including actions

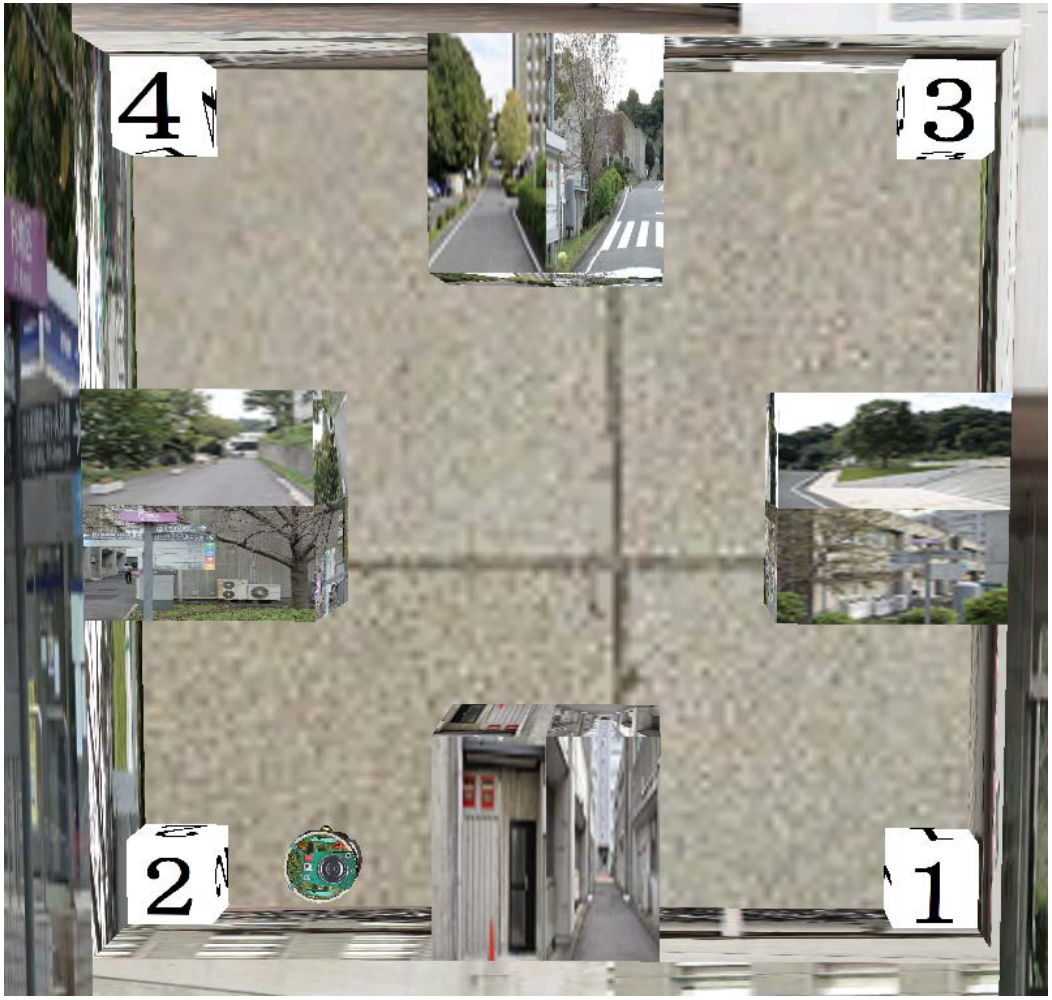


Experiment 1

- Autonomous path planning

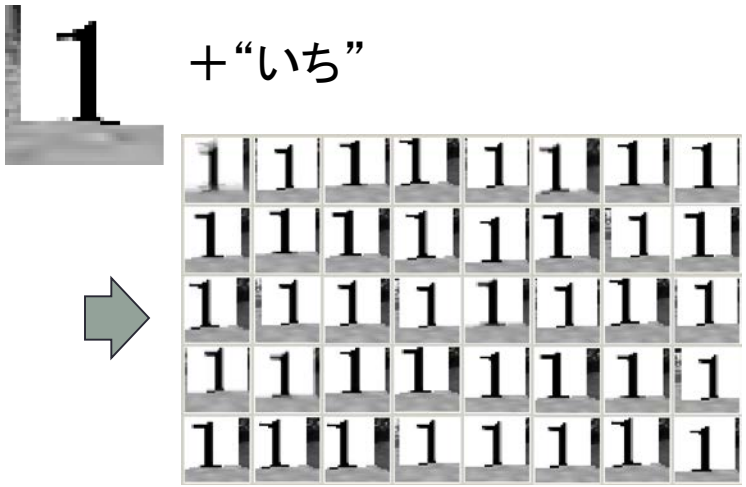


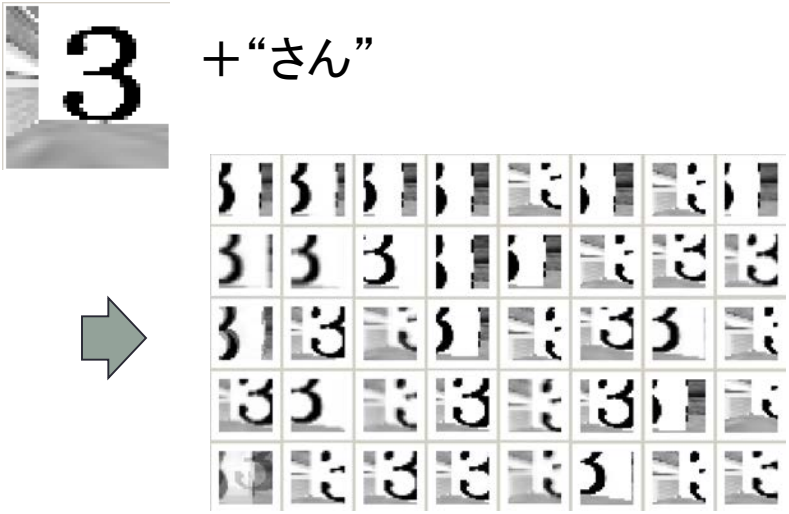
Experiment 2

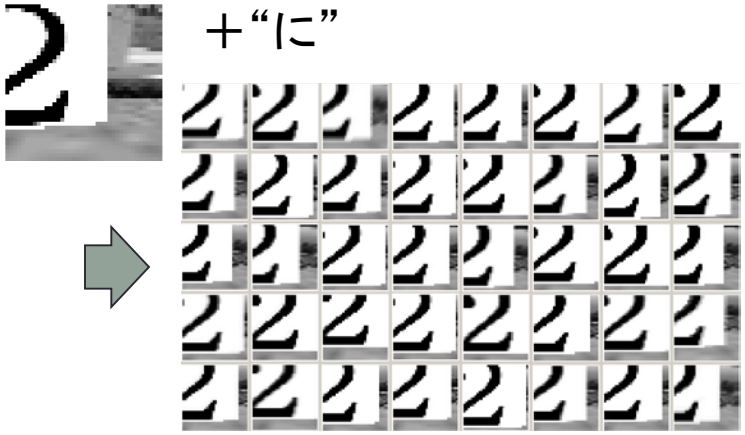


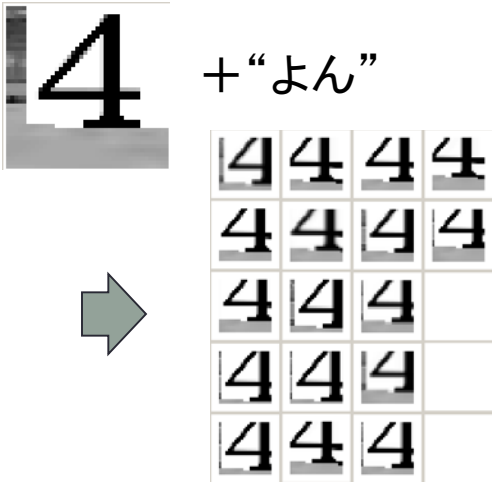
Experiment 2

- Training



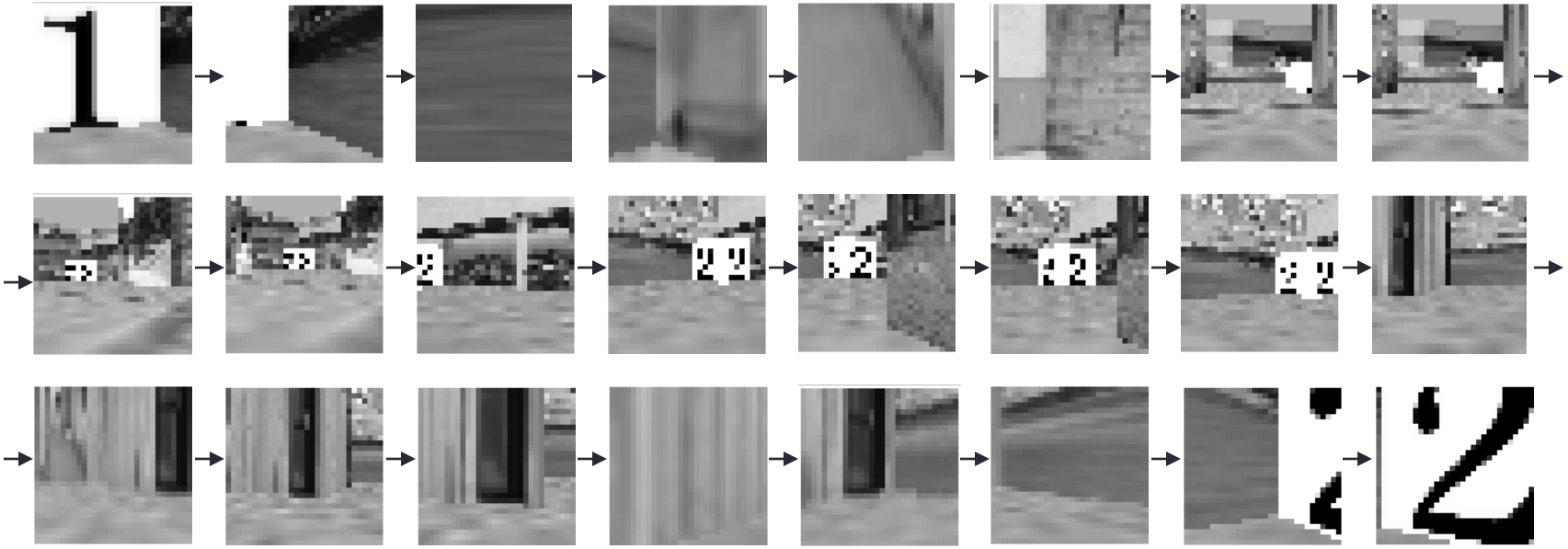






Experiment 2

Autonomous path planning from「いち」to「に」



Experiment in crowded environment

すずかけ台キャンパスすずかけホール　　すずかけ台キャンパスの中央にある建物です。

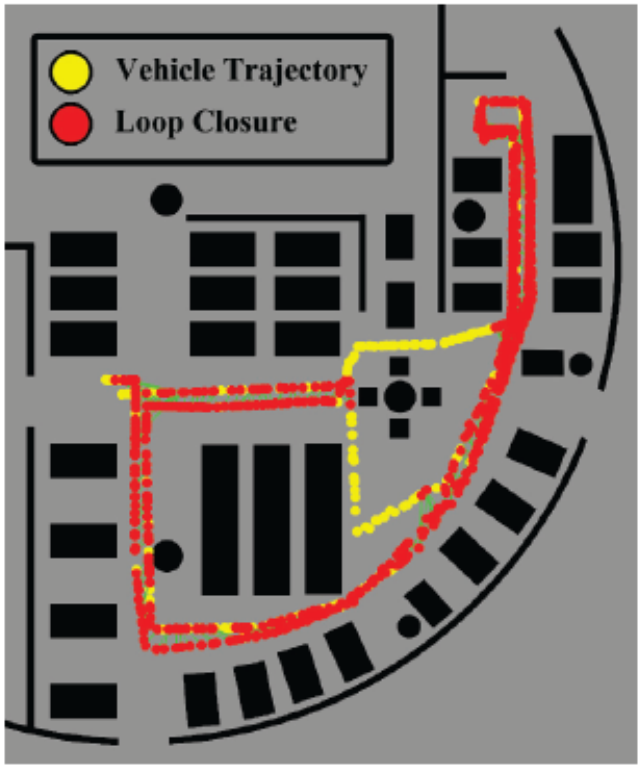


Fig. 8. Vehicle's trajectory. Yellow dots represent the vehicle's trajectory. Red dots represent loop-closure detection.

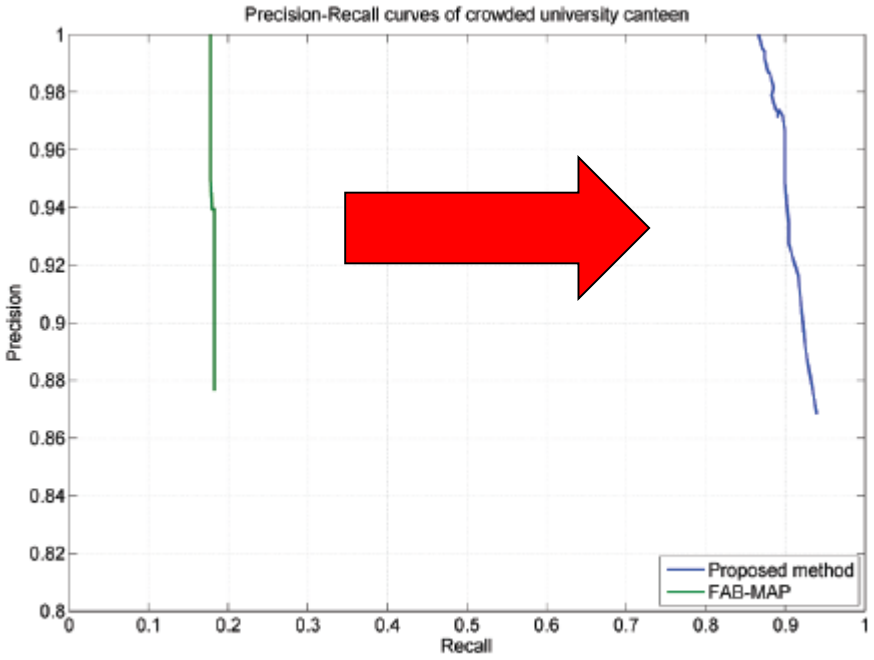


Fig. 9. Precision and recall curves for crowded university canteen.

Autonomous Robot Navigation

全方位カメラ
解像度: 800x600

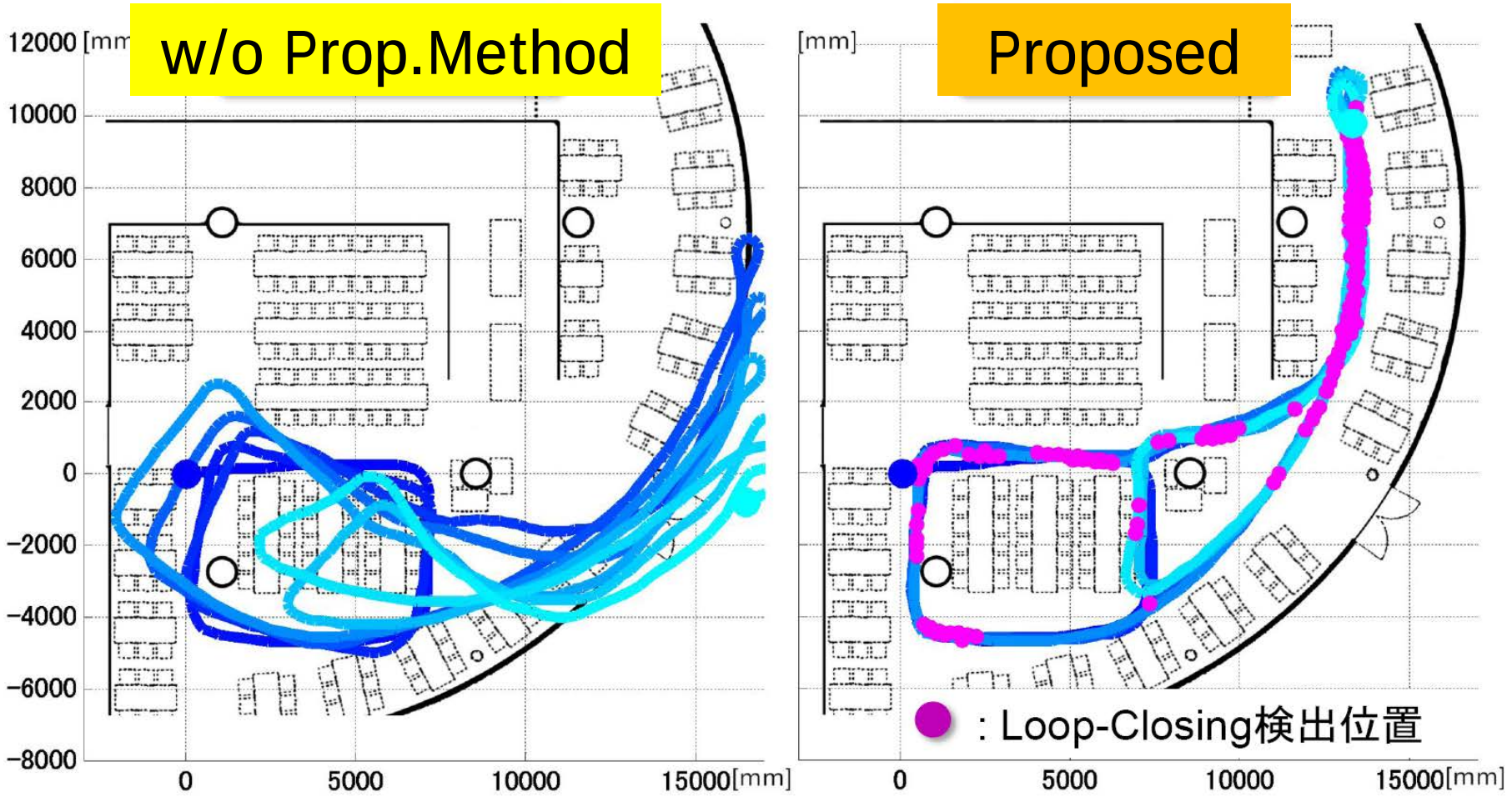
ノートPC
IntelCore2Duo 2.53GHz
メモリ : 2GB
プログラム : MATLAB

ロータリーエンコーダ

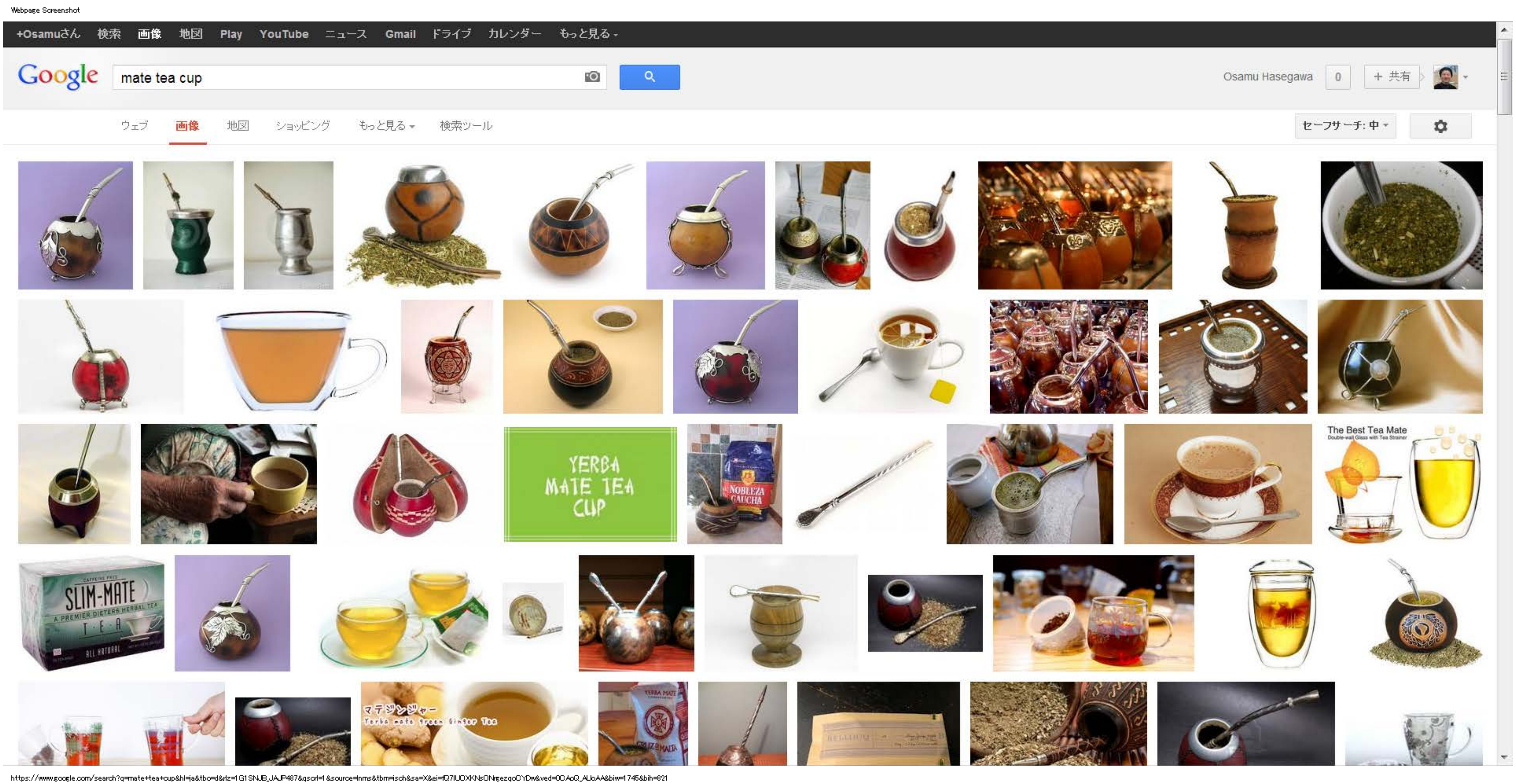
測域センサ

Morioka 2010

Final results



Mate Tea Cup …??

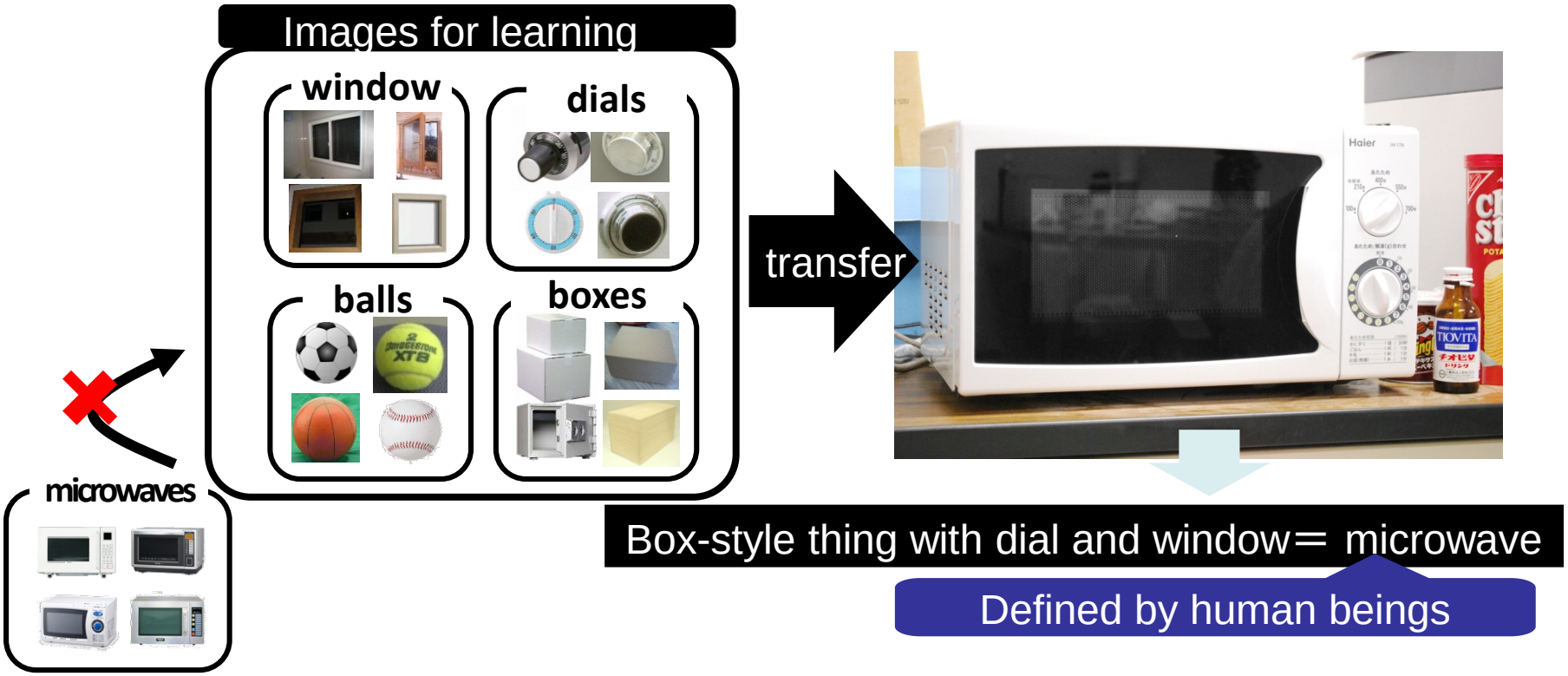

Webpage Screenshot
+Osamuさん 検索 画像 地図 Play YouTube ニュース Gmail ドライブ カレンダー もっと見る
Google
mate tea cup
Osamu Hasegawa
0
+ 共有
ウェブ 画像 地図 ショッピング もっと見る 検索ツール
セーフサーチ: 中
YERBA MATE TEA CUP
SLIM-MATE
The Best Tea Mate

SOINN + internet

- With internet SOINN learns instantly and becomes wiser.
  - High-speed learning and online learning
    - In the ever-changing real world environment, it is extremely difficult to preliminary assume effective attributes.
    - SOINN extracts and decides effective attributes by interacting with human beings and the environment.
  - Internet information is extremely noisy.
    - SOINN is highly noise-resistant.

Transfer Learning

- SOINN learns basic concepts (“attributes”), not objectives
- SOINN recognizes non-pre-learned objectives by combining attributes.



Alphabet and Dictionary.

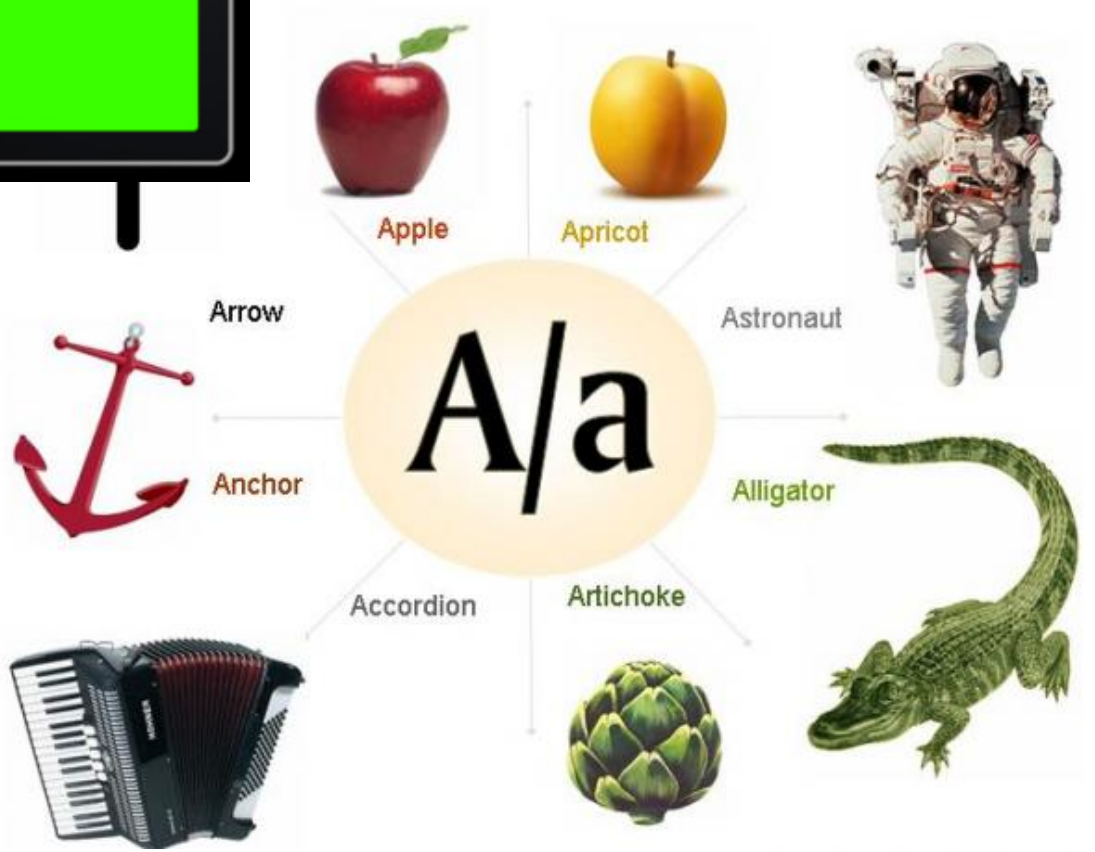
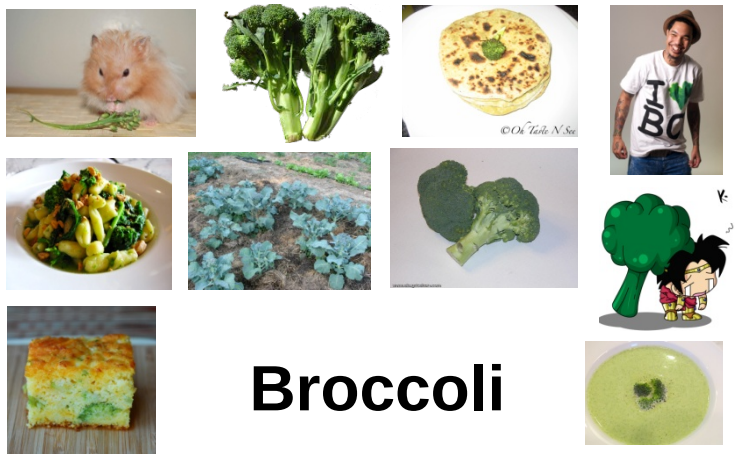
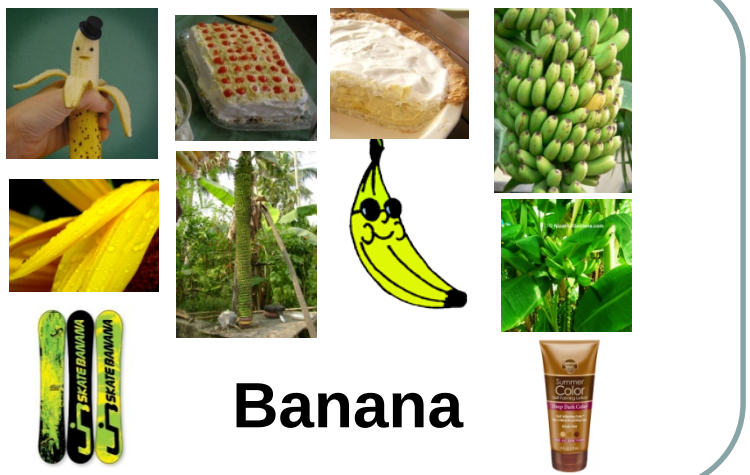


Image examples for experiments

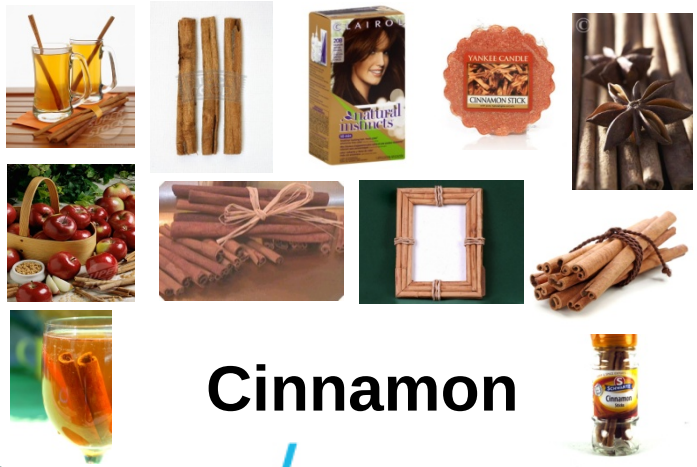
Tomato



Broccoli



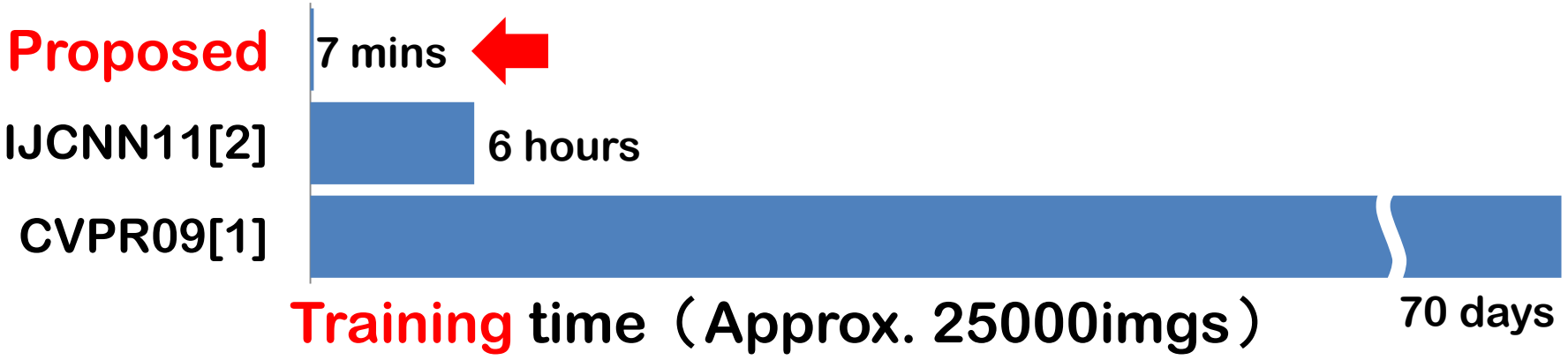
Banana



Cinnamon

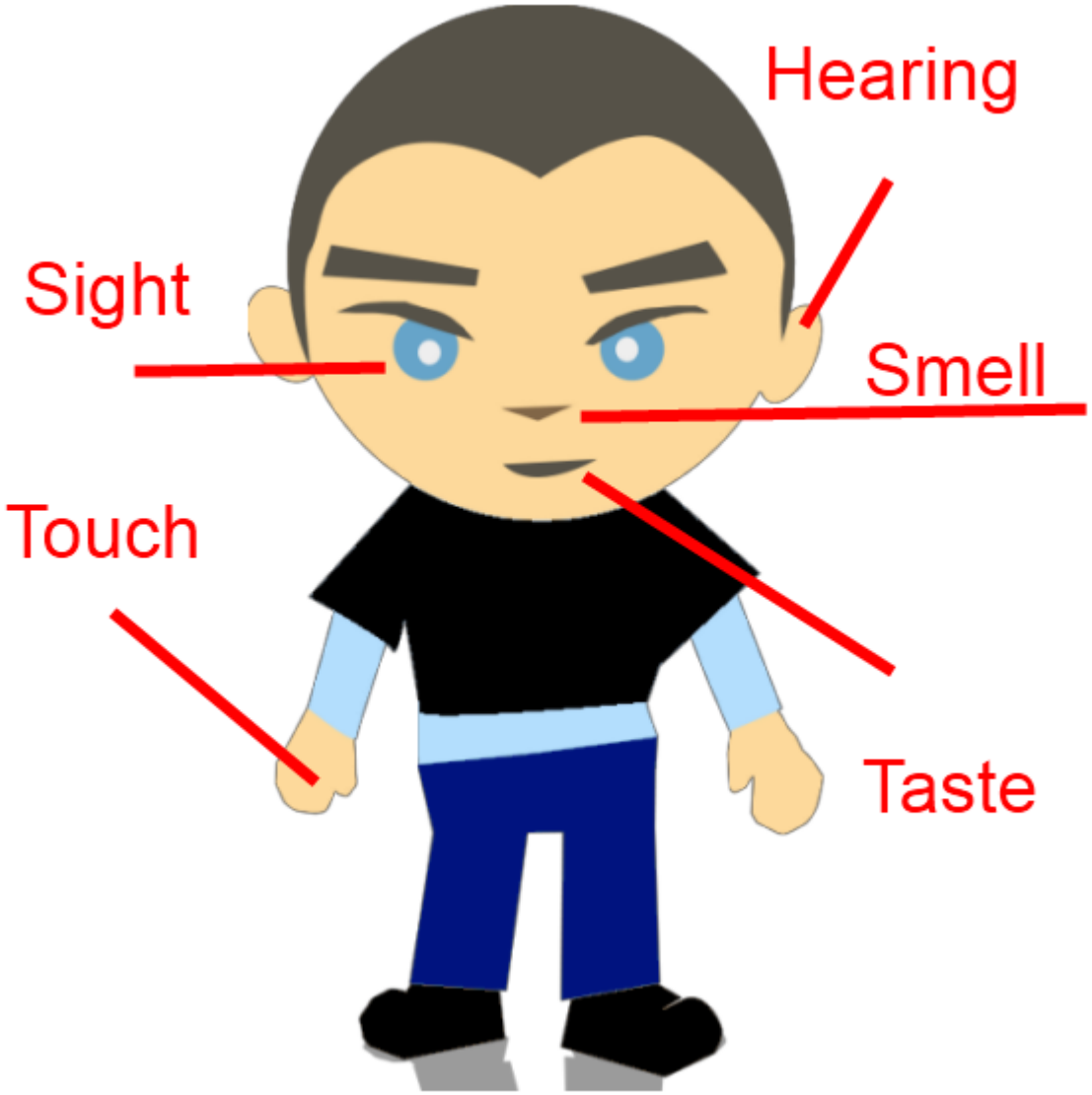
“Guess unknown objects”

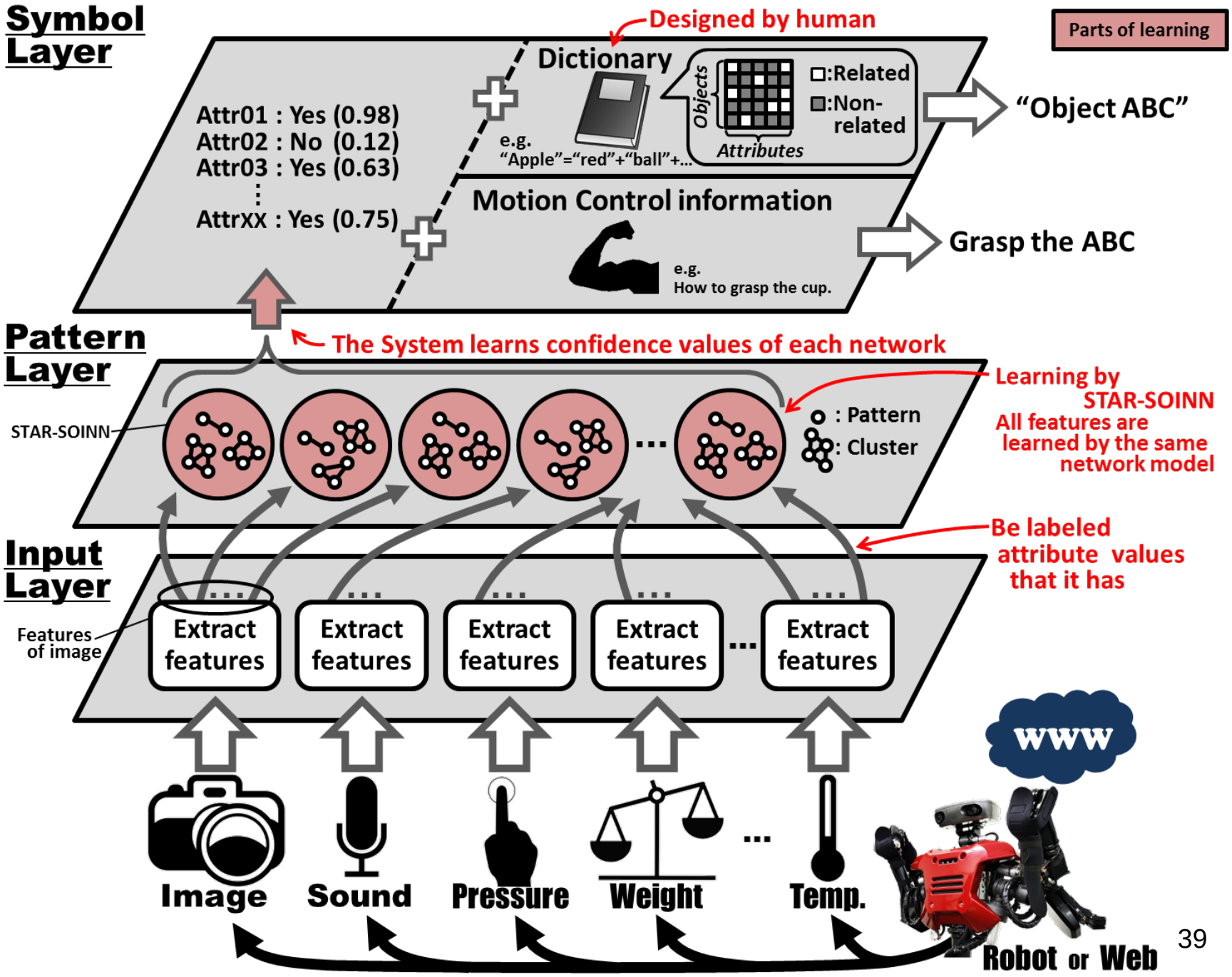
Results



Without time to extract features

We have many modalities.




Symbol Layer
Designed by human
Parts of learning
Dictionary
Objects
Attributes
□:Related
■:Non-related
e.g.
"Apple"="red"+"ball"+...
"Object ABC"
Attr01 : Yes (0.98)
Attr02 : No (0.12)
Attr03 : Yes (0.63)
AttrXX : Yes (0.75)
Motion Control information
e.g.
How to grasp the cup.
Grasp the ABC
Pattern Layer
The System learns confidence values of each network
Learning by STAR-SOINN
All features are learned by the same network model
STAR-SOINN
: Pattern
: Cluster
Input Layer
Be labeled attribute values that it has
Features of image
Extract features
Extract features
Extract features
Extract features
Extract features
Image
Sound
Pressure
Weight
Temp.
www
Robot or Web

Modalities of SOINN Robot

1. Image
2. Sound
3. 3D-Info
4. Pressure
5. Weight

SOINN robot also learn Weight of attributes.

*Attribute of "Wooden" is mostly understood by **Sound***

Mate tea cup


→ Image

→ Depth


→ Sound

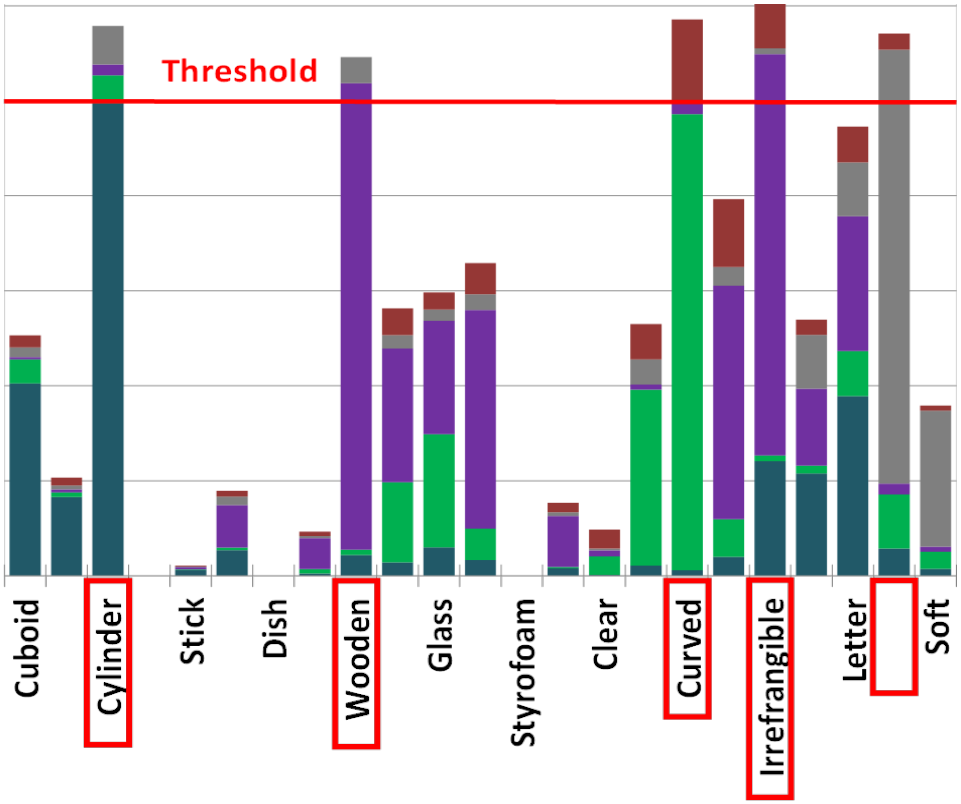

→ Pressure


→ Weight

e.g.,

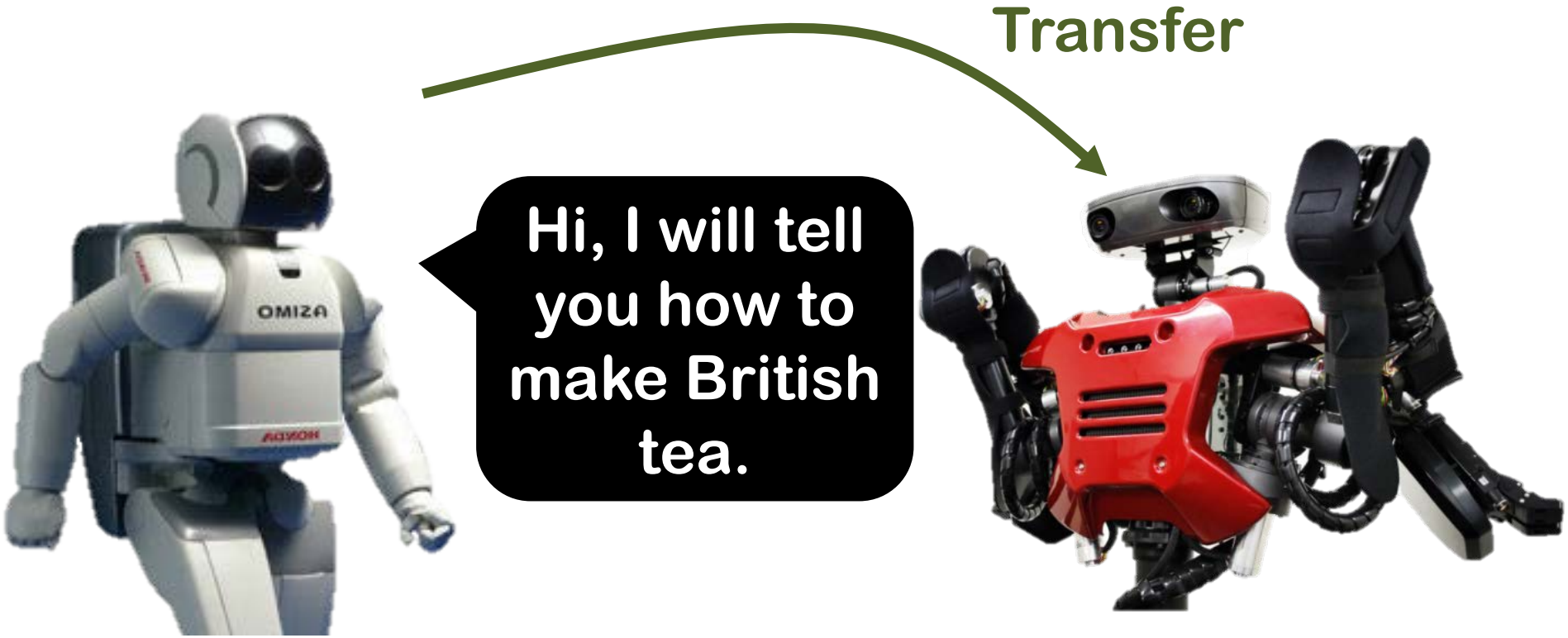
Wooden -attr

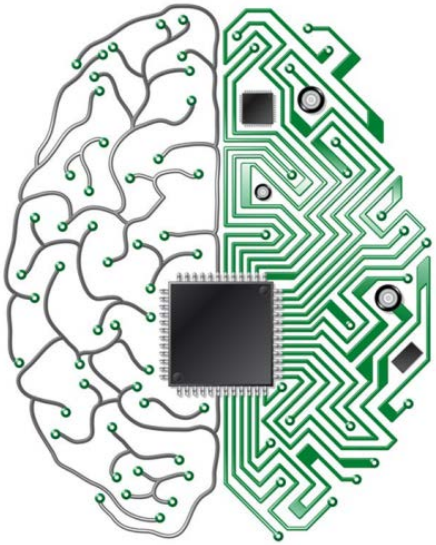
- Image
- Depth
- **Sound**
- Pressure
- Weight

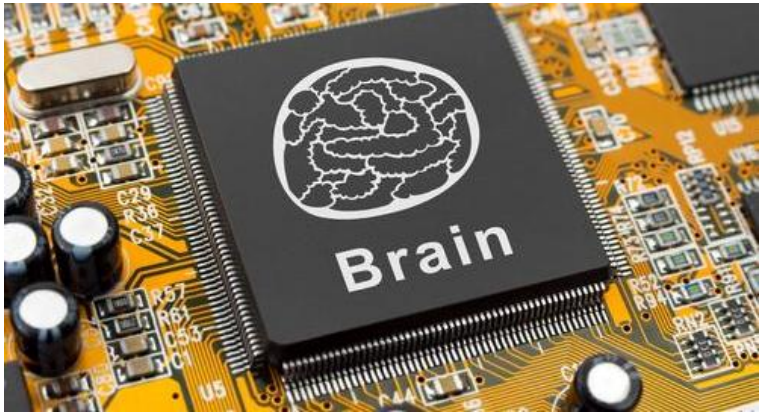


Robots teaching robots

- Knowledge **transfer** between robots







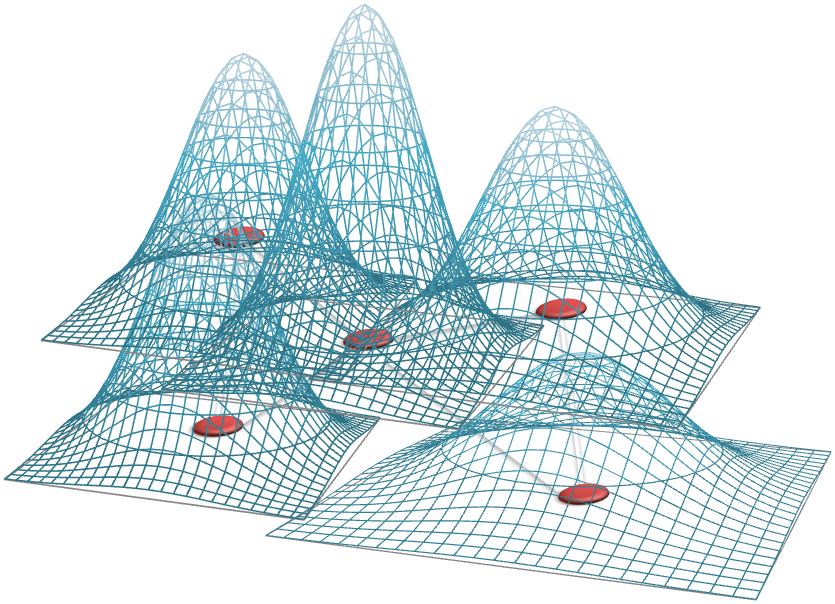
In the future, people will grow up with her/his own Artificial Brain to supplement brain functions.

MY Artificial Brain, Always with Me !

Appendix

SOINNによる超高速・汎用確率密度推定

$$\hat{p}(\boldsymbol{x}) = \sum_{n \in \mathcal{N}} \frac{t_n}{T_{\mathcal{N}}} K_{\boldsymbol{C}_n}(\boldsymbol{x} - \boldsymbol{w}_n)$$



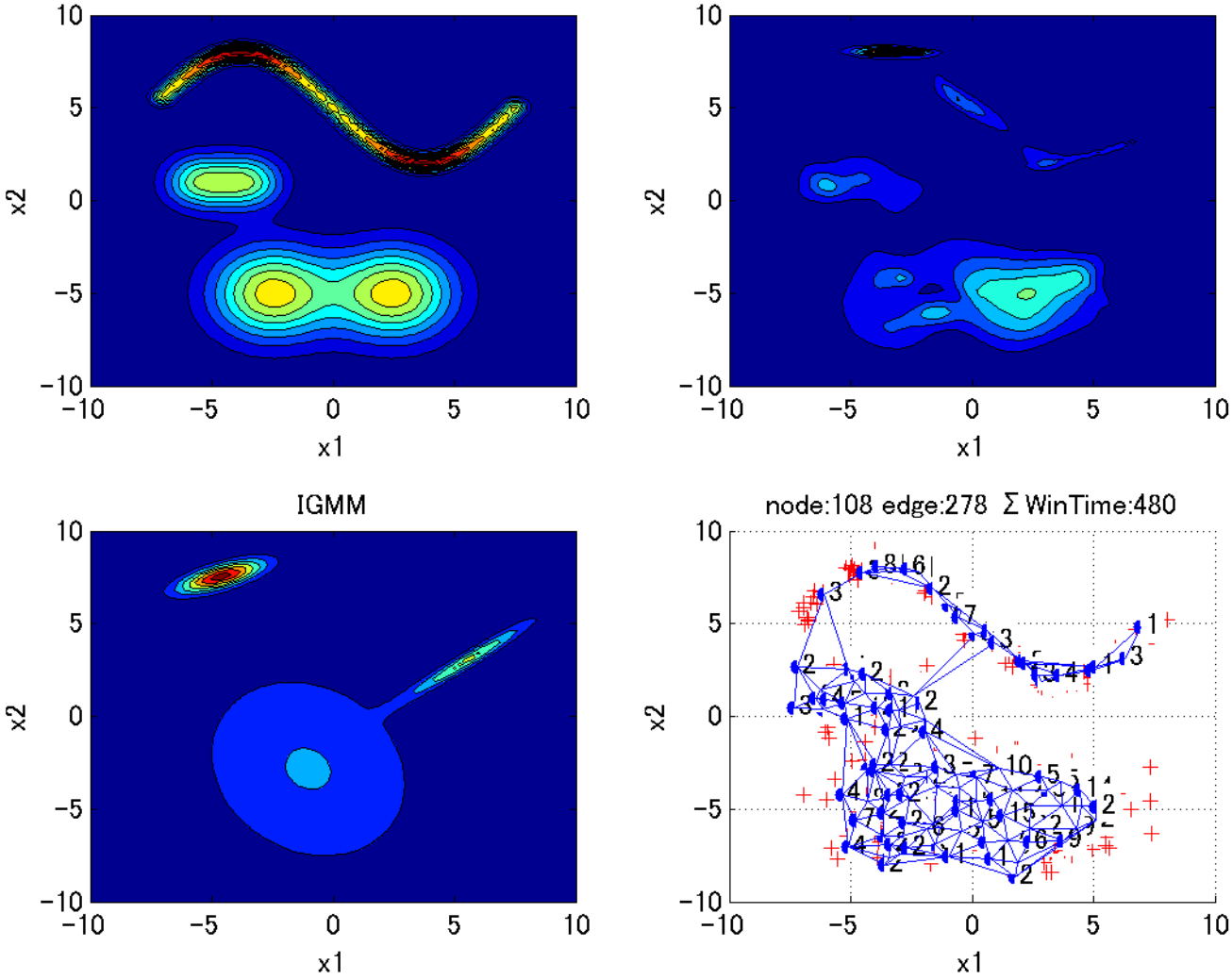
$\mathcal{N}$:ノードの全体集合

$\boldsymbol{w}_n$:ノード n の位置ベクトル

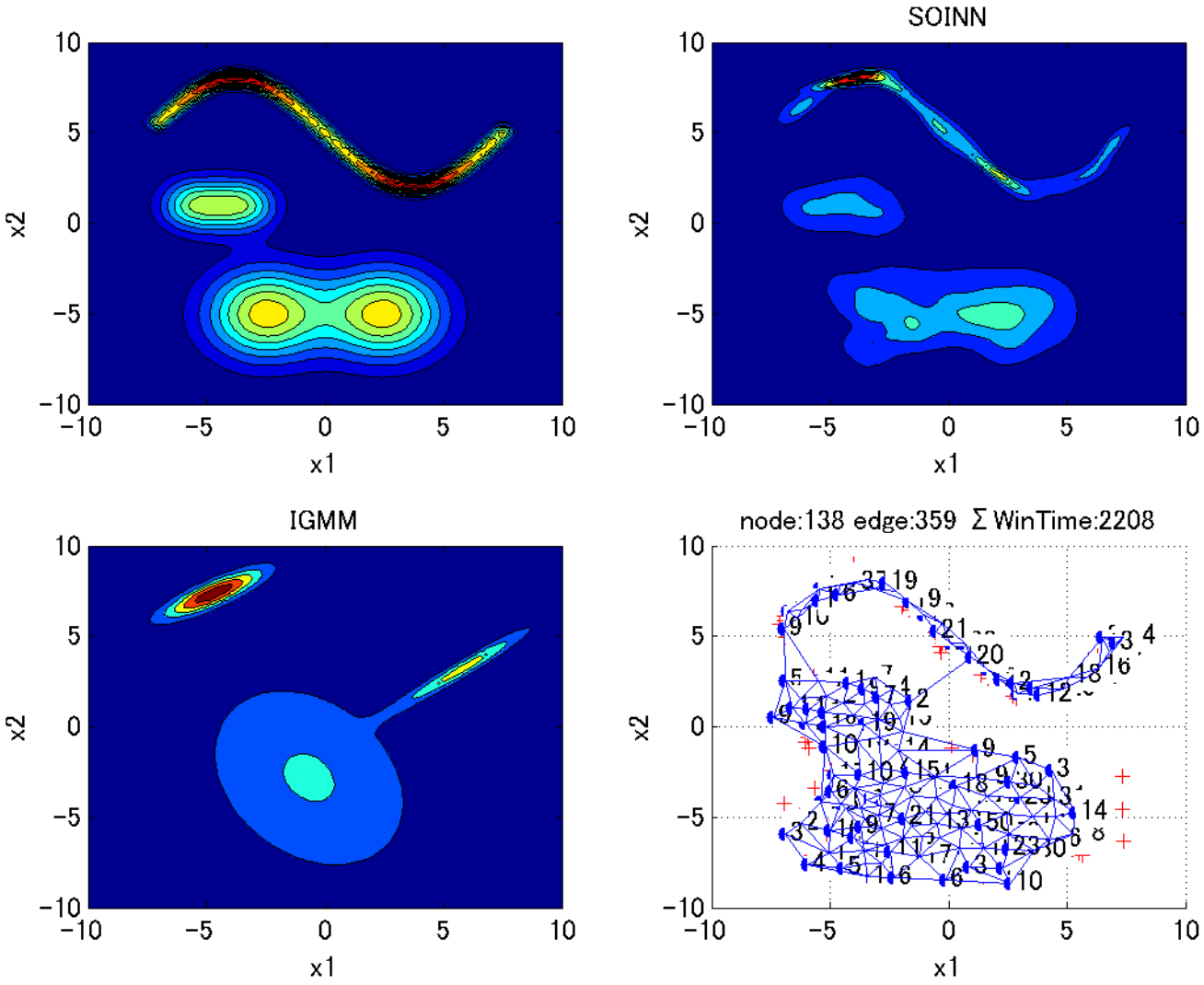
t_n :ノード n が競合学習で勝者になった回数

$T_{\mathcal{N}} = \sum_{n \in \mathcal{N}} t_n$

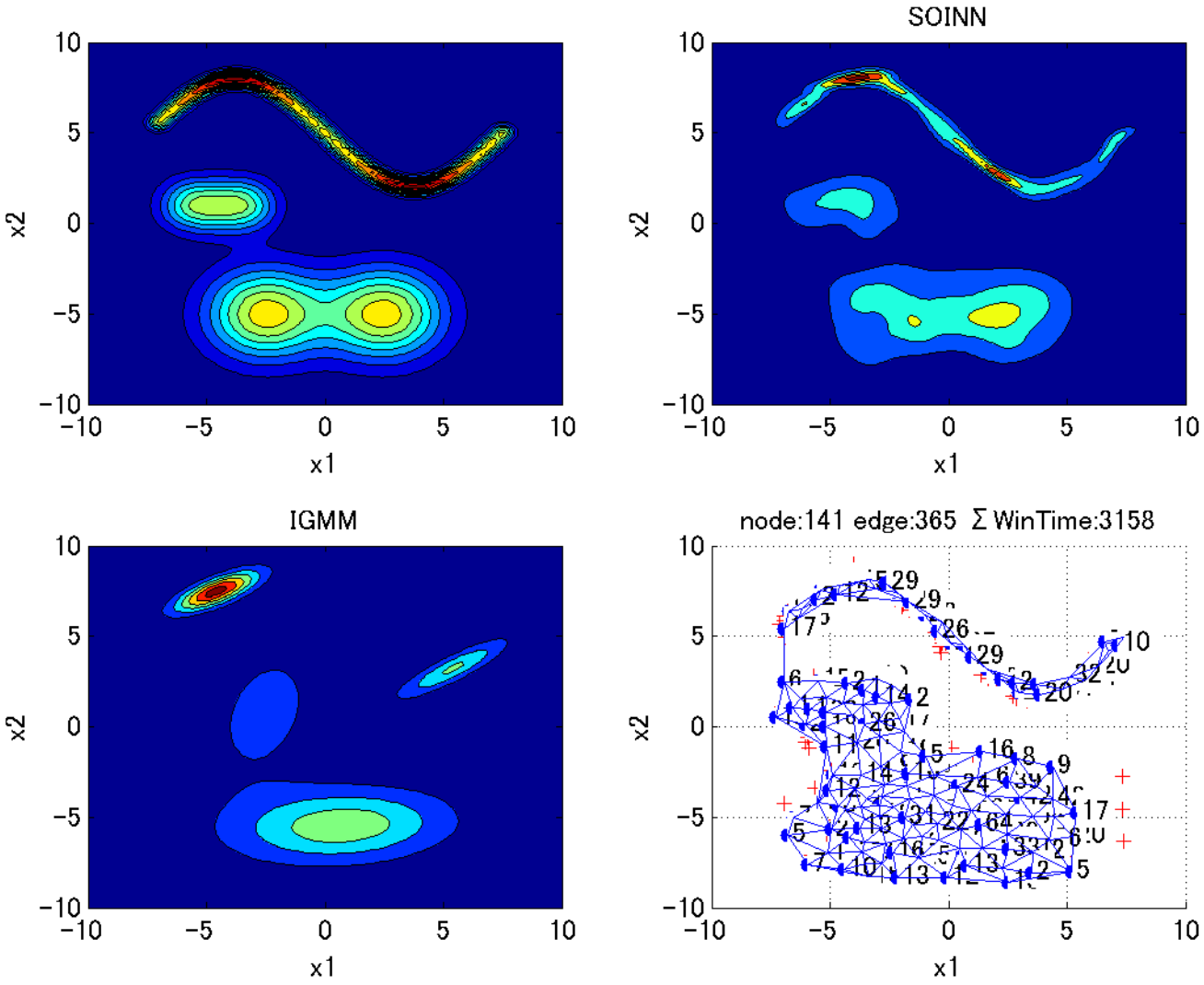
$K_{\boldsymbol{H}}(\boldsymbol{x}) = \frac{1}{\sqrt{(2\pi)^d |\boldsymbol{H}|}} exp\left(-\frac{1}{2}\boldsymbol{x}^T \boldsymbol{H}^{-1} \boldsymbol{x}\right)$: Gauss Kernel



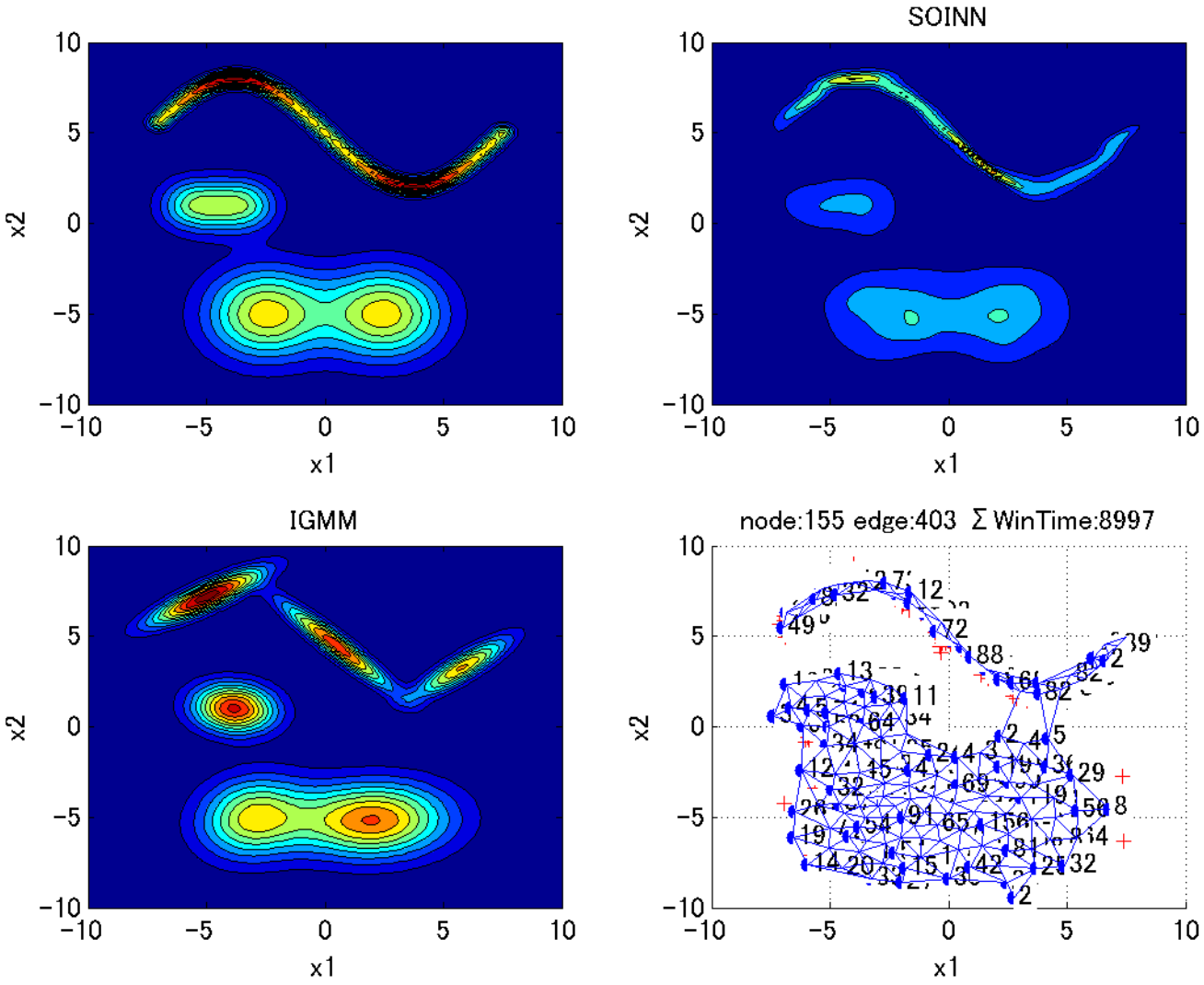
SOINN vs Infinite Gaussian mixture model (IGMM)



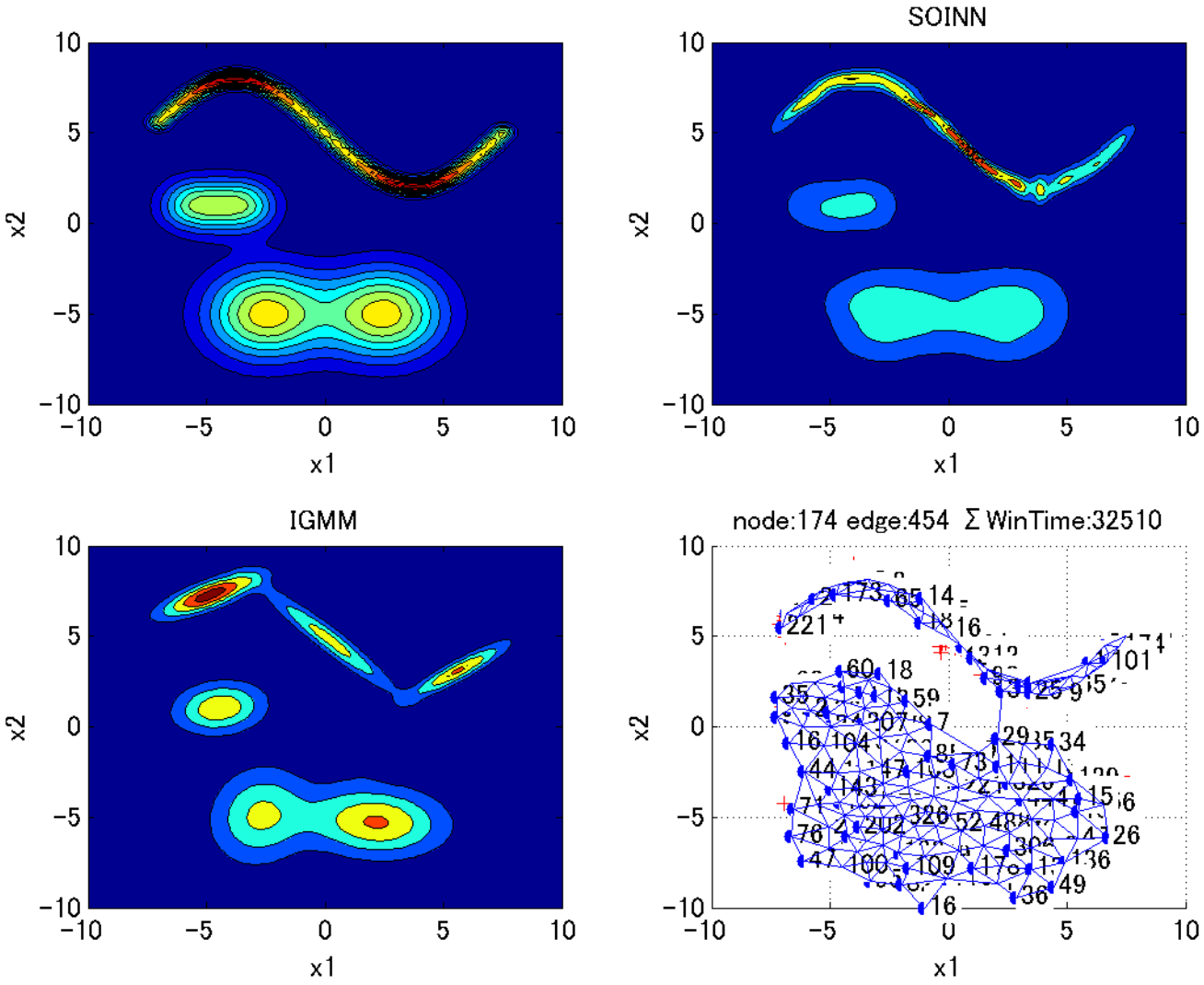
SOINN vs Infinite Gaussian mixture model (IGMM)



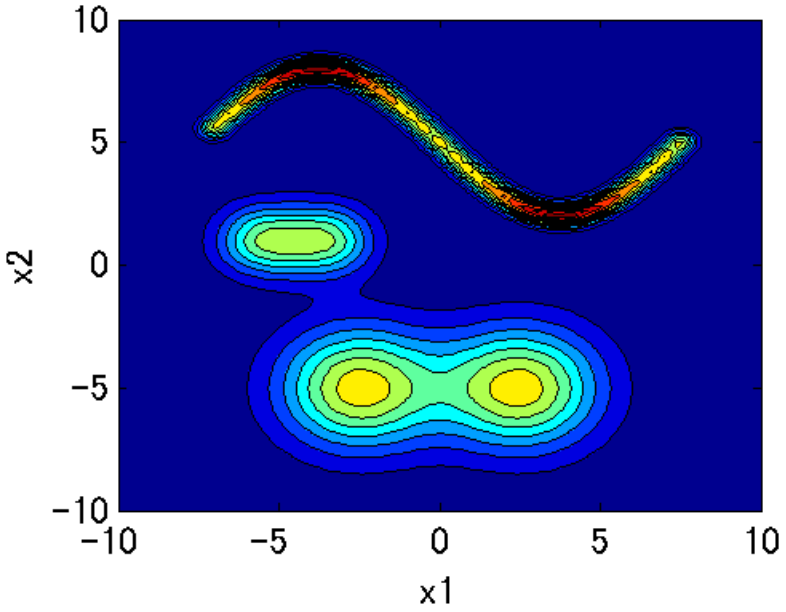
SOINN vs Infinite Gaussian mixture model (IGMM)

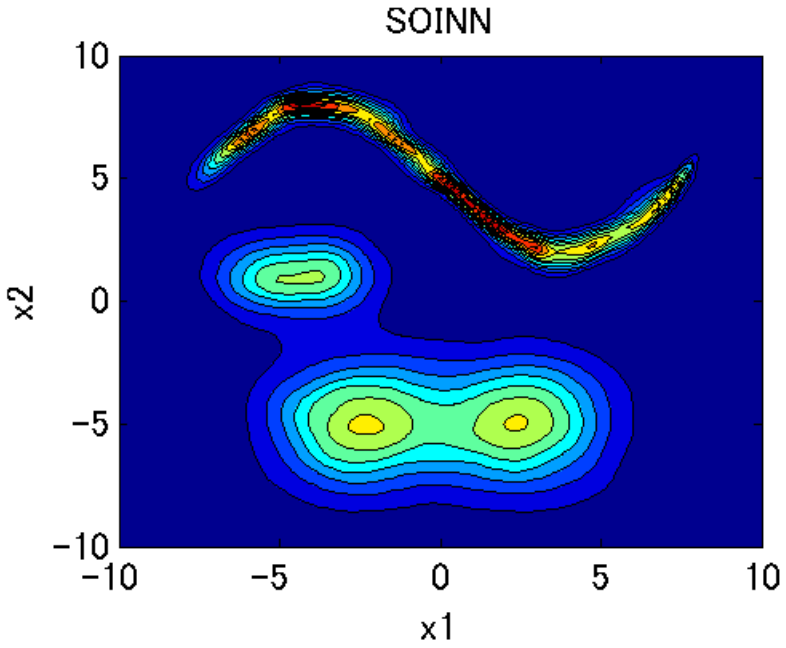


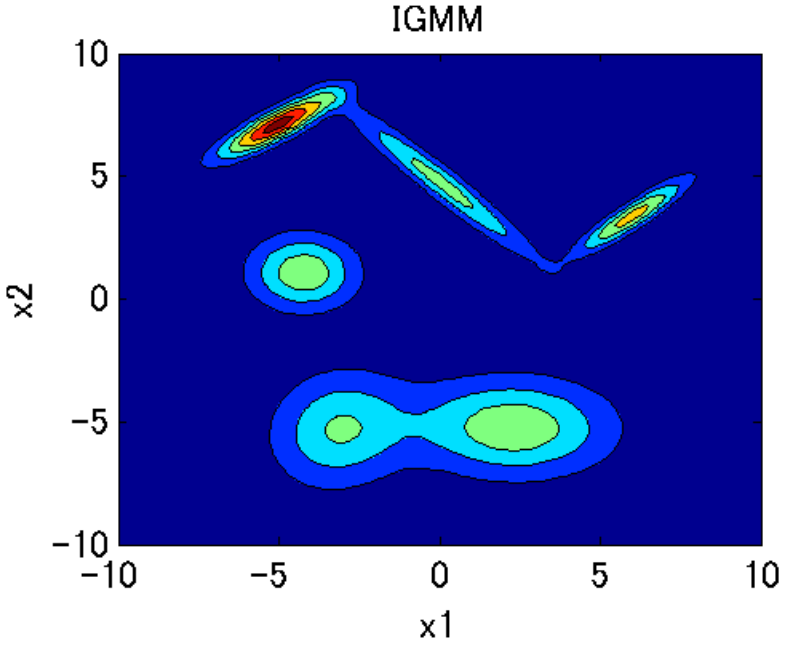
SOINN vs Infinite Gaussian mixture model (IGMM)

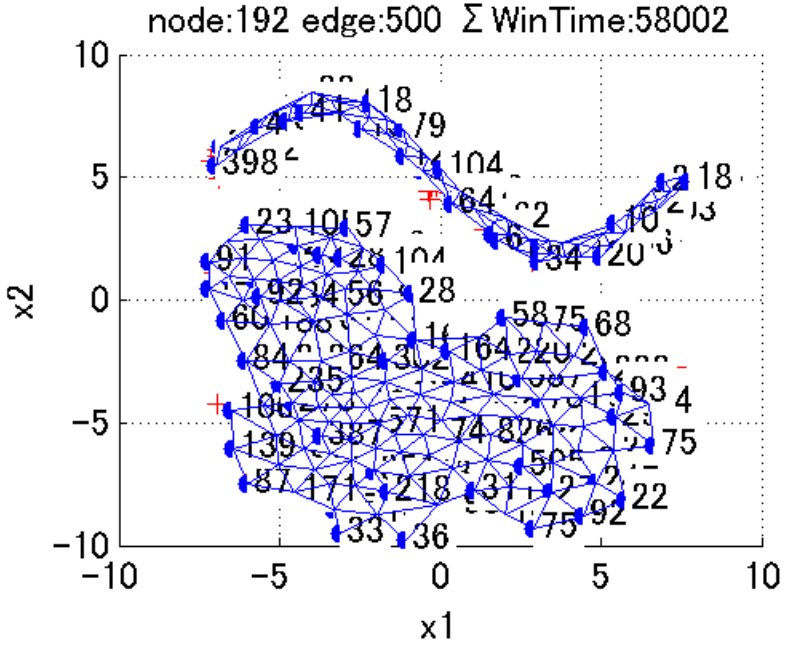


SOINN vs Infinite Gaussian mixture model (IGMM)


10
5
0
−5
−10
x2
−10
−5
0
5
10
x1

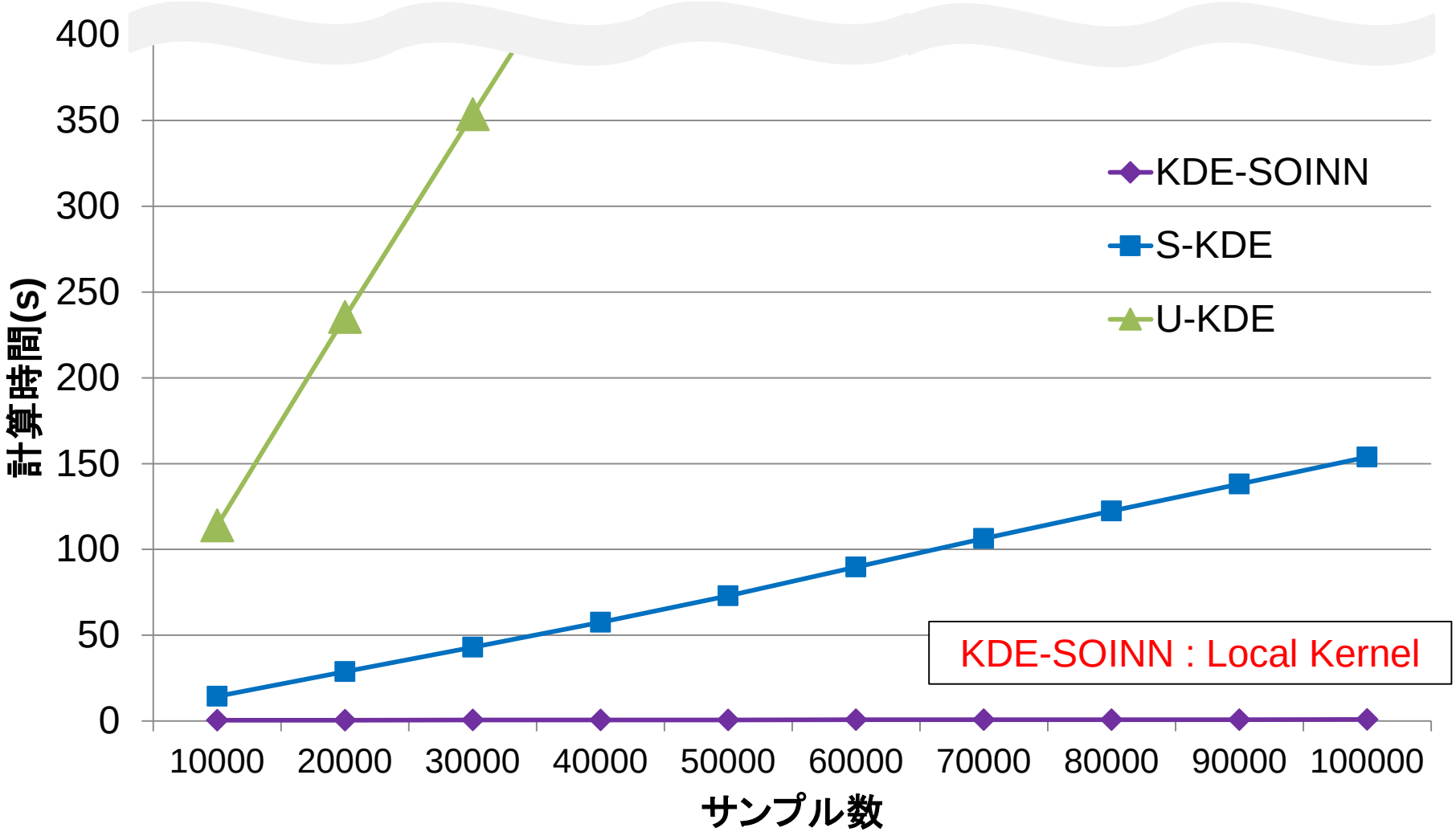

SOINN
10
5
0
−5
−10
x2
−10
−5
0
5
10
x1


IGMM
10
5
0
−5
−10
x2
−10
−5
0
5
10
x1

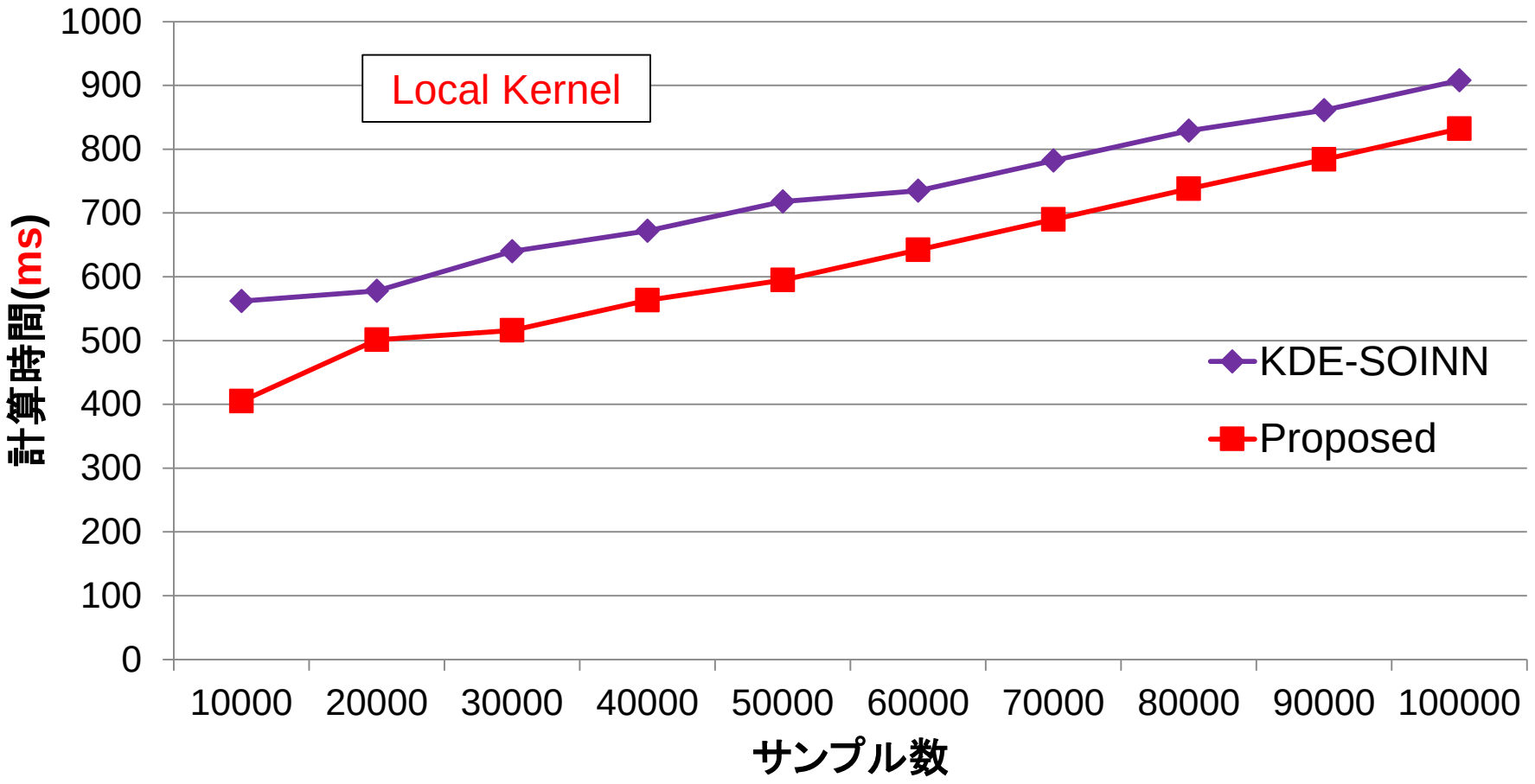

node:192 edge:500 Σ WinTime:58002
10
5
0
−5
−10
x2
−10
−5
0
5
10
x1

実験：計算時間

S-KDE : $H = \sigma^2 I$ (行列計算なし)
U-KDE : H (行列計算あり)



実験：計算時間(前頁の拡大図)



サンプル数が10倍に増えても計算時間は2倍程度の増加に収まっている！