About “Sensor Engineering” class

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My profile

Name : Atsushi Saito

Age : 55

Background:

- Bachelor's, Master's, and Doctor's degree(2000.3) from SIT
- 1995 ~ 1997 : Research assistant in TIT
- 2000.4 ~ : Lecturer, Associate Prof. in SIT.

Research field :

Sensor engineering, especially chemical sensor, and its application

What is sensor engineering?

Sensor engineering is …..

- Development of sensors to get data we want
- Development of electronic circuits to get signal we want
- Study of signal processing to get desired data that is reduced noise and unwanted signal
- Study of data processing to get useful information from measured data

Key words of this class

- Biomimetic technique in sensor engineering
  - for development of sensor device, data processing…
- Sensor device + “something”
  - to improve sensor response property
- Multi sensor system and its data processing
  => Sensor (data) fusion technique
  - to recognize more complex sensing objects

Contents of This Class

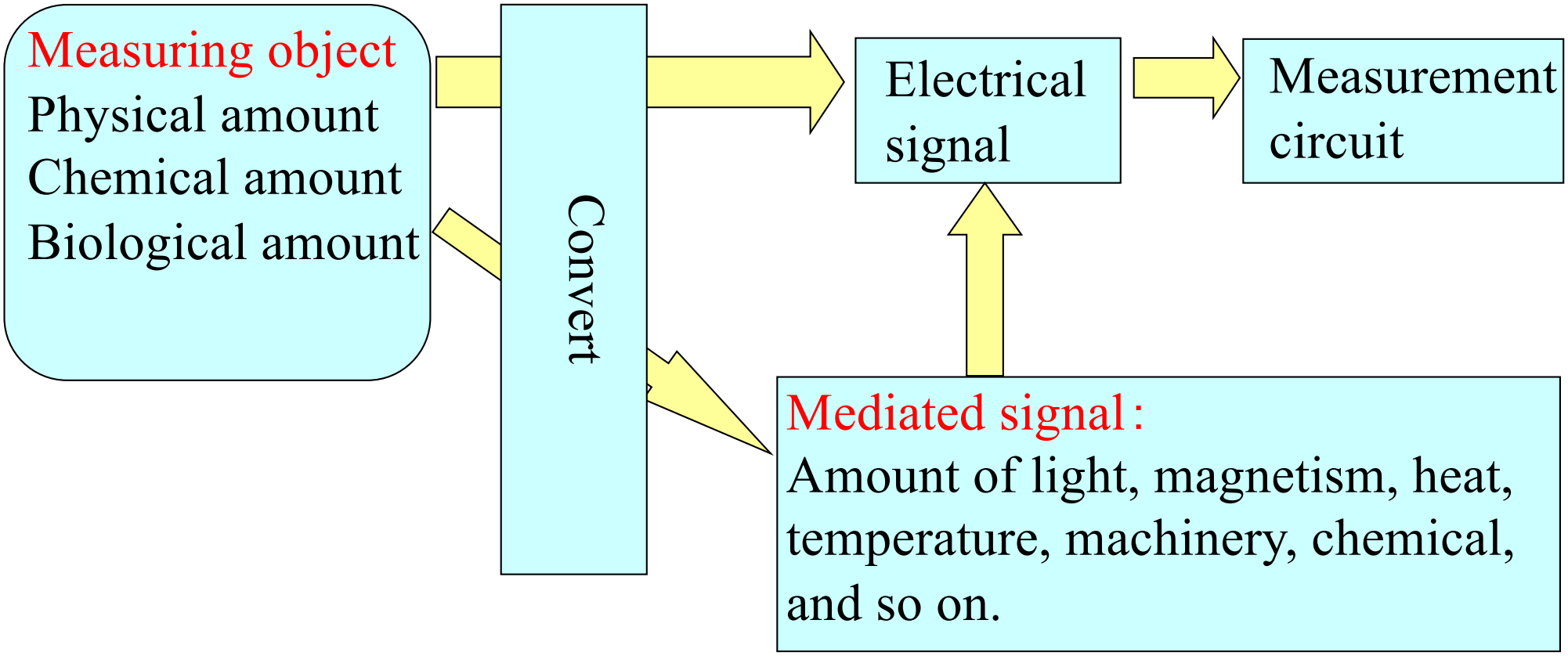
- Introduction of sensor devices and its applications
  - Tactile sensors
  - Taste sensors
  - Olfactory sensors
- Introduction of measurement circuits
- Practice of measurement using sensor
  - Temperature measurement using thermistors
    => Modeling of sensor response process
- Introduction and practice of sensor data processing

Introduction of my Lab's work

- Simple measurement circuit
- Odor sensor and odor recognition
- Multi sensor system as a gas sensor's application
  ⇒ Daily activities monitoring using multi sensor system

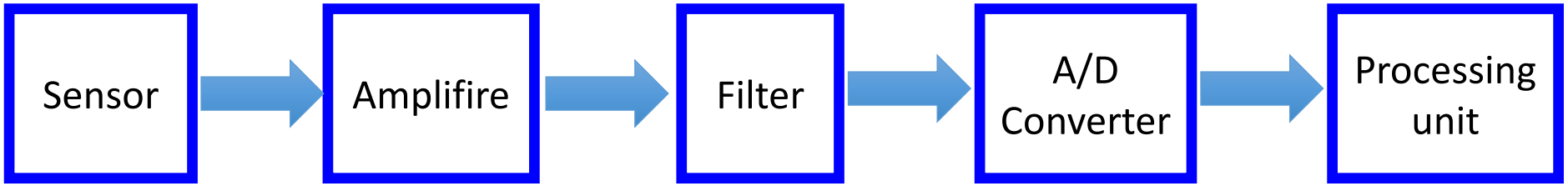
What is sensor?

Amount of measuring object → convert → Electrical signal



And sensor can realize *expanding our sense*!!

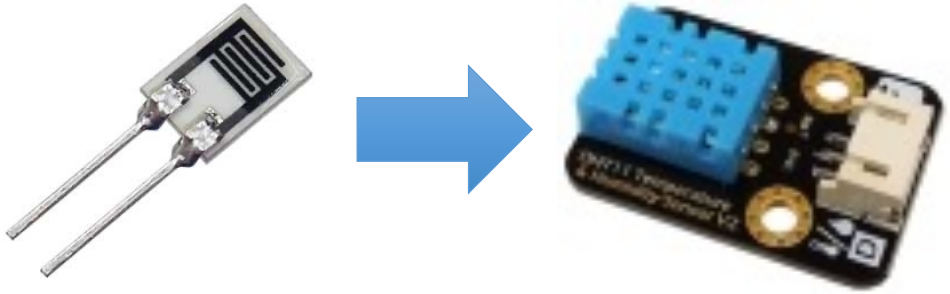
General composition of measurement system using sensor



- PC
- Micro Controller

In these day, sensor includes suitable circuit for sensor device on board.

For example, humidity sensor



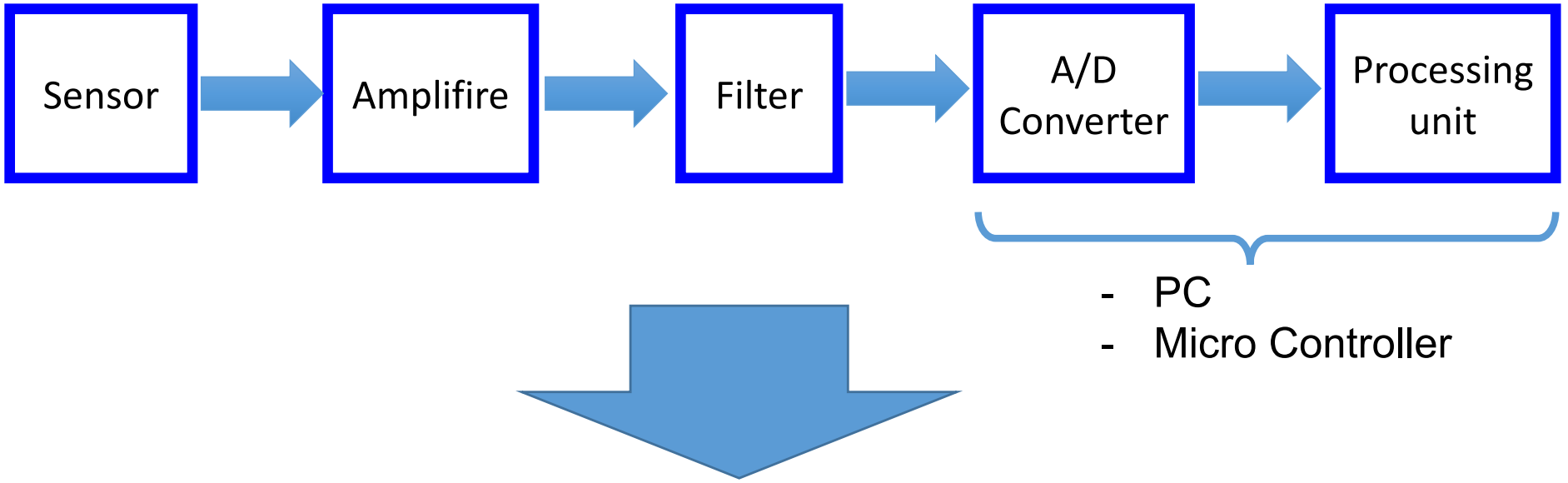
- Sensor
- Amp.
- Filter
- A/D converter
- Communication

Example for
“Development of sensing circuit…”

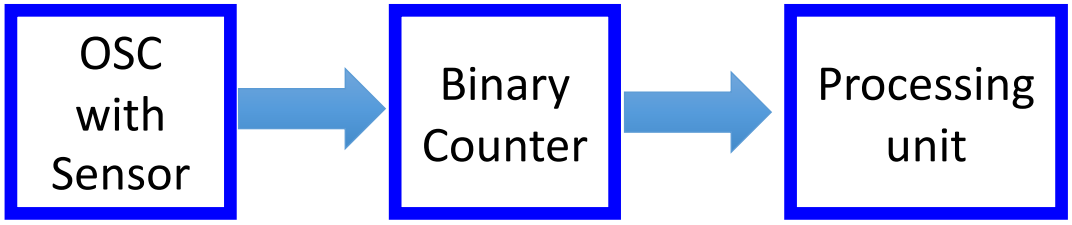
Simple sensing circuit using oscillator for measurement of environmental change

Simple Measurement Circuit

General composition of measurement system



In our lab, a simple circuit is used for measurement.



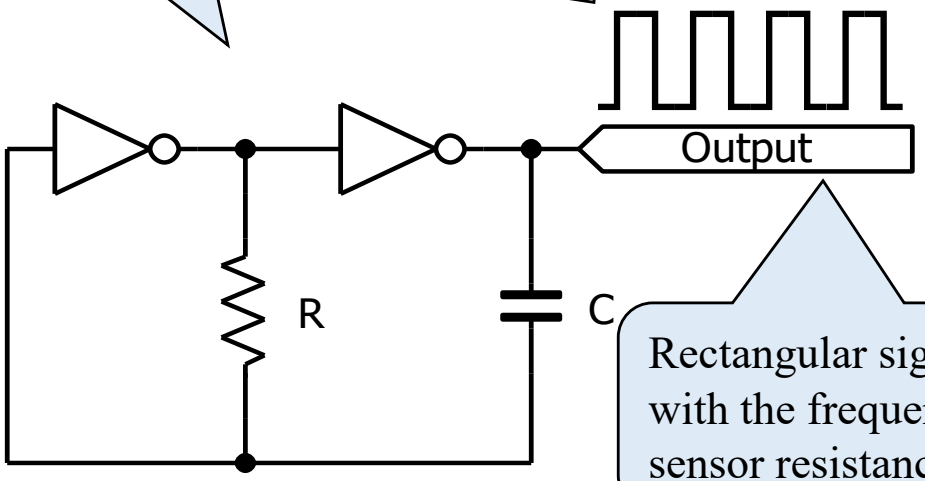
Sensing based on frequency measurement

Resistance (or capacitance) type sensor + Oscillator circuit

➡ Resistance change → Frequency change

Simple circuit

Signal's period is proportional to sensor resistance (or capacitance)



Astable multi vibrator using CMOS invertor

Rectangular signal (digital pulse) with the frequency depending on sensor resistance (or capacitance)

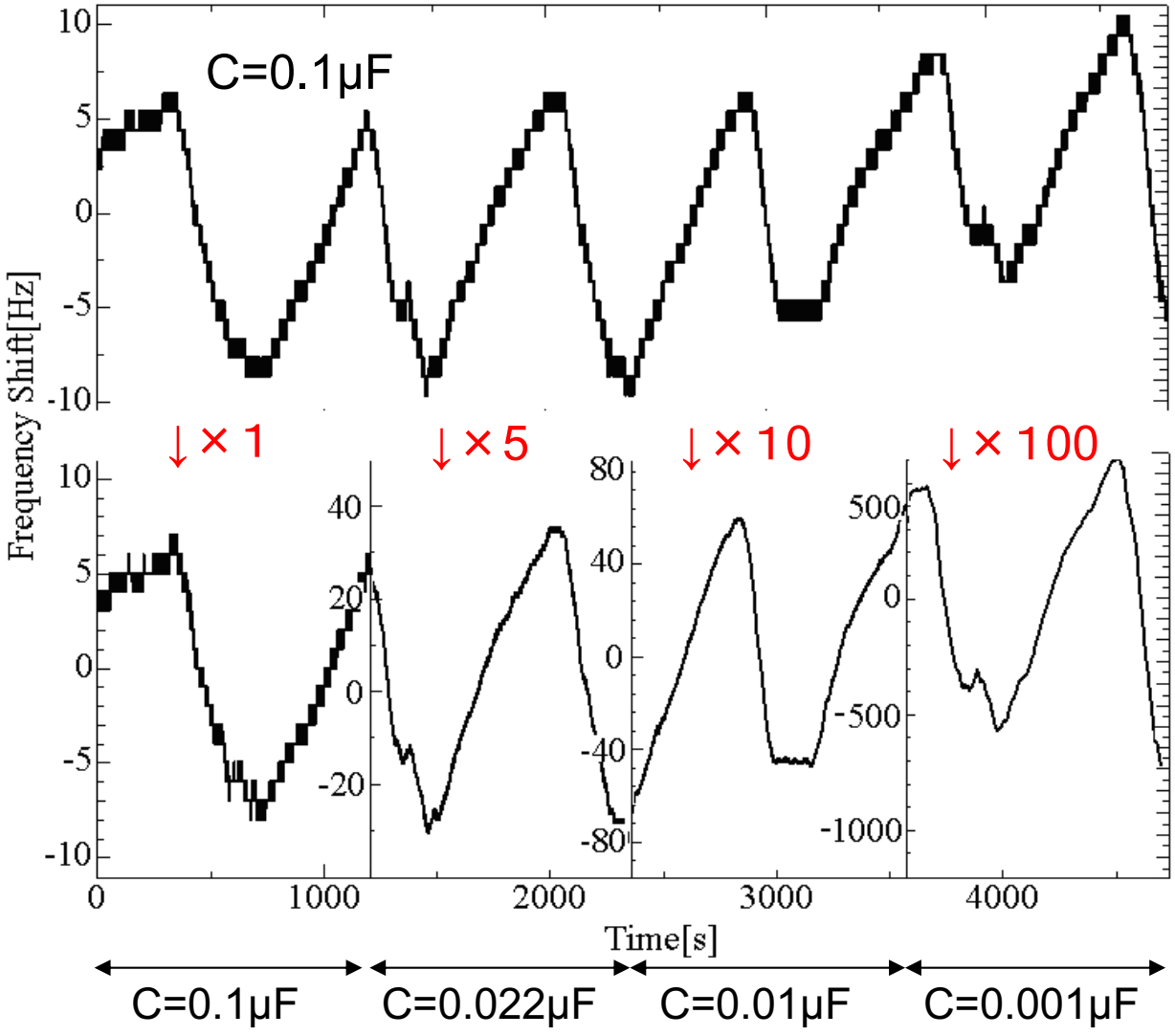
Equation for OSC Freq.

$$T = CR\left\{\left(\ln\frac{2E - V_{th}}{E - V_{th}}\right) + \left(\ln\frac{E + V_{th}}{V_{th}}\right)\right\}$$

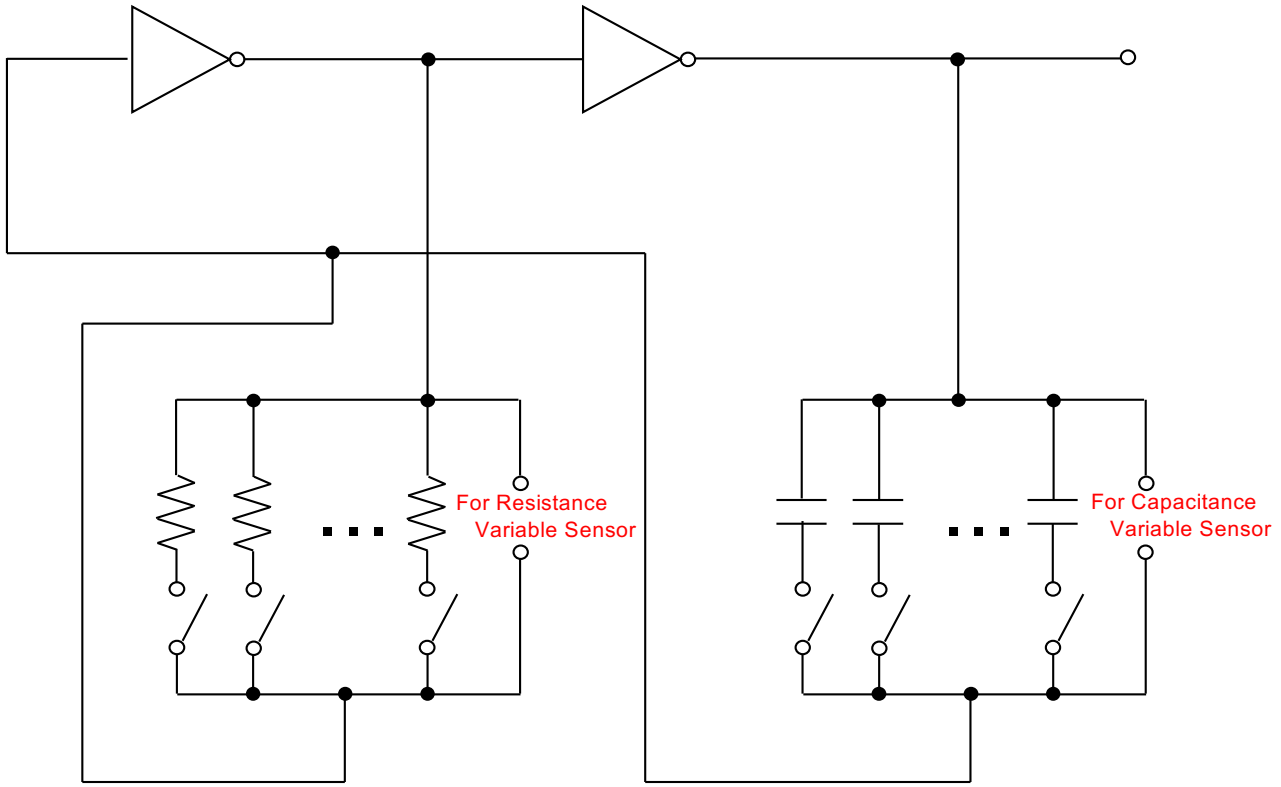
T [s]: signal's period
C [F] : capacitance
R [Ω]: resistance
E [V]: supplied voltage for circuit
V_{th} [V]: threshold voltage of CMOS inverter

Sensitivity adjustment demonstration

Used sensor : thermistor



More practical circuit and its feature



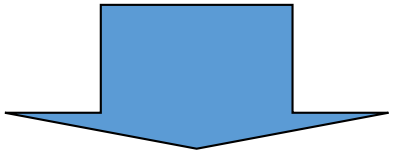
- Sensor's resistance is converted into OSC period (or frequency).
- A/D converter, Amplifire, Filter is not necessary for digitalizing sensor output.
- This technique can be adopted for resistor type and capacitor type sensor.
- Easy to change sensor without re-design of circuit.
- Sensitivity adjustment is easy.

Example for
“Development of sensors…”

Odor sensor and Odor recognition

Our Olfactory Sense

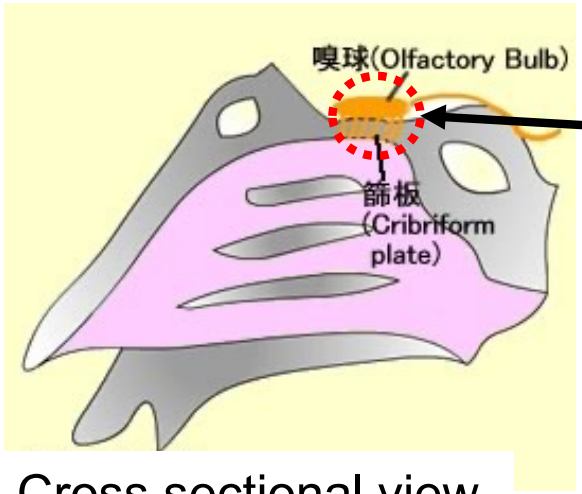
★Most living things have the sense organ which corresponds to olfactory sense.



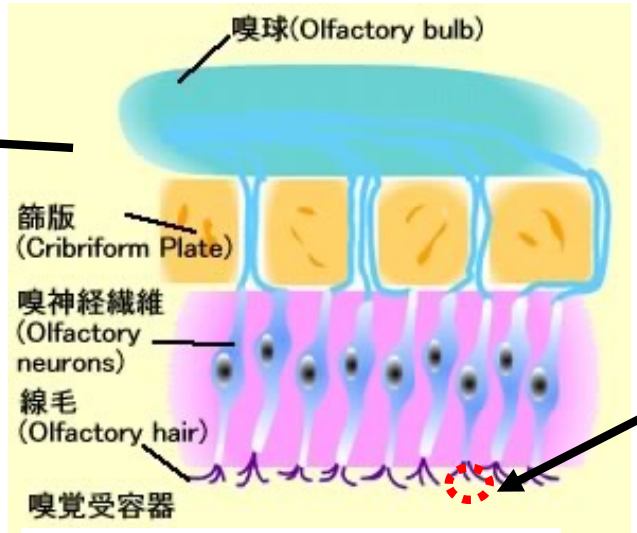
Olfactory sense is very important for our life.

- We are always living in chemical signals.
- All animals and plants give off a genetically determined chemical signature that is unique to each individual.
- Odors carry information about animal's sex, fertility, age, eating habits and health.
- Odors (chemicals) are used for the communication between animals, insects, plants, and those.

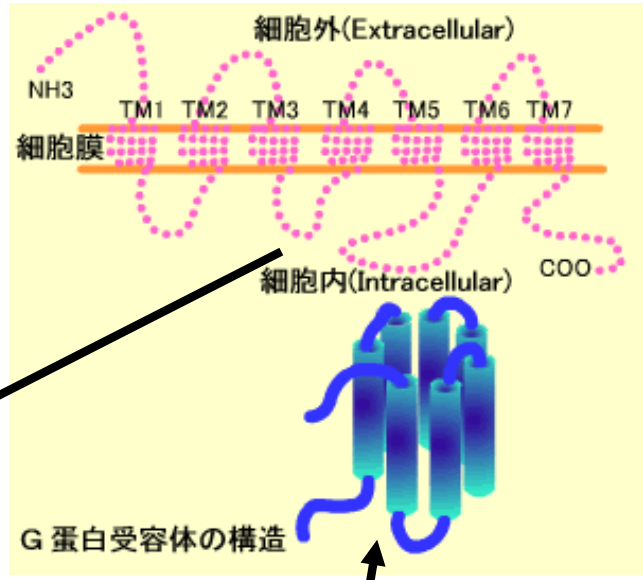
Our Olfactory Sense



Cross sectional view
of cavity of nose



Blow-up figure
around olfactory bulbs

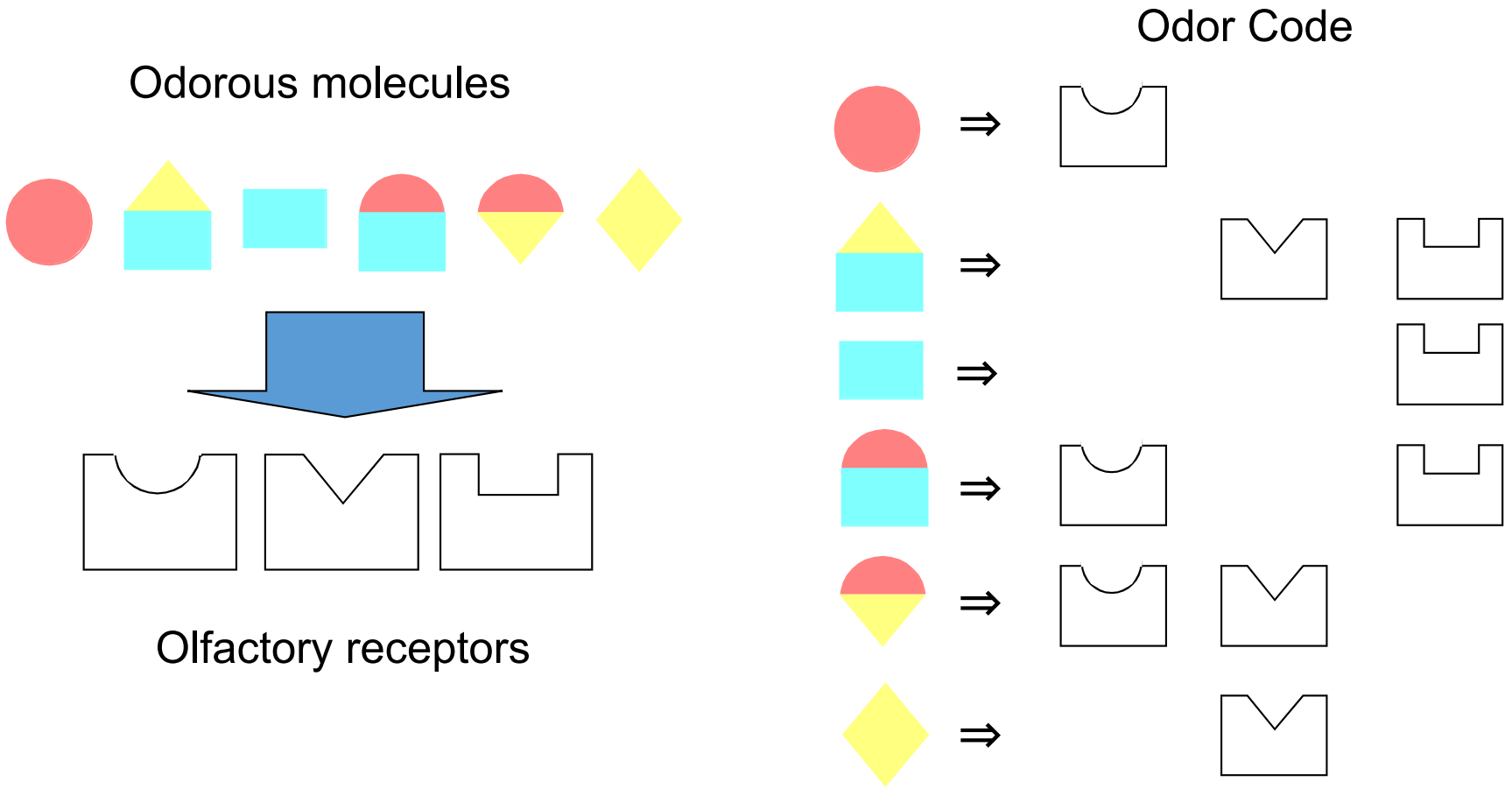


Structure of
receptor protein

Nervous signal from olfactory receptor reaches amygdaloid body and hippocampus, directly.
⇒ The signal relates directly to the activity before recognition of odor or rational judgments to the odor.

We have about 400 kinds of receptors, and 5 million olfactory cell.

Encoding of odor by olfactory receptor



※An odor is encoded by the combination of reacted receptors.

Features of Odor Sensing

- Primary odors are not determined.
- The mechanism of sense of smell is discovered twenty years ago.
- There are about more 100 thousands of odorous molecules (almost volatile organic compounds).
- An odor is determined by the combination of odorous molecules

  ⇒ The combination is infinite.
- Odors which can be classify by common people is 2,000～10,000.
- We use many types of gas molecule receptor to get odorous information. ⇒ multi-sensor system

Acoustic Wave Device as a Chemical (gas) Sensor

Sensor Device

Quartz Crystal Resonator :

Resonator for precise clock generator (oscillator).

SAW device (Surface Acoustic Wave) :

Solid state filter device used for high frequency circuit.

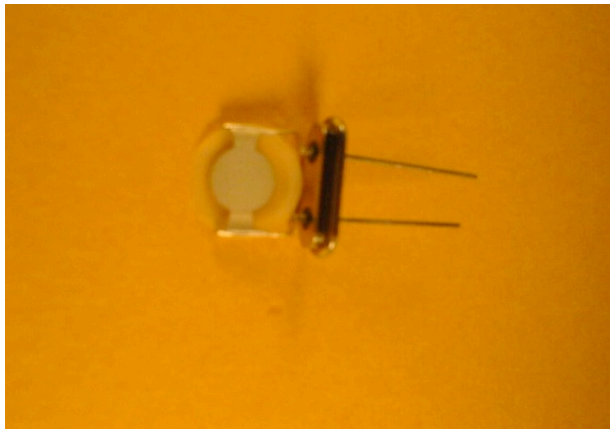
Operational principle

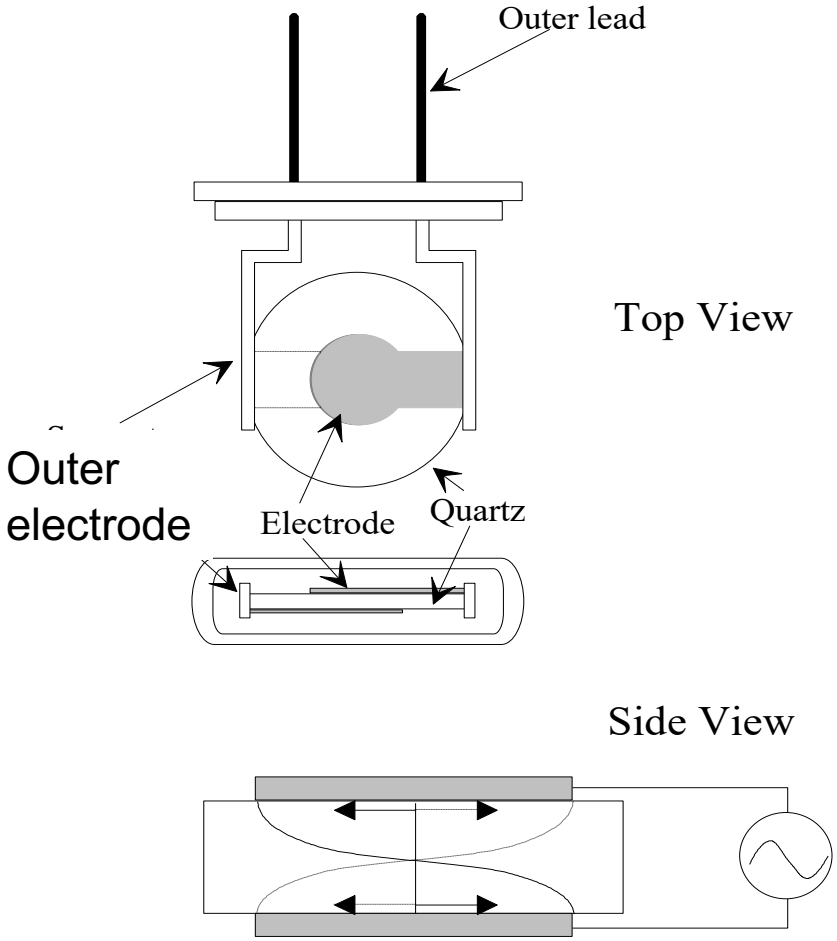
Mass-Loading Effect :

The parameters of acoustic wave are affected by the changes on a sensor device surface.

Quartz Crystal Resonator

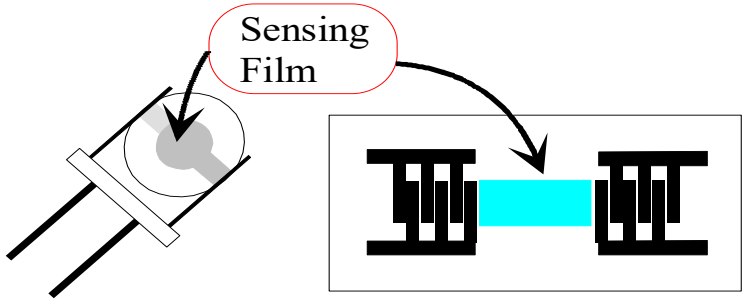
Quartz Resonator

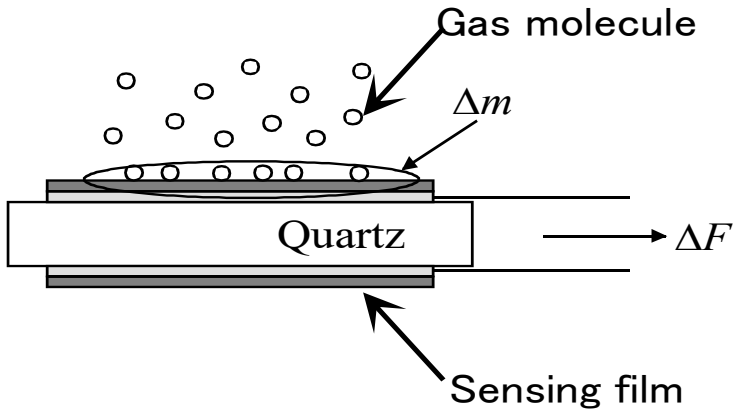




Mass-Loading Effect, and its application for gas sensor

Acoustic device with sensing film





Amount of adsorbed molecules is affected by the interaction between the sensor surface and gas molecules.

$$\Delta F = -2.3 \times 10^{-6} \times F^2 \times \frac{\Delta M}{A}$$

F : Fundamental Freq. (Hz)
ΔM : Mass change on the surface (g)
A : Surface area (cm^2)

Response property is determined by sensing film.

※ Quartz resonator is called “Quartz Crystal Micro-balance: QCM”.
QCM can detect 1ng mass change by 1Hz frequency change in the case of 9MHz device.

Gas recognition using multi-sensor system

Adsorption phenomena is not specific.

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Multi-sensor system composed
by sensors with different response property.

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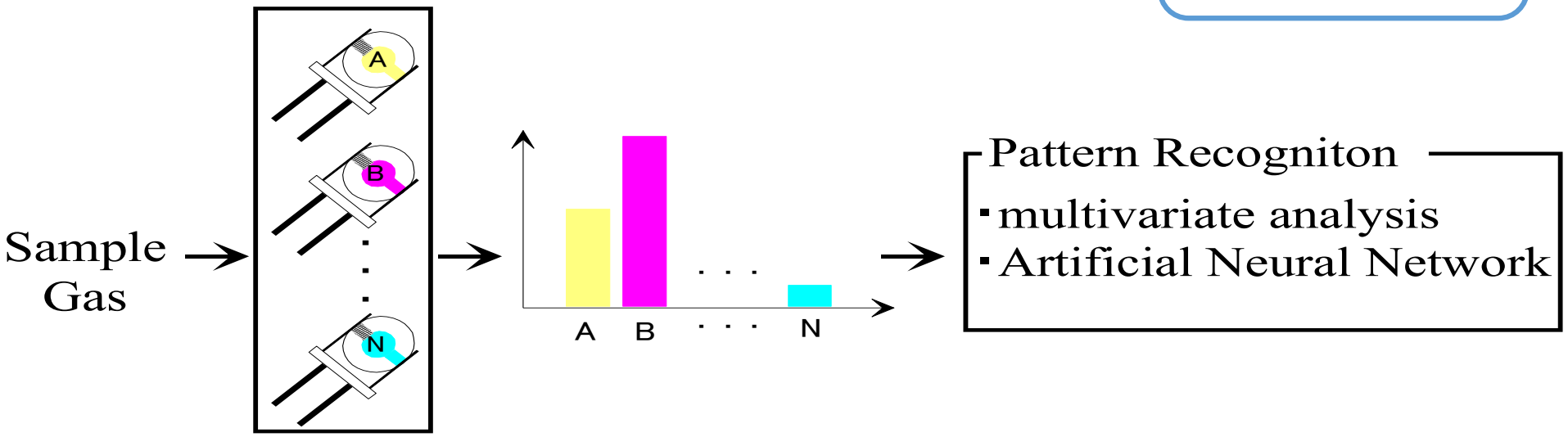
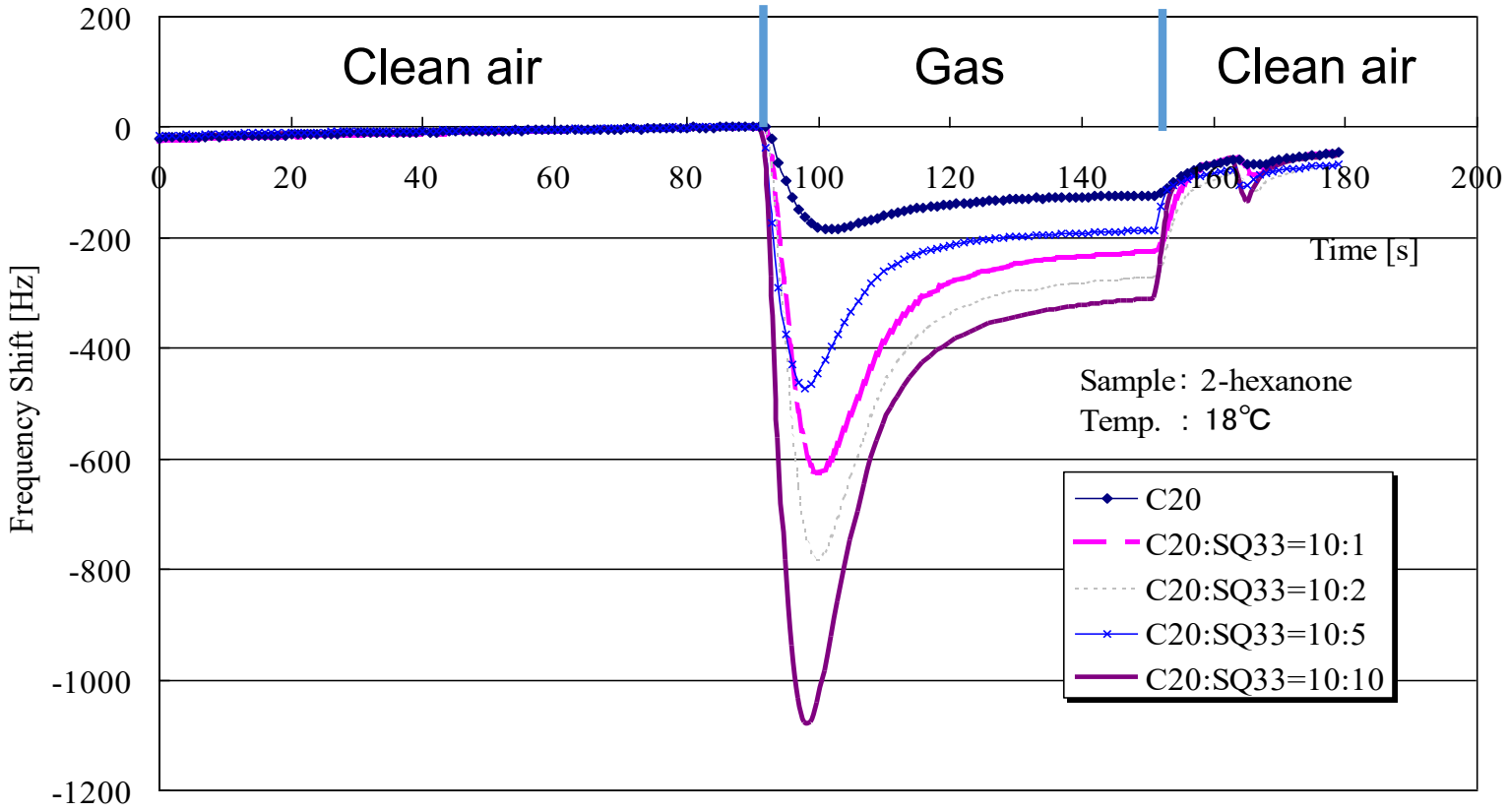
The measured gas is expressed
by multi-dimensional vector

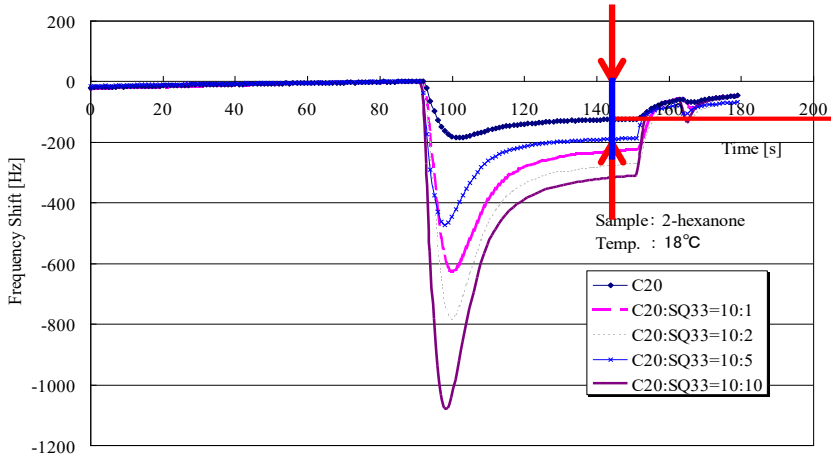
Biomimetics

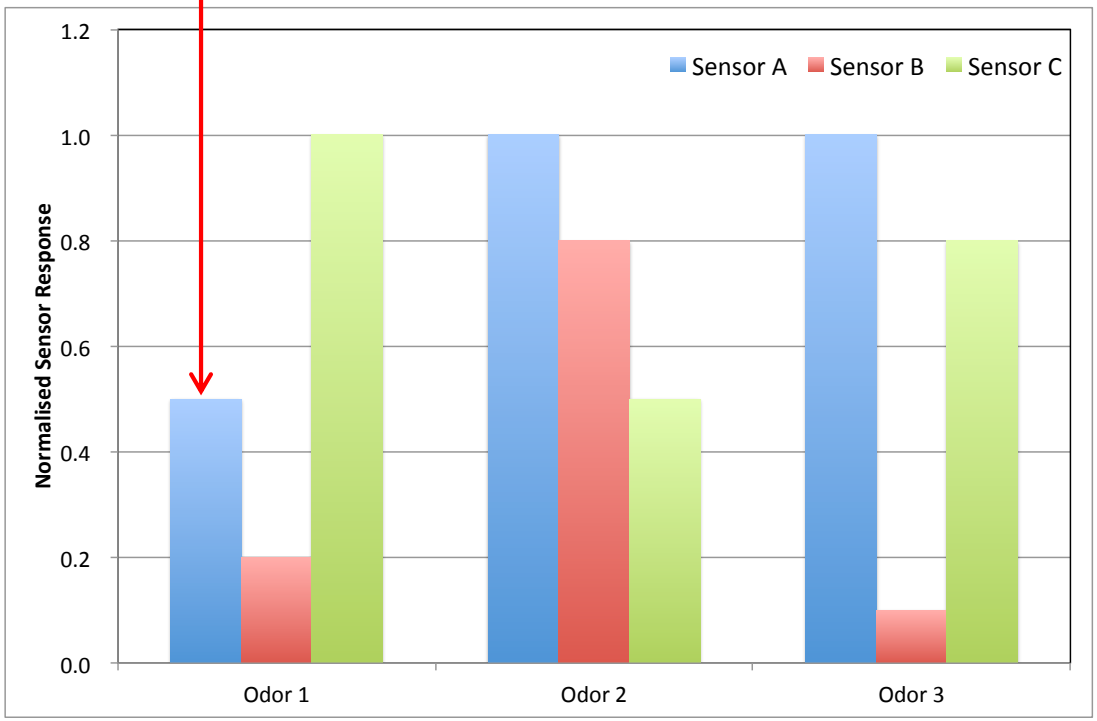


Response of QCM gas sensors

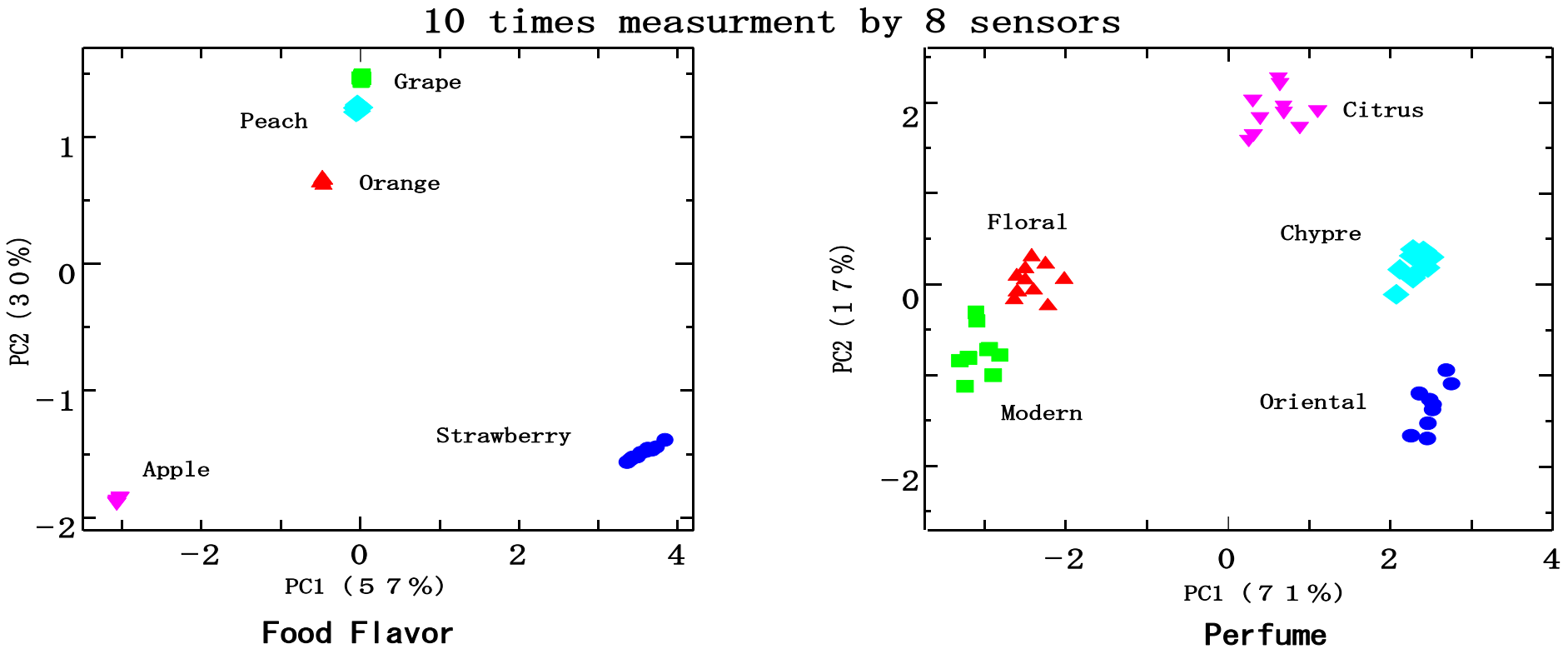


Sensor responses => Response pattern





Classification of food flavor and perfume using PCA method



- High performance classification
- Fluctuations in the result for perfume is caused by the design concept of perfume.

Example for

"Study of signal processing …"

and

"Study of data processing …"

Recognition of daily activities in a room using information about atmosphere

Recognition of daily activites using information about atmosphere in a room

Our activities often affect atmosphere in a room

※ “atmosphere” in here is defined as an “air condition” and “brightness” in a room.

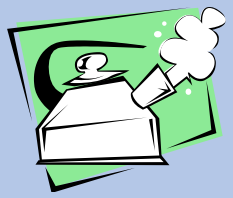
Change of gas(scent) Conc.

Change of Brightness

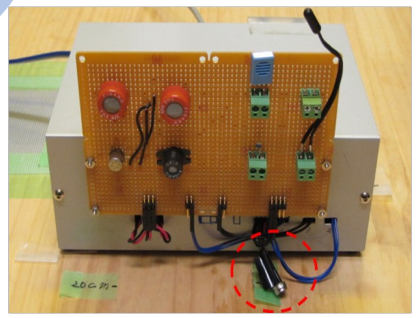
Daily activities generate…

Change of Temp.

Change of Humidity



Information about daily activities in room atmosphere!!



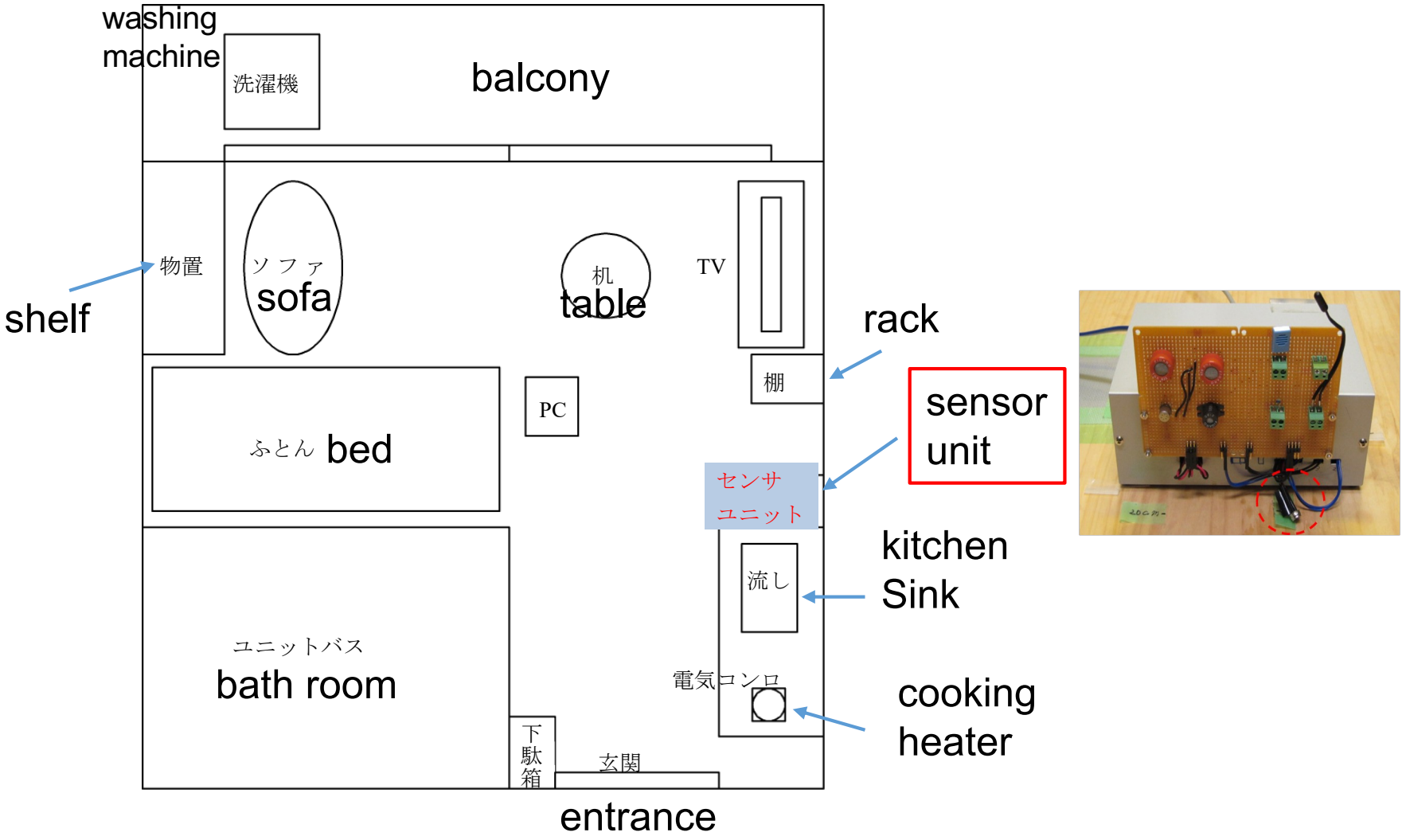
Features of our sensing system

- Multi-sensor system (Up to 8 sensors).
- Sensor can select depending upon a resident's habit, lifestyle.
- Sensitivity of sensor can adjust easily.
- Simple and low cost.
- Privacy safe.

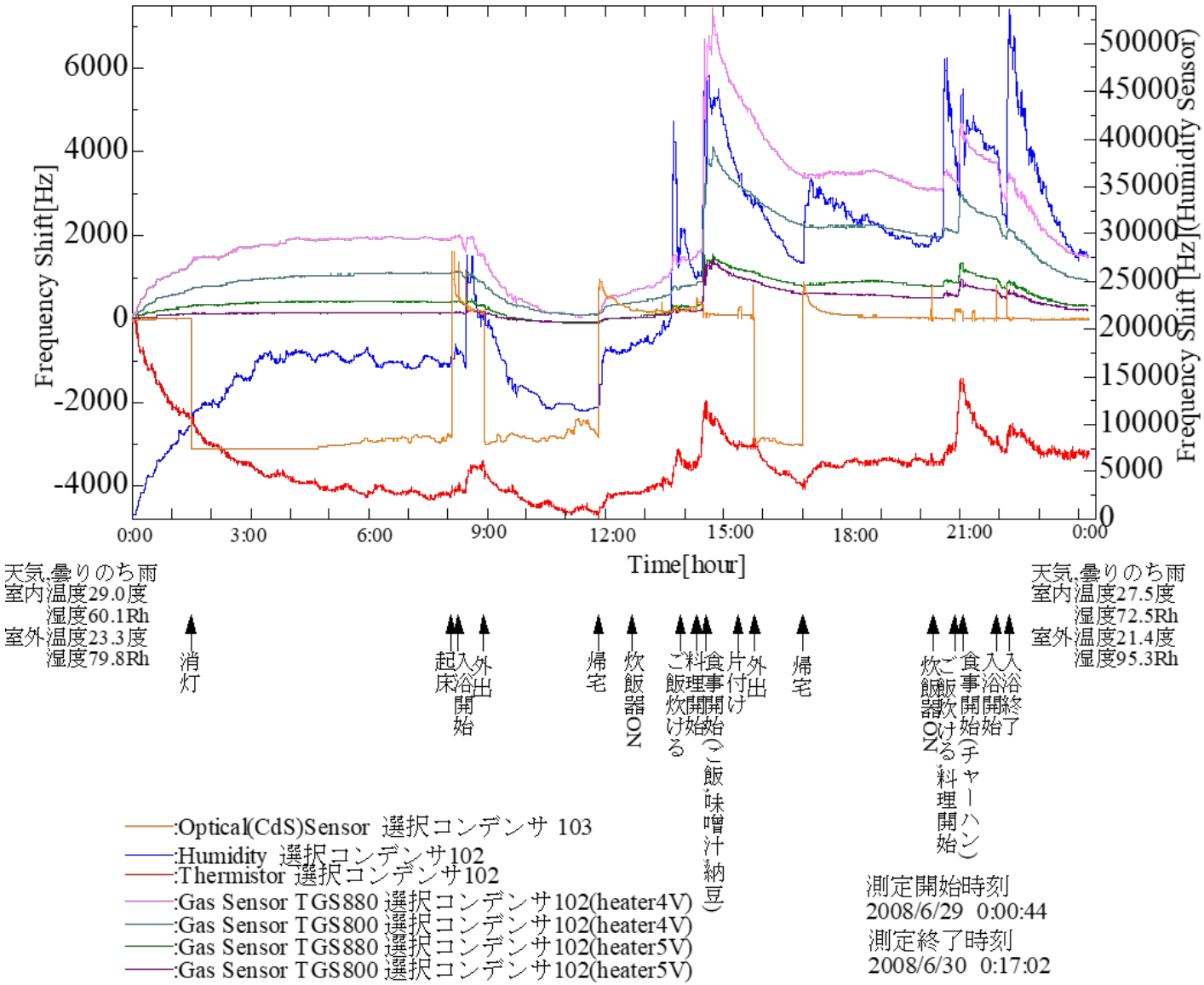
Used sensors in our sensing system

Sensor	Type	Features
Metal oxide semiconductor gas sensor	TGS880	High sensitivity for gas from food, alcohol
	TGS800	High sensitivity for H_2, ethanol, isobutane, CO, and also smoke from tobacco
Thermistor	103AT-2	Thermal time constant τ = 15[s]
Humidity sensor	HS-15P	Sensor for measurement Relative Humidity(RH). Available range：10～90 %RH
Light sensor	CdS	Resistance under dark：1MΩ

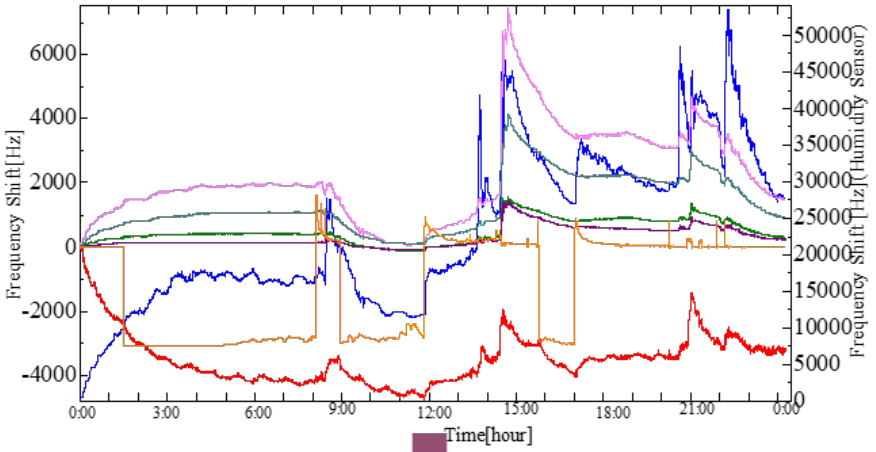
Experimental environment



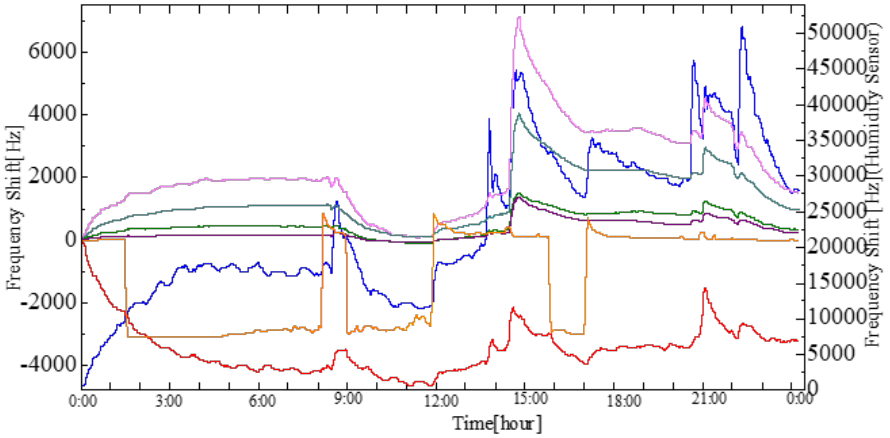
Typical sensor response in a day

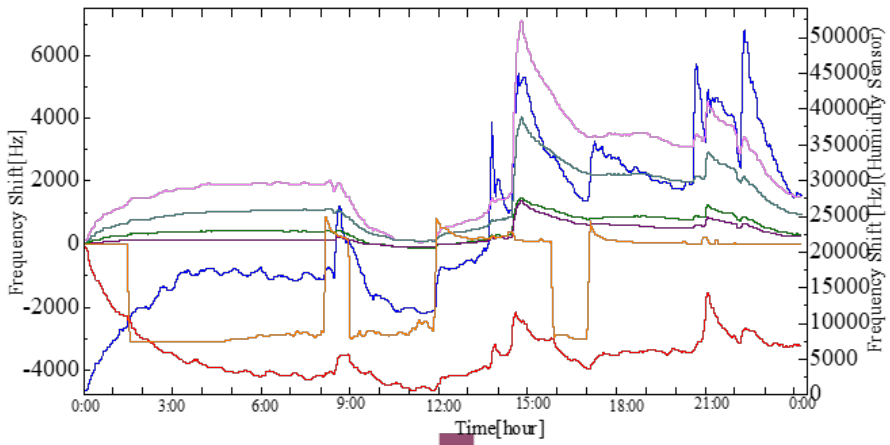


Example signal processing

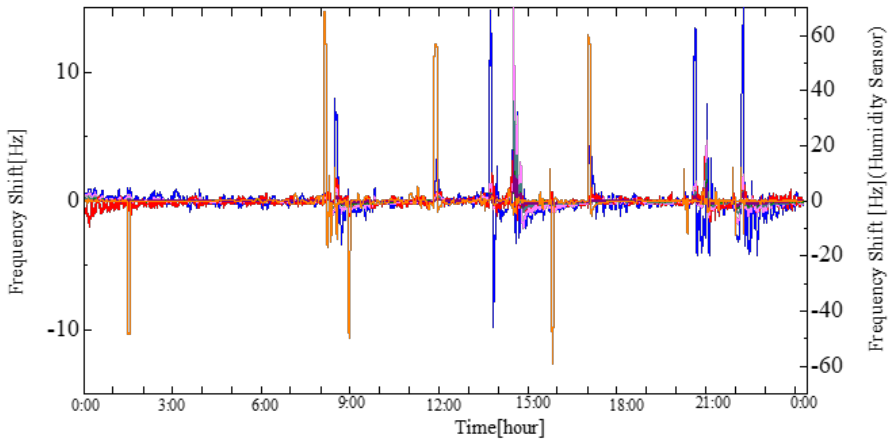


Moving average filter using 301points data





Calculation of the difference between responses



Data categorizing by Self-Organizing Map (SOM) method

Input data

21 dimensional vectors :

Sensor response at the beginning of activity, after 150s, and after 300s

↓

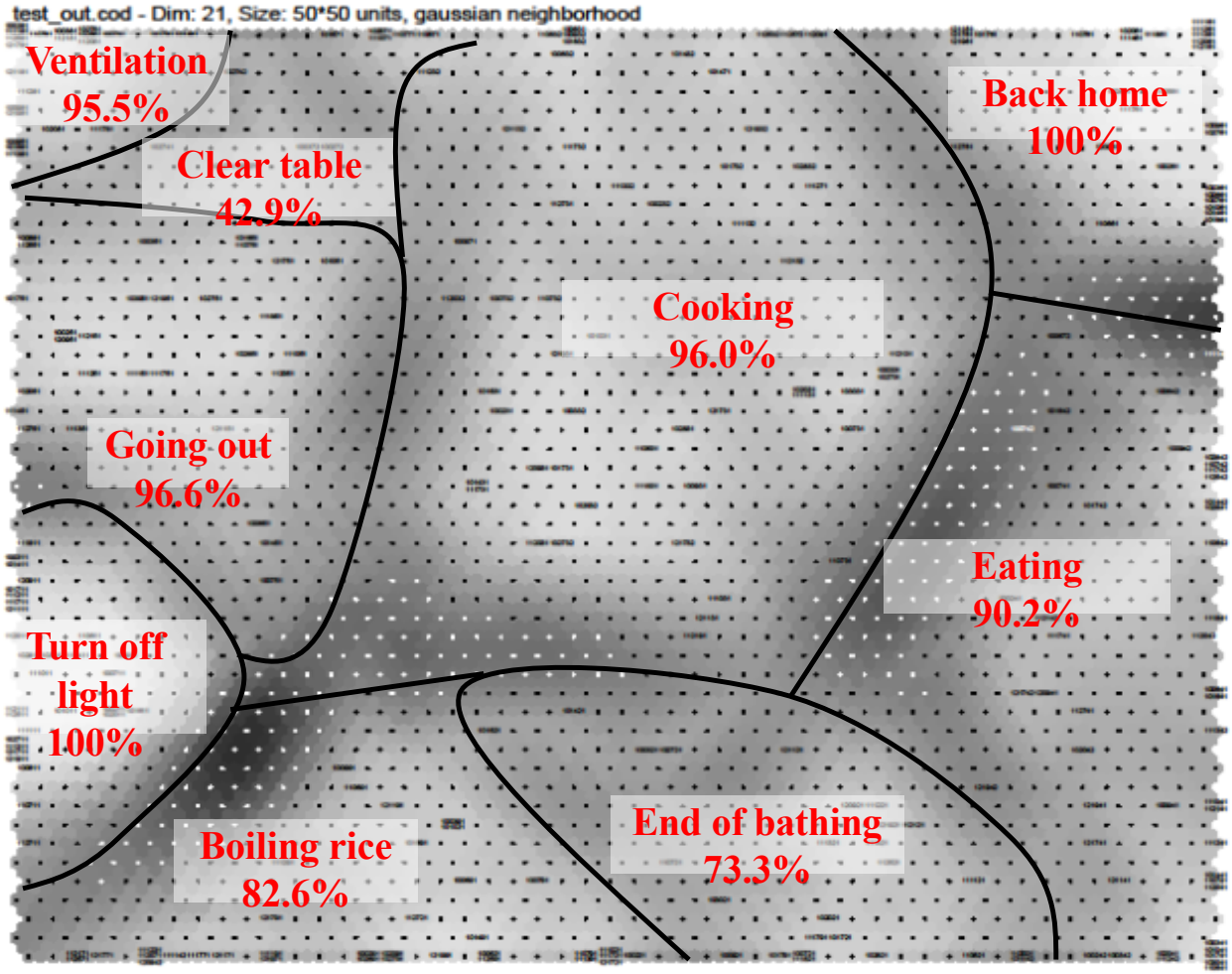
3point × 7sensor = 21 dimensions

* Vectors are normalized.

SOM : Self-Organized Map

⇒ Unsupervised learning algorithm for categorizing high dimensional vector.

A kind of Artificial Neural Network.



Next class’ topic…

Tactile sensor and its application

* I’ll give you the class material via Scomb, later.