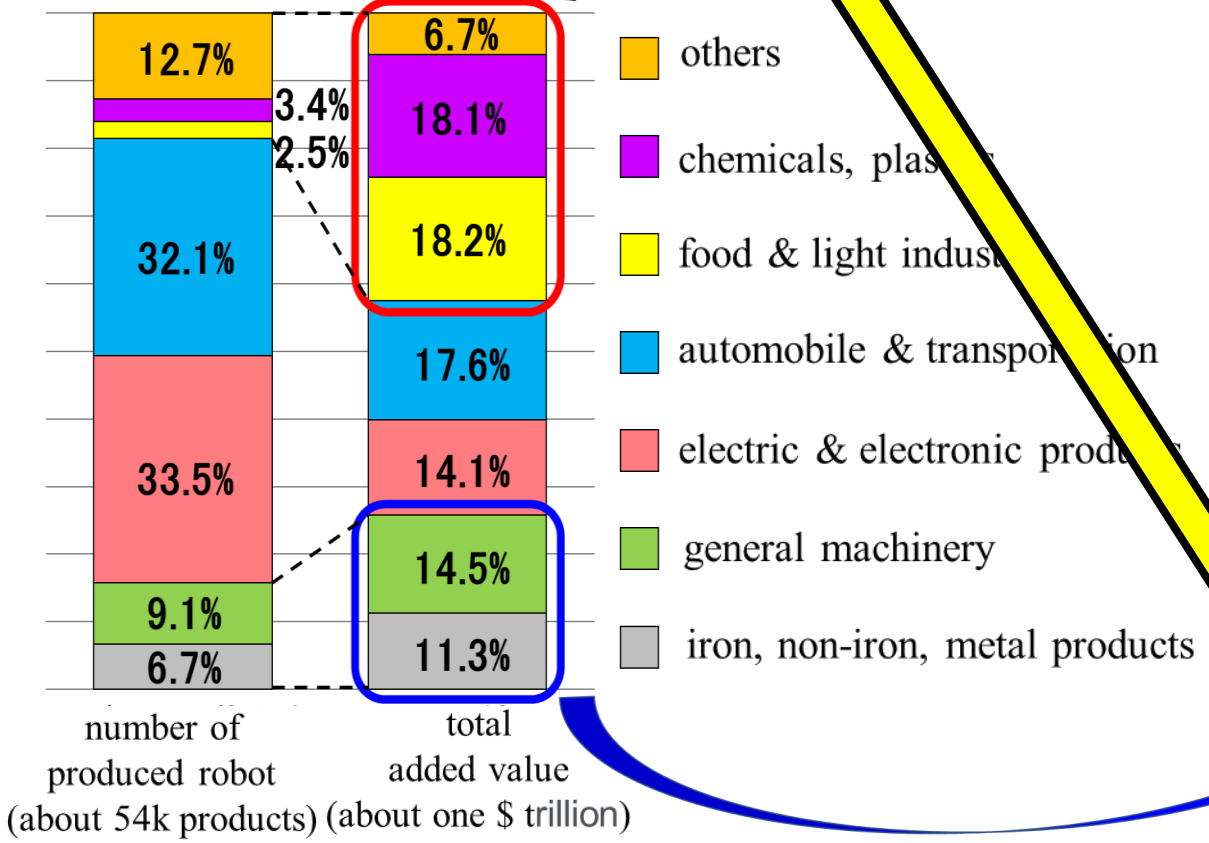
# Development of Smart Robot for Revolution of Industry

**Professor Kouhei Ohnishi, Keio University**
ohnishi@sd.keio.ac.jp

**Research Alliance**
**Ohnishi Group : Keio Univ., Yokohama Nati'l Univ.**
**Morimoto Group : Kyoto Univ., ATR, NAIST, AIST**
**Yamazaki Group : AIST, NEC**

# Next robot market




Robot Market in Japan as of 2018

**indeterminate shape soft, difficult handling**

**atypical task operated by human workers (non-automation process)**

**3D shape with complicated contour stiff, long time duration**

**automation of atypical routine task**

# Industrial robot is not a solution

- Atypical routine tasks by human will be remained much in future
- 20million or more robots will be required in 2050’s
- A bottle neck of production after 2030’s must be difficulty of automation for atypical routine tasks
- Industrial robot is suitable for typical routine tasks in mass production
  But it does not have dexterousness and flexibility for atypical routine tasks
- **Why**?
- Industrial robot lacks sensation  Particularly force/tactile sensation is indispensable for skilled and dexterous motion as well as safe motion

# Lacking human sensing, robot …….

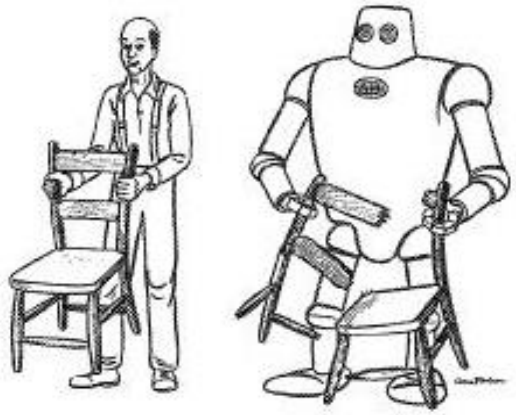


Figure 4b. Lacking Human Sensing, Robot Shatters Chair.

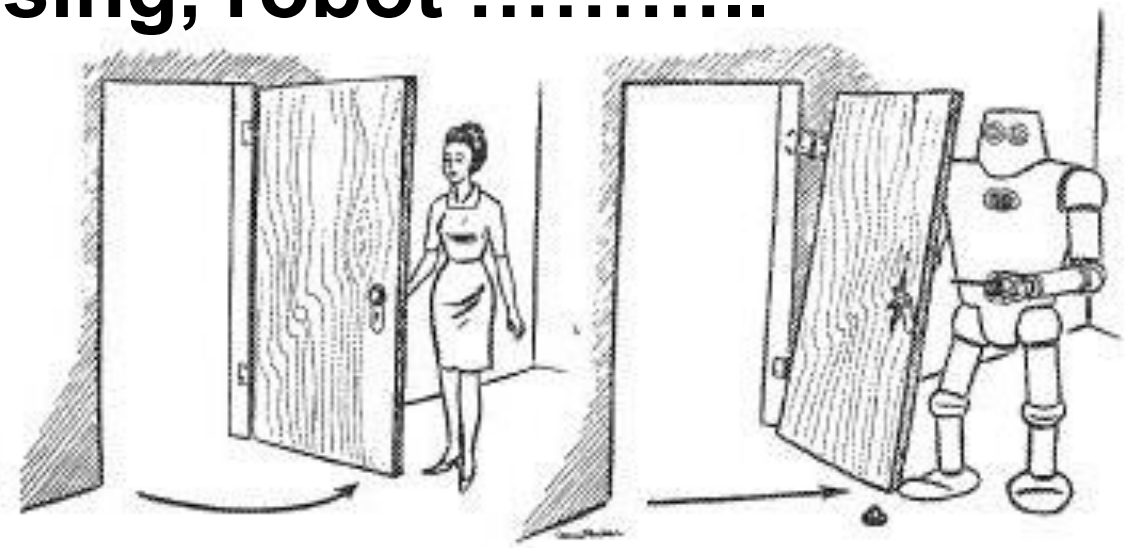


Figure 4a. Lacking Human Sensing, Robot Snaps Door.

**From a paper in 1967 by Ralph Mosher at GE**

Handyman to Hardiman

Ralph S. Mosher
Research and Development Center
General Electric Company

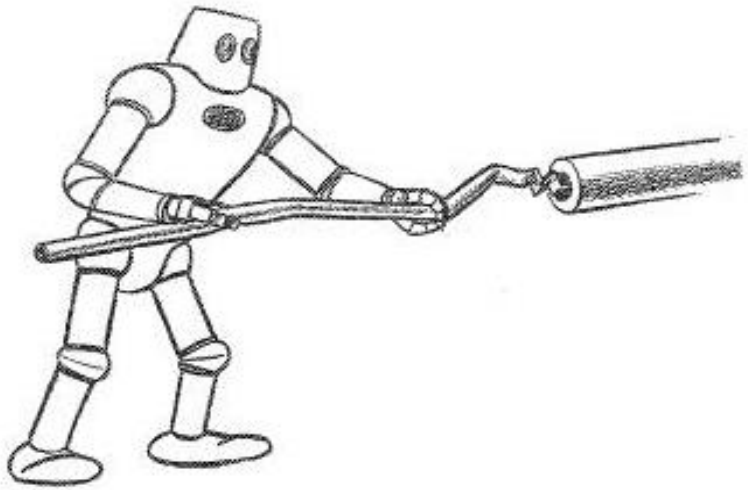


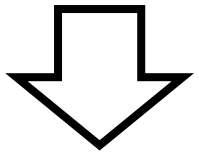
Figure 4c. Lacking Human Sensing, Robot Jams and Bends Pipe.

- Robot needs sensations if it acts like human
- Development of robot having ***unified*** **function of sensation and motion** like human is highly expected for full automation

# Real haptics® ---- force/tactile sensation for robot motion

## Real haptics

- A unique technology to transmit force/tactile sensation which is one of the five sensations of human (human-to-human, human-to-machine, machine-to-human, and machine–to-machine are ***all*** possible)

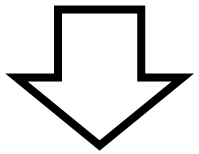


## Remote control

- Operation of distant objects with force/tactile sensation

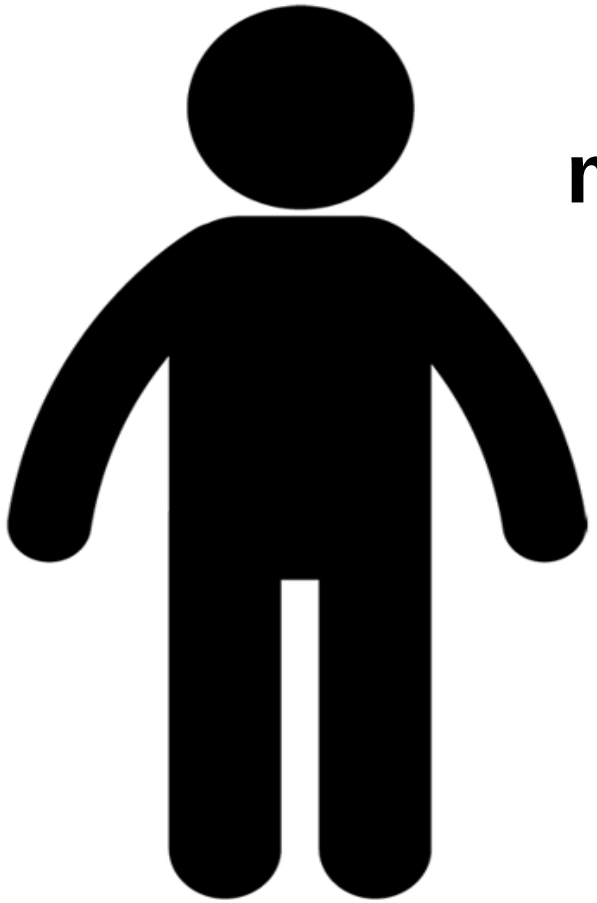
## Record & playback

- Force and position data of operator is recorded and transferred to the robot to be able to reproduce actions of operator including the dexterousness

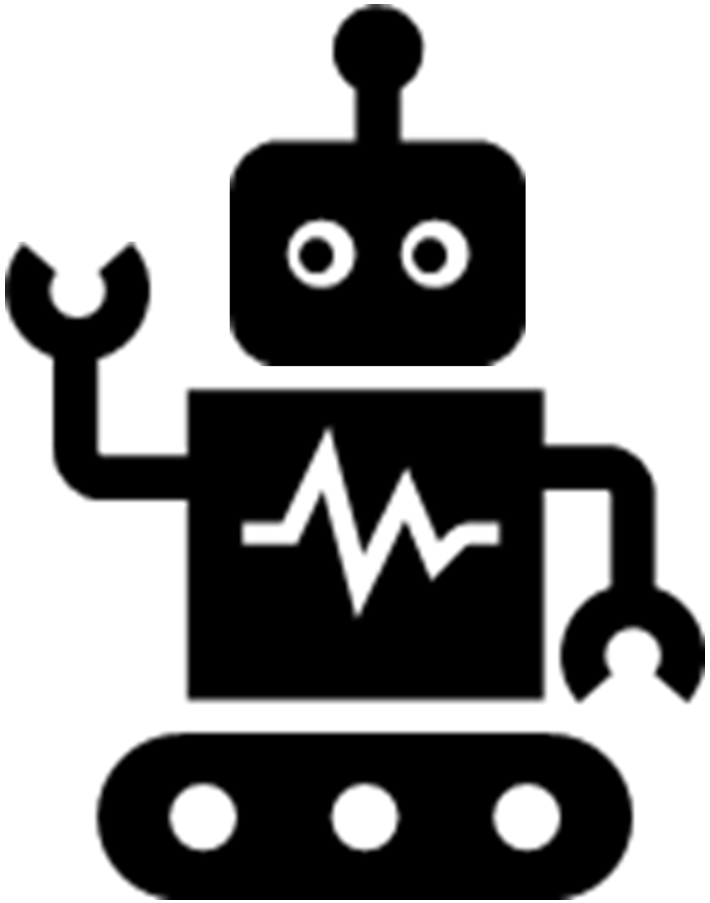


## Tacit knowledge of skilled motion can be digitalized and databased

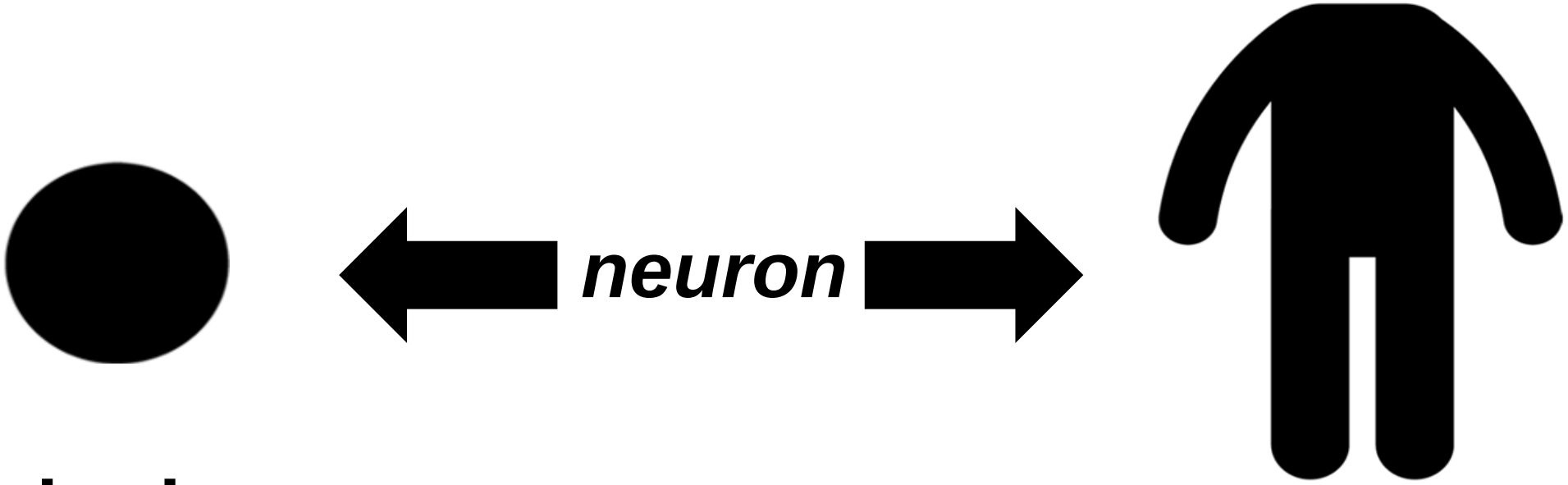
# Connecting brain and body for “moves as thinks”



moves as thinks



# Human

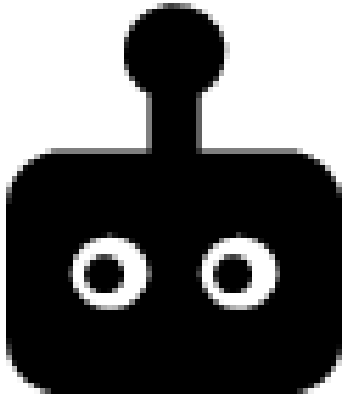



**brain (think)**

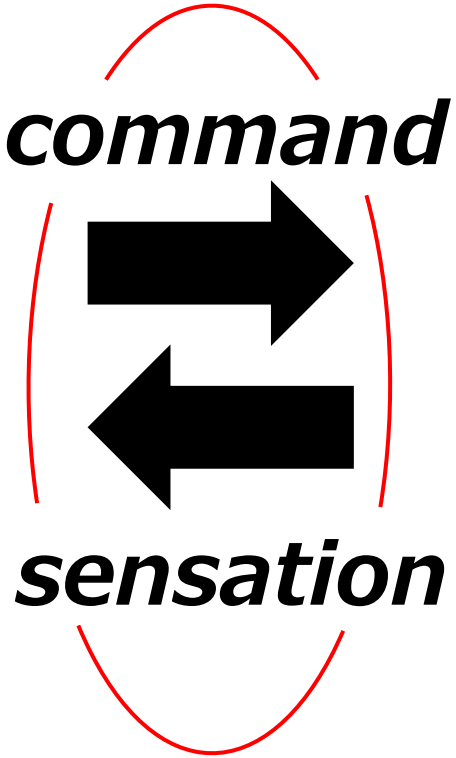
**body (move)**

Human feels the hardness and softness of target and performs safe and dexterous motion based on function of neuron
It is easy

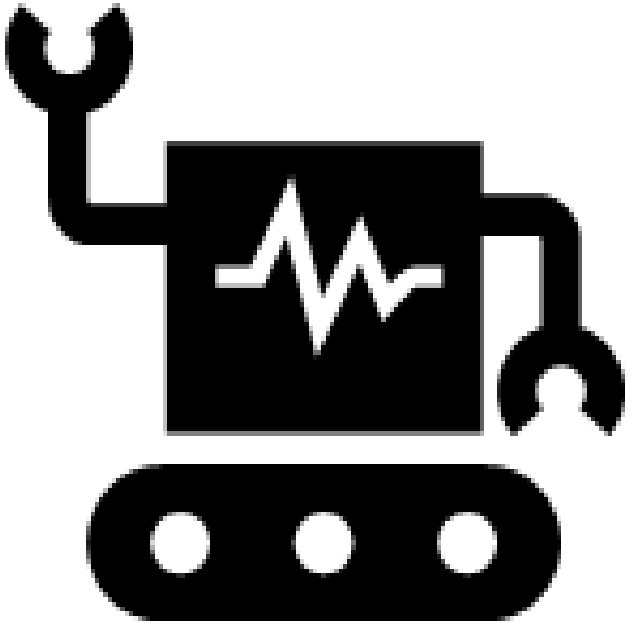
# Robot



**brain**
**(think)**




*artificial neuron*



**body**
**(move)**

Real haptics has a bidirectional function as artificial neuron
which connects brain and body
It is difficult, but possible by real haptics

# What are *command* and *sensation* for robot ?

## *command* for robot

= selecting the best motion data from human-experienced task

## *sensation* for robot

= identifying mechanical parameters of contact-target

# Motion cycle for fast adaptation to contact target

## Human motion cycle

- contact → sensation → modification of motion for adapting to target → sensation → modification of motion for adapting target → ・・・・・・

## Robot motion cycle

- contact → identification of mechanical parameters of target → command from most suitable data of human motion → identification of mechanical parameters of target → ・・・・・・

# Skill of simple and short-time atypical task by robot

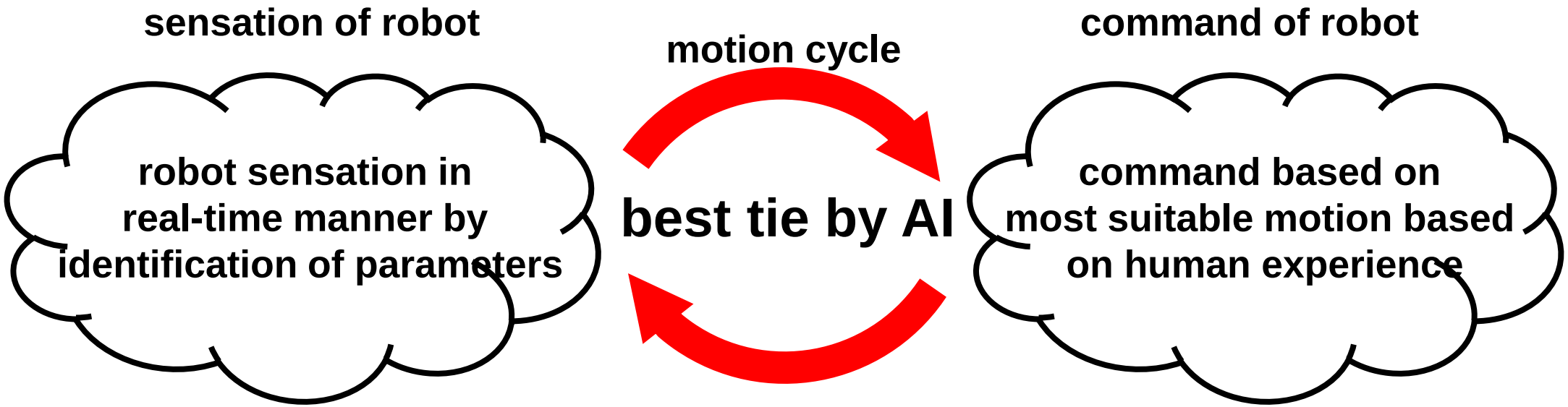
## Utilization of human experience to get skill

- skill – adaptive motion in real-time manner
  – embedded in a set of motion data
- command for adaptive motion based on robot sensation to obtain human skill
  – utilization of piled knowledge of human experience
  – learning process already done by human
  (much better than self-learning by robot)
  – AI-aided selection of command from big data of recorded human motion in real-time manner

# Connecting sensation and command

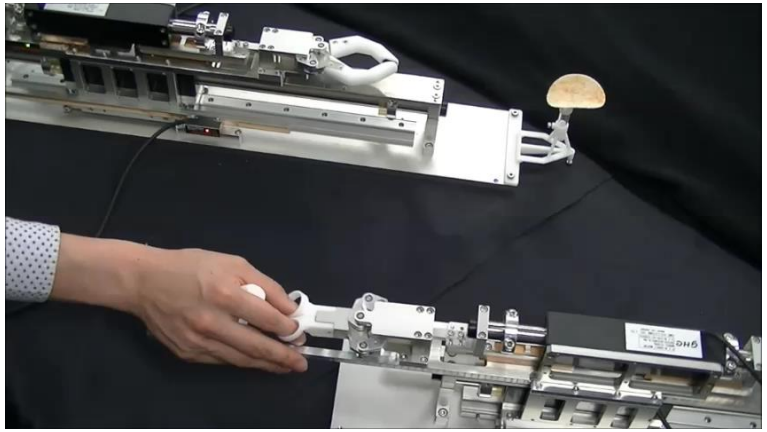
## Best tie between robot sensation and command

- skill by robot ⇒ AI-aided discovery of best tie between robot sensation and most suitable motion data in the past experience of human

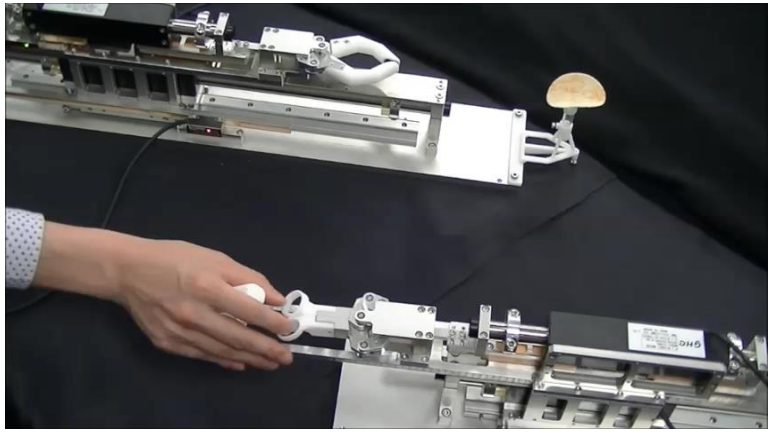


# Preliminary experiment

## Abstraction of human motion data and adaptive motion of grasping hand for various targets



**abstraction and recording of human motion on grasping fragile material**
**(below - hand side,  above - remote side)**



**playback motion based on recorded data of human operation**
**(below – no operation,  above - playback)**

**adaptive motion for variation of grasping target**
**(strawberry, thin cookie, plastic cap)**

# Evolution of robot

| features / categories | Adaptivity to Contact Target | Applicable Environment and Possible Tasks | Synthesis of Motion Command | Necessary Functions for Robot |
|---|---|---|---|---|
| **Industrial Robot** | None | Routine Tasks in Structured Environment | Position Teaching | Servo Function with Kinematics |
| **Real Haptics® Robot** | Passive Adaptivity | Quasi-routine Tasks in Quasi-structured Environment | Passive Replay of Recorded Motion of Human (Mimic Motion) | Real Haptics Function with Dynamics |
| **Smart Robot** | Active Adaptivity | Atypical Tasks in Non-structured Environment | Active Motion with Decision-making | AI Function with Unification of Decision-making and Motion |