

Development of Smart Robot for Revolution of Industry

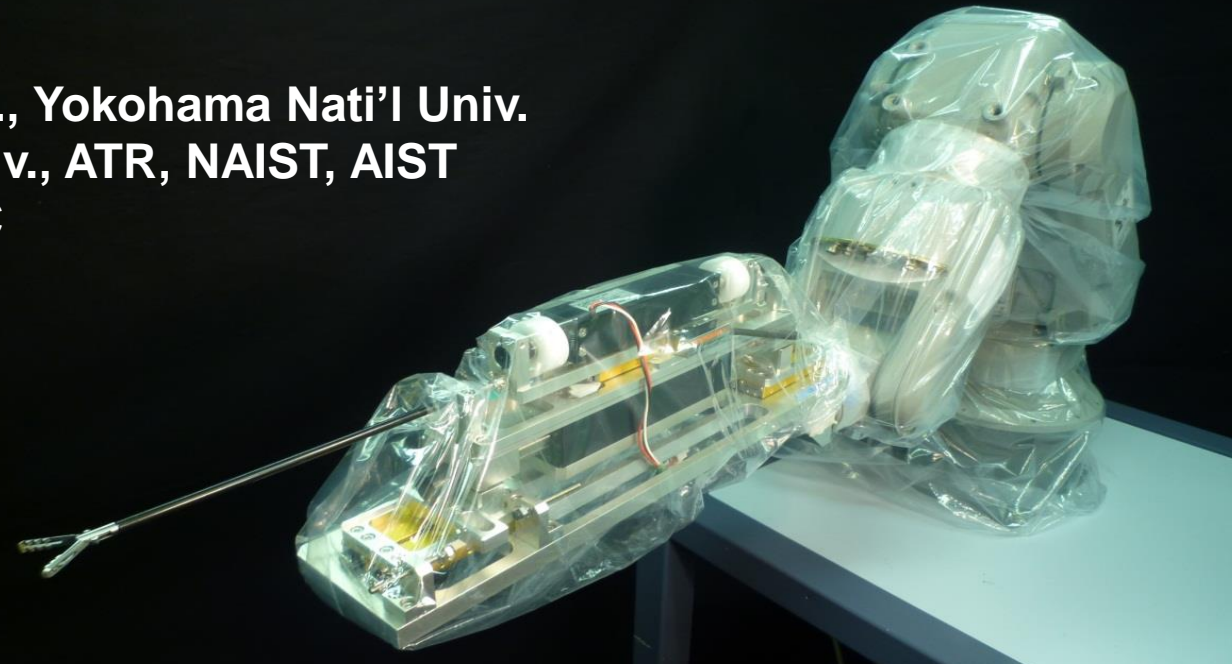
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Research Alliance

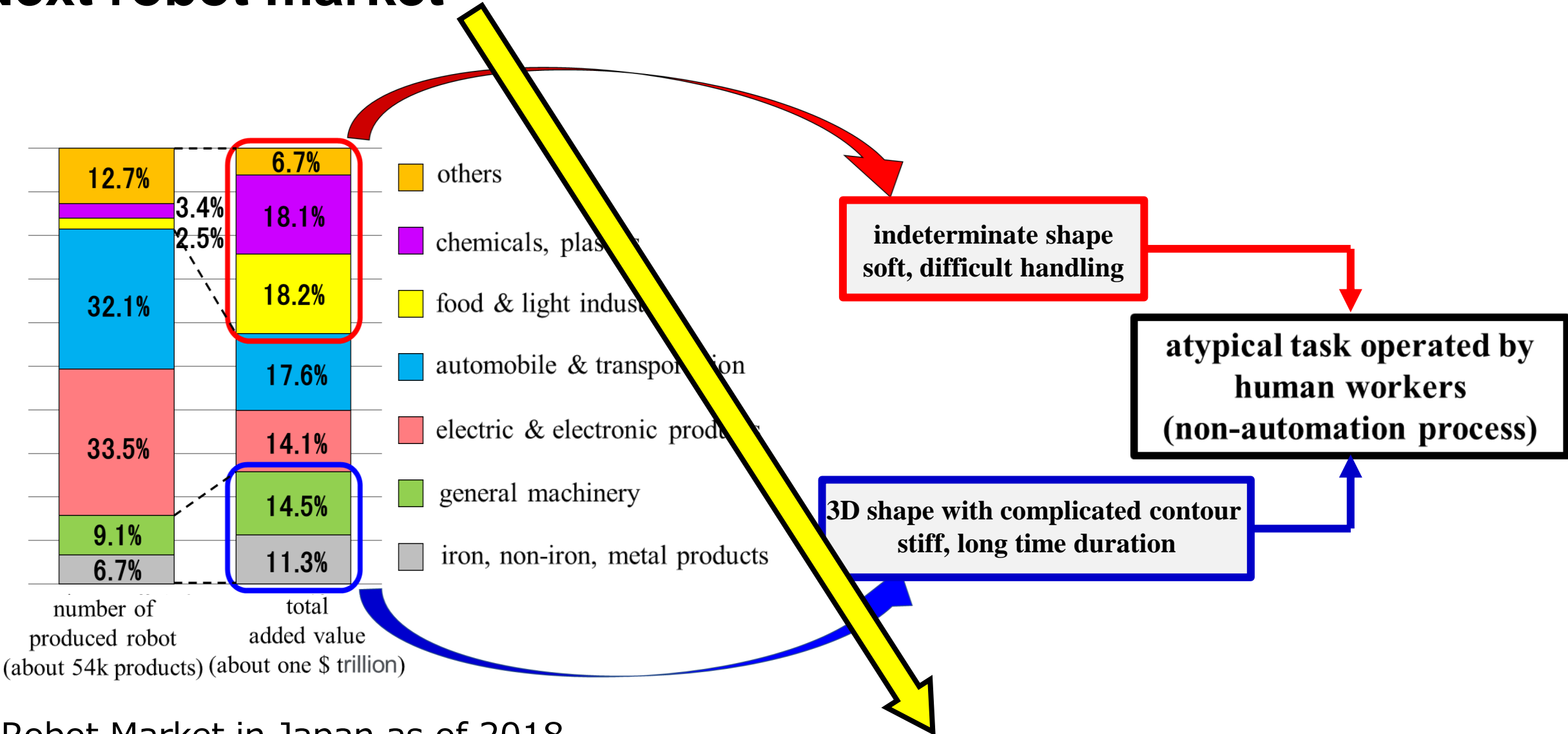
Ohnishi Group : Keio Univ., Yokohama Nati'l Univ.

Morimoto Group : Kyoto Univ., ATR, NAIST, AIST

Yamazaki Group : AIST, NEC



Next robot market



Robot Market in Japan as of 2018

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

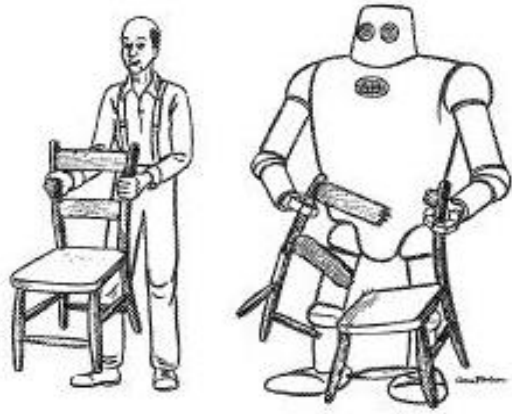


Figure 4b. Lacking Human Sensing, Robot Shatters Chair.



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

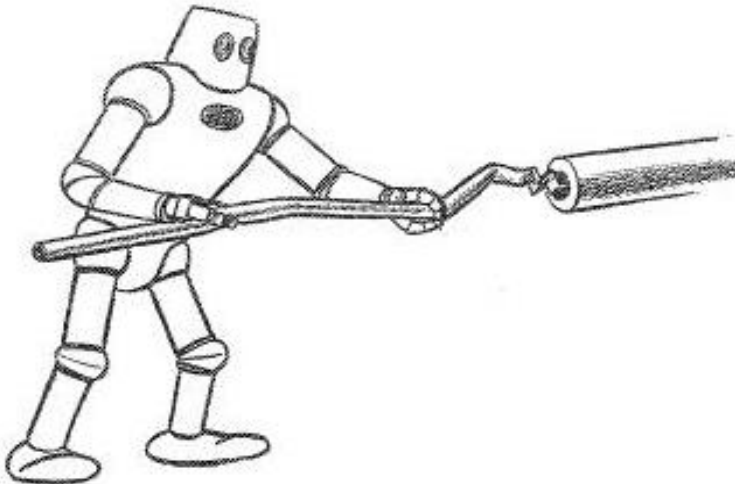


Figure 4c. Lacking Human Sensing, Robot Jams and Bends Pipe.

From a paper in 1967 by
Ralph Mosher at GE

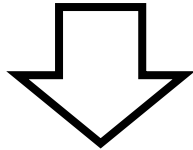
Handyman to Hardiman

Ralph S. Mosher
Research and Development Center
General Electric Company

- 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

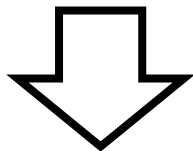


Remote control

- 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)

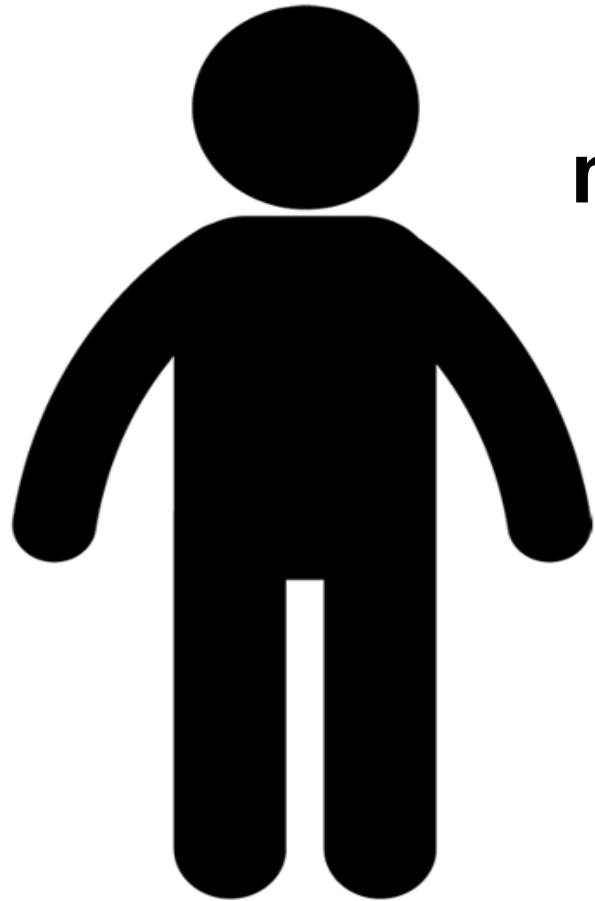
Record & playback

- Operation of distant objects with force/tactile sensation
- Force and position data of operator is recorded and transferred to the robot to be able to reproduce actions of operator including the dexterousness

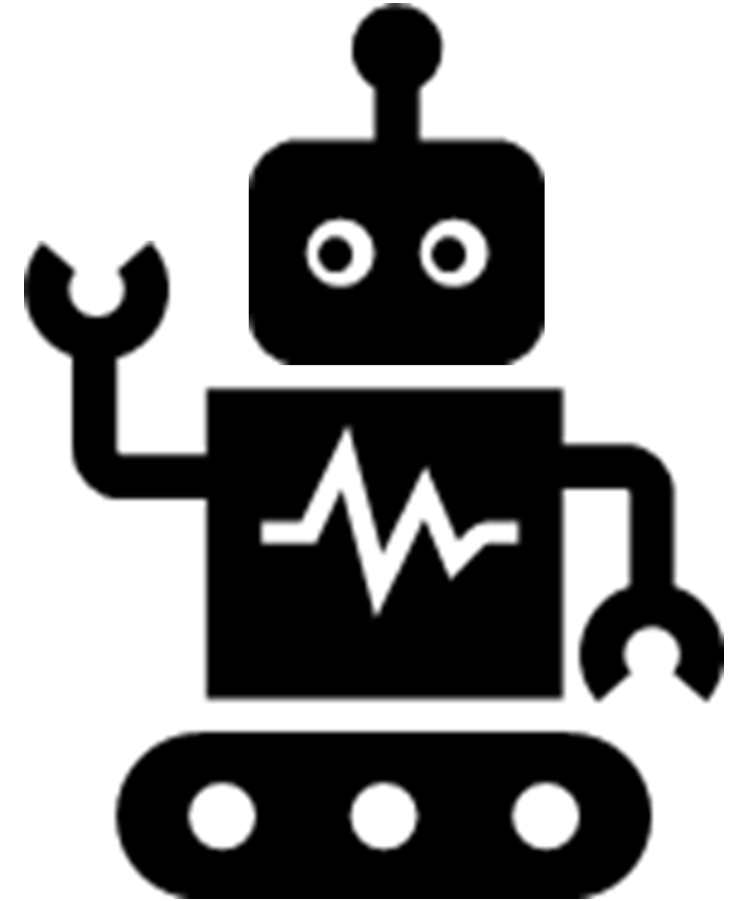


Tacit knowledge of skilled motion can be digitalized and databased

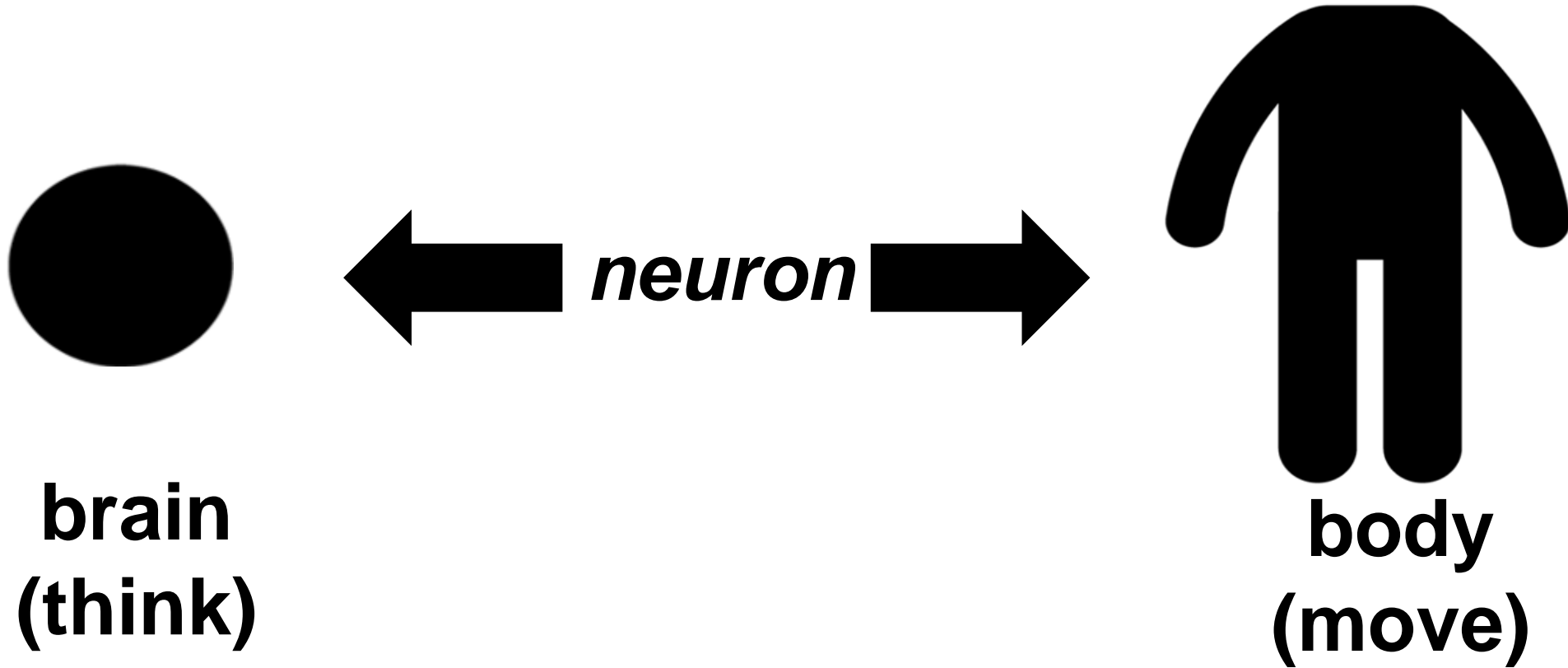
Connecting brain and body for “moves as thinks”



moves as thinks

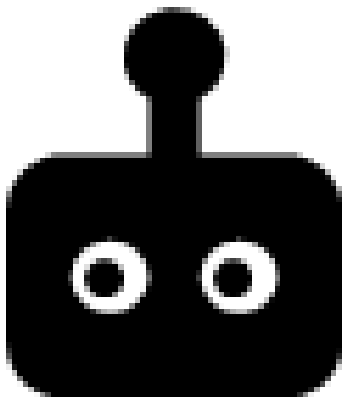


Human

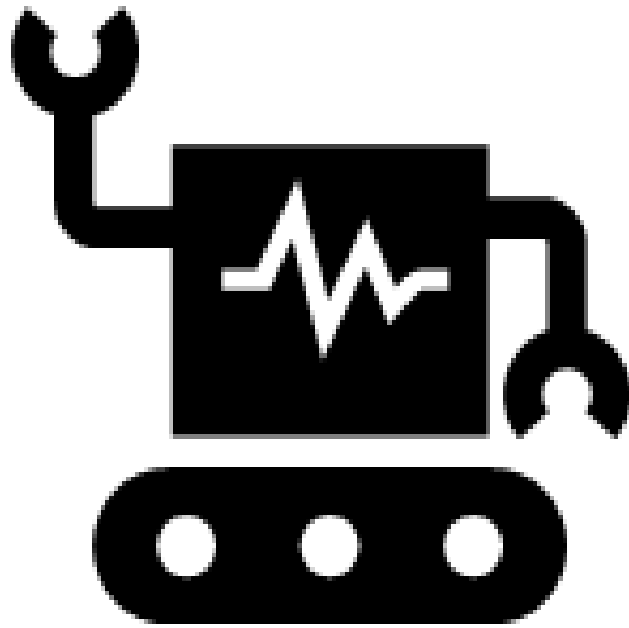
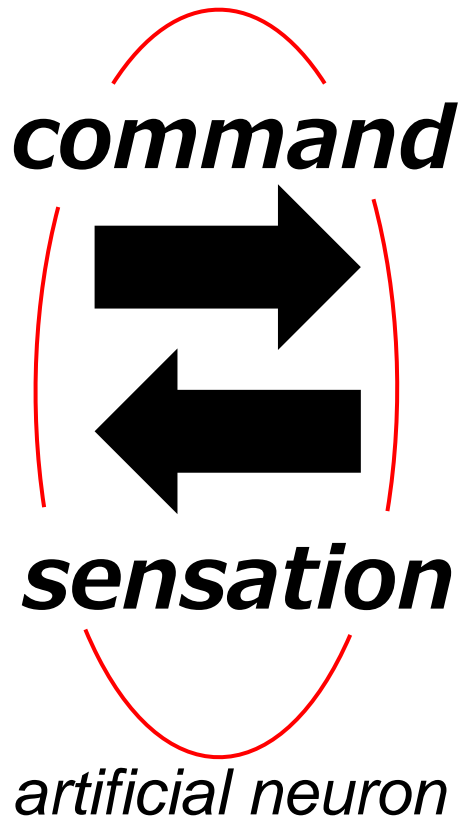


Human feels the hardness and softness of target and performs safe and dexterous motion based on function of neuron
It is easy

Robot



brain
(think)



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

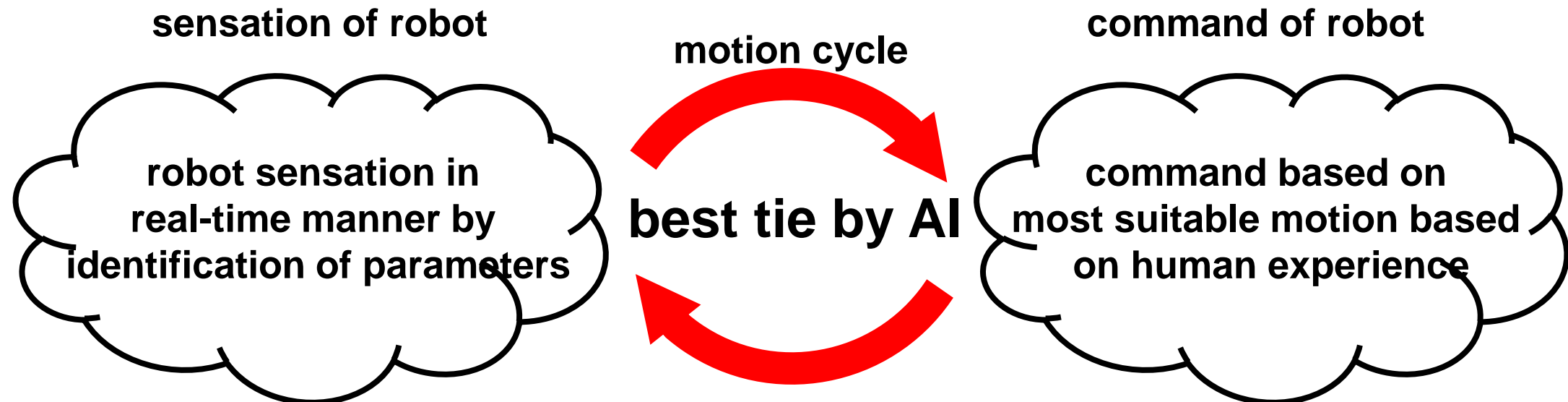
Utilization of human experience to get skill

- 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

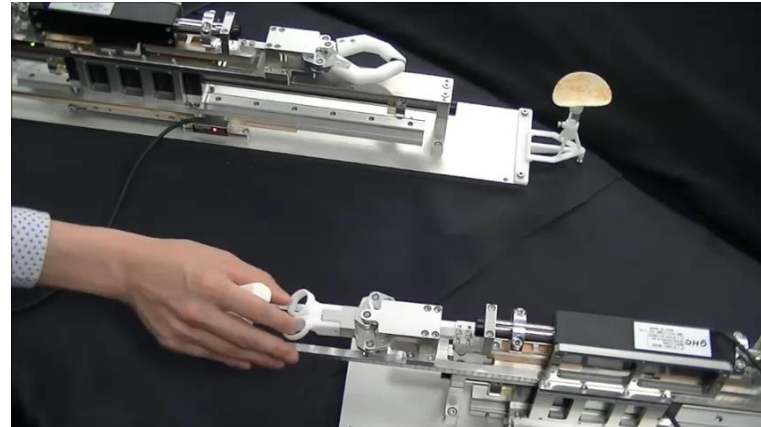
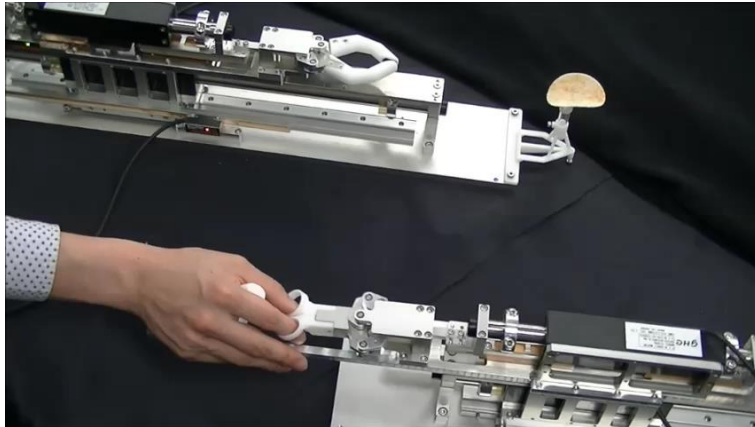
Best tie between robot sensation and command

- skill by robot \Rightarrow 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	1980's 1 st generation
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	2020's 2 nd generation
Smart Robot	Active Adaptivity	Atypical Tasks in Non-structured Environment	Active Motion with Decision-making	AI Function with Unification of Decision-making and Motion	2040's 3 rd generation