Information changes the world

Information, Robots and Life

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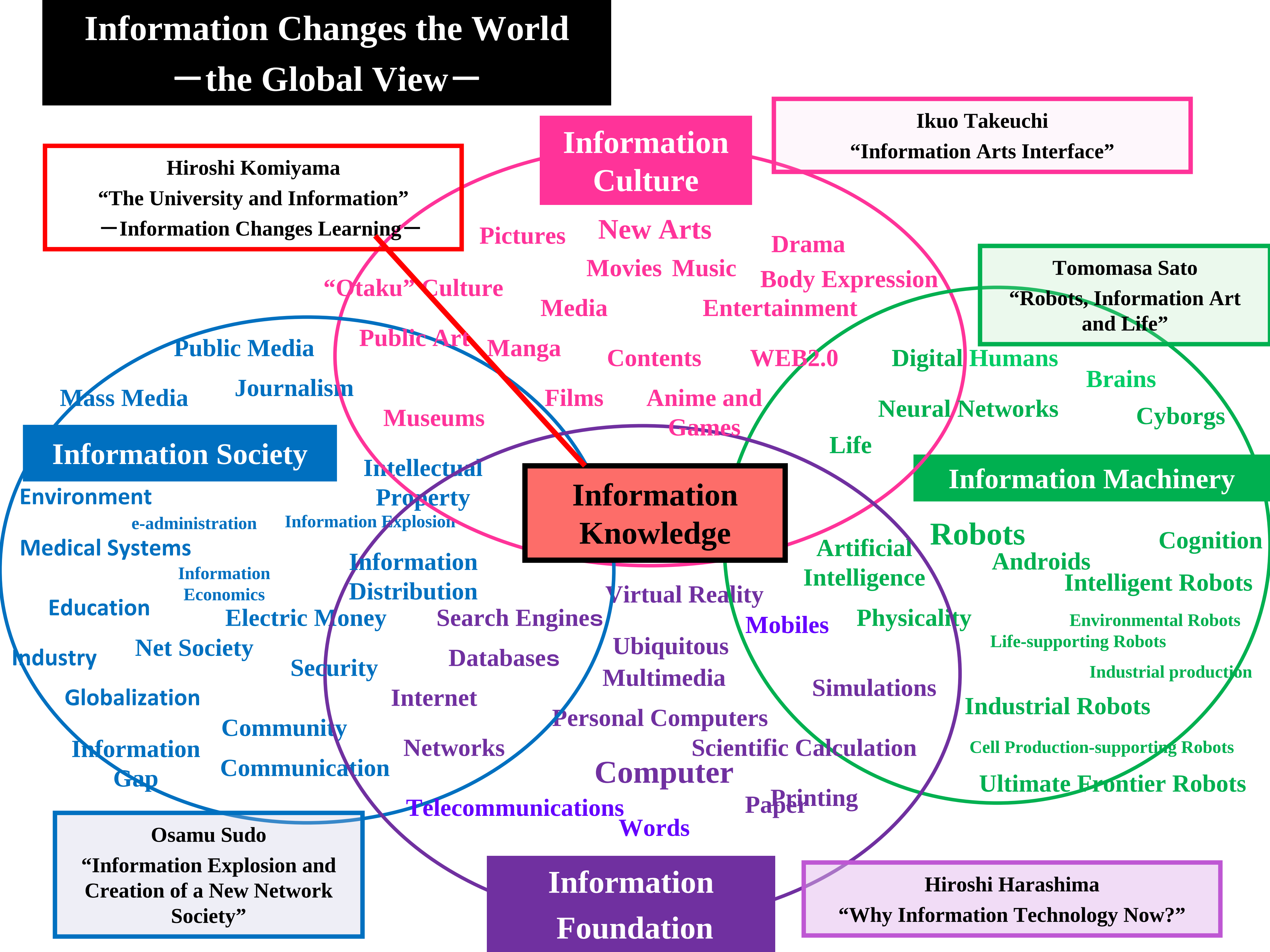
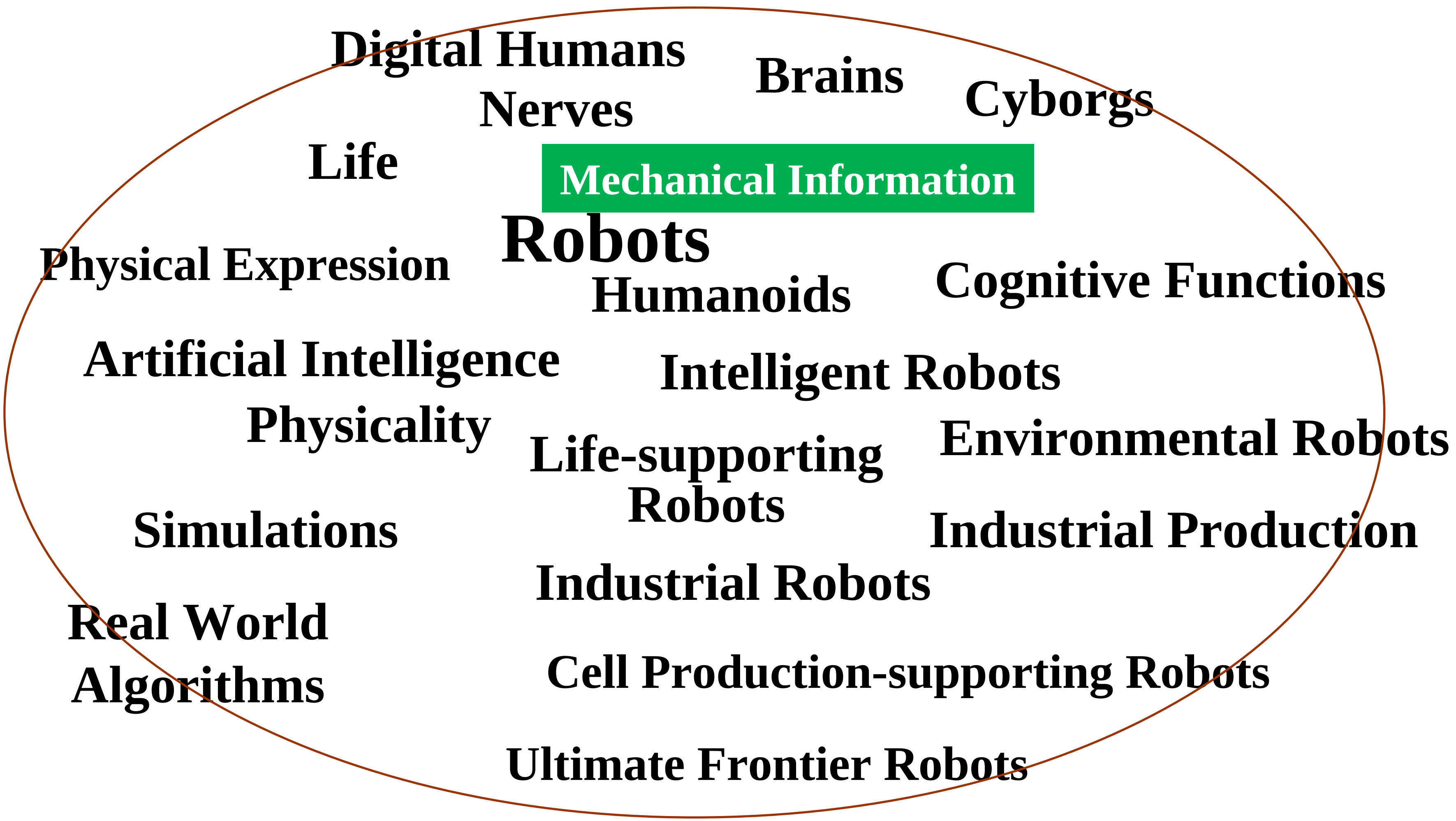
Tomomasa Sato


Information Changes the World
—the Global View—
Information Culture
Ikuo Takeuchi
"Information Arts Interface"
Hiroshi Komiyama
"The University and Information"
—Information Changes Learning—
Pictures
New Arts
Drama
Movies
Music
Body Expression
"Otaku" Culture
Media
Entertainment
Tomomasa Sato
"Robots, Information Art and Life"
Public Art
Manga
Contents
WEB2.0
Digital Humans
Brains
Public Media
Mass Media
Journalism
Films
Anime and Games
Neural Networks
Cyborgs
Museums
Life
Information Society
Intellectual Property
Information Knowledge
Information Machinery
Environment
e-administration
Information Explosion
Robots
Cognition
Medical Systems
Artificial Intelligence
Androids
Information Economics
Information Distribution
Intelligent Robots
Education
Virtual Reality
Electric Money
Search Engines
Mobiles
Physicality
Environmental Robots
Life-supporting Robots
Industry
Net Society
Ubiquitous
Security
Databases
Multimedia
Industrial production
Simulations
Globalization
Internet
Industrial Robots
Personal Computers
Community
Information Gap
Networks
Scientific Calculation
Cell Production-supporting Robots
Communication
Computer
Ultimate Frontier Robots
Telecommunications
Paper
Printing
Words
Osamu Sudo
"Information Explosion and Creation of a New Network Society"
Information Foundation
Hiroshi Harashima
"Why Information Technology Now?"

Robot's Areas of Coverage (an enlarged diagram)



Introduction
Part 1

Why robots in a lecture on information?

Why Robots in a lecture on Information?

Robots are responsible for conveying information to humans in the last 1-meter distance.

- **We are figures in motion.**
- **Our senses are in tune with our facial or body shapes and movements.**
- **Information systems normally reach us as bodies in motion (= robots); or at least as far as the computer will reach, this their aim.**

Humanoid →

‡

Professor Masayuki INABA,
Graduate School of Information Science and Technology,
The University of Tokyo

～ Real World Informatics ＝ Robotics ～

● **Robots are machines controlled by information**

* Creating robots helps you learn about data processing in humans and other living creatures.
* Also, robots adapted to the information outside and well-controlled can be useful for humans.

As stated above, robots are appropriate tools in learning the data processing of humans and other living creatures and in clarifying how to handle information in the real world. In short,

● **To pursue gathering information about the world we live in (the real world) is to pursue robotics.**

Environmental Robots →

The Robot’s 3 Roles

● **To be useful to humans → to create a new industry rivaling that of the automobile → to solve social problems and to meet social needs**

※ The last 1-meter to humans in the information system depends on the world of robots that have figures and movements

● **¶ To learn about humans → learn about robotics**

※ Robots are not just a terminus. They are science as well. Creating a robot deepens your understanding.

● **To impress humans → Robotics provides education and motivation**

※ Education and the development of human resources are managed in a collaboration of software and hardware

※ New robotics projects

With perspectives from **“Information Systems Functioning in the Real World ＝ Robots,”** we will study **the past 50 years and the coming 50 years** of robotics data processing as it applies to humans and the real world.

Introduction
Part 2

Lecture **“Information, Robots and life”**

Contents and Summary

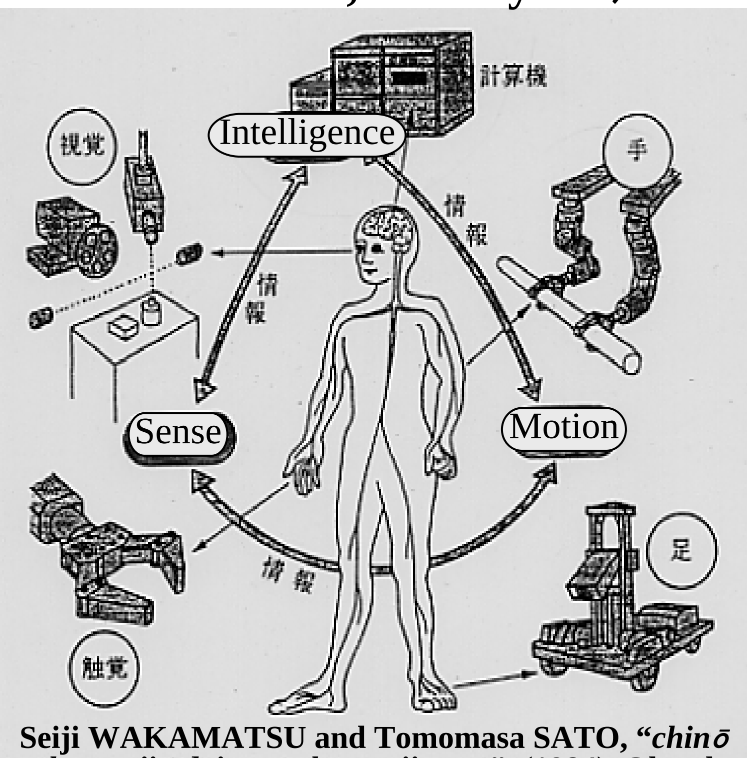
- **Informatics in robots designed to emulate and surpass human capability**
- **Informatics in robots designed to clarify human cognition**
- **Informatics in robotics designed to learn about life**
- **Informatics in robotics designed to be useful to humans**

Information, Robots and Life Dec. 8

Informatics in robots designed to emulate and surpass human capability

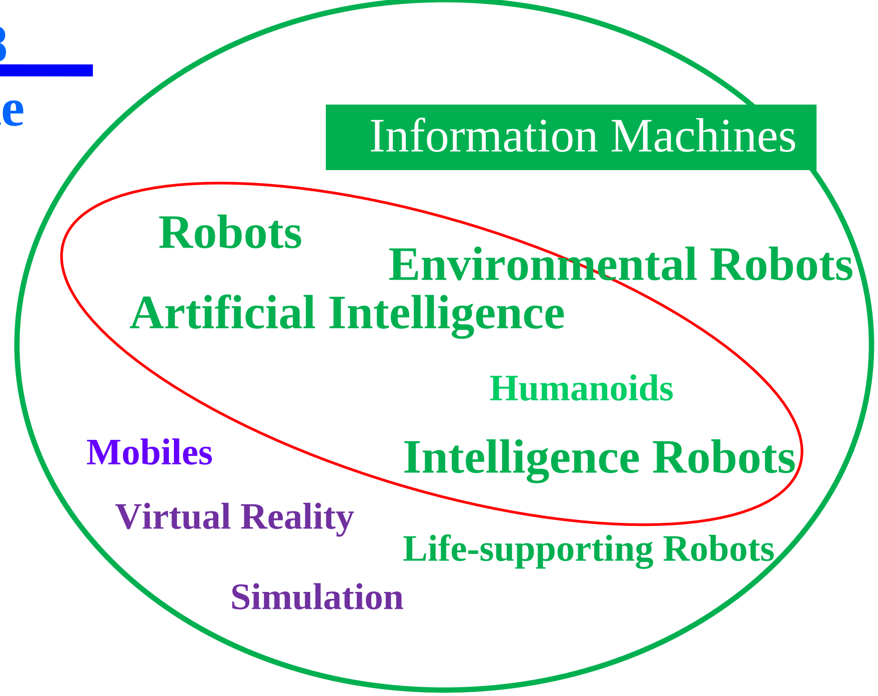
～ Tomomasa Sato～

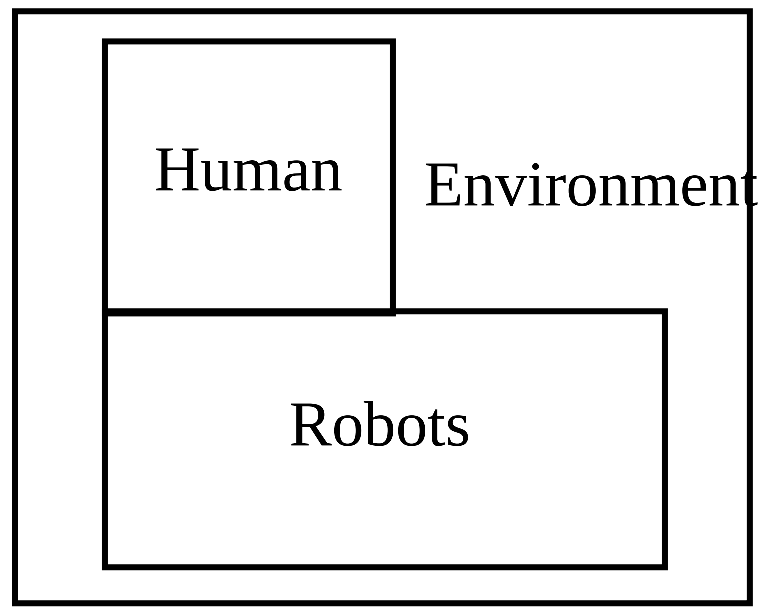
History of Intelligent Robots (Video images of robots from the 1960’s to 2000, and beyond）



Seiji WAKAMATSU and Tomomasa SATO, “*chinō robotto –jisedai no robotto gijutsu -*”, (1984), Ohmsha, p.4 Fig.1-2 ‡

Sense – Plan - Execute model and its data processing capabilites, limitations and development





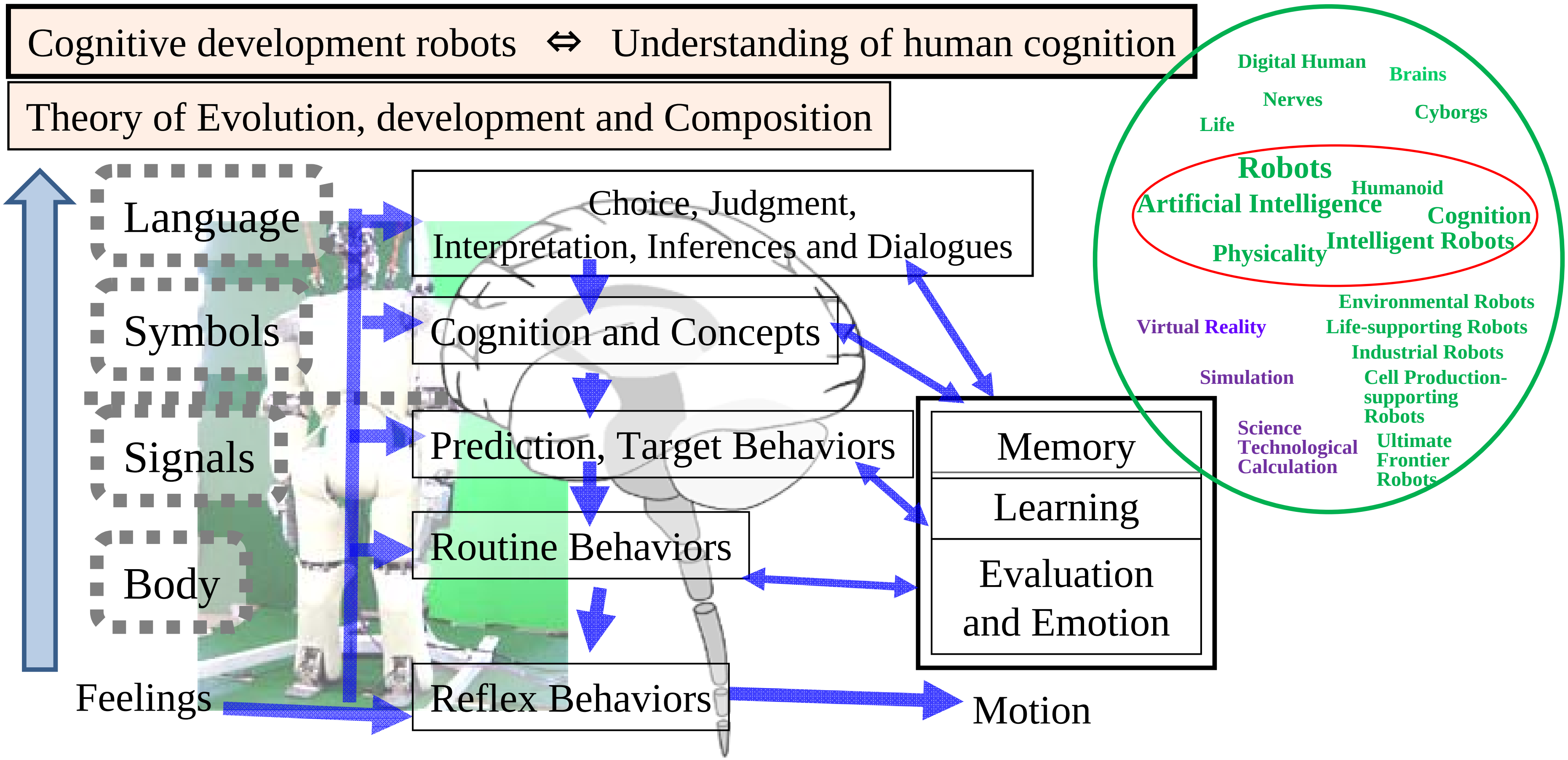
Man – Robot - Environment model and data processing

Information, Robots and Life Dec.13

Informatics in Robots Designed to Clarify Human Cognition

～ Yasuo Kuniyoshi～

Robots and Intelligence
（Learning and improving on robotics informatics）



Information, Robots and Life Dec. 20

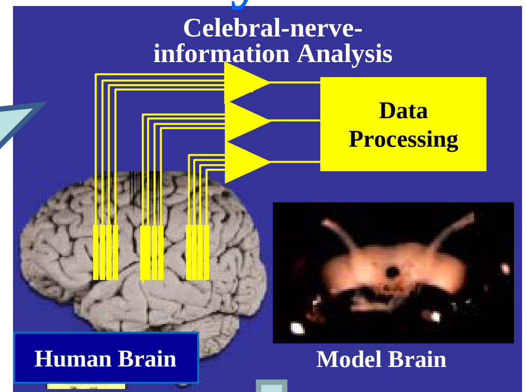
Informatics in Robots designed to study Life

～ Ryohei Kanzaki ～

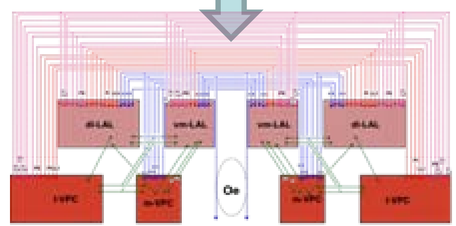
Life and Robots
（Informatics in brains and nerves through robots）

Digital Humans
Brains
Life
Nerves
Cyborgs
Information Machines
Robots
Artificial Intelligence
Cognitive Functions
Humanoids
Physicality
Intelligent Robots
Mobiles
Environmental Robots
Life-supporting Robots
Virtual Reality
Industrial Robots
Industrial Production
Simulation
Cell Production-supporting Robots
Science-Technological Calculation
Ultimate Frontier Robots

Understanding of humans and other creatures through robots



Biological Analysis of Brain and Nerves



Brain Model

Bio-informatics, Neuro-informatics

Robotic humanoid

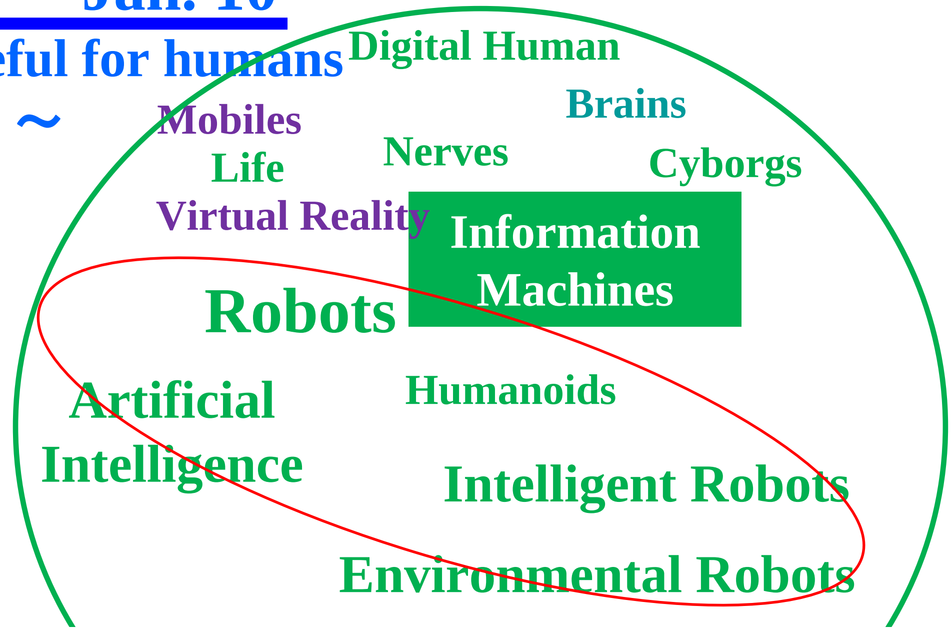
Biotic-model Robot

Evaluation by creating robots

Information, Robots and Life Jan. 10

Informatics in Robots designed to be useful for humans

～ Tomomasa Sato ～



Information Environment and Robots (Indoor-robot's informatics and ubiquitous systems)

Tomomasa SATO, editorial supervisor : The University of Tokyo 21 century COE *jitsusekaijōhō* project, *"hito to kyōzon suru conpyūta, robottogaku jitsusekai jōhō sisutemu"*, Ohmsha, p.2 Fig.1-1-1

A history of Automotive Technology-development and its Application to Robotic Development Strategy

History of automotive technological development

Age of Basic Technology Development - 1859 to WWI

Internal combustion engines, 4 wheel gas-fueled cars, pneumatic tires

Age of Social Technology Development - 1920's to WW2

Asphalt roads, highways, highway networks

Consumer Technology Development Age - 1946 - present

‡ **Japanese cars prevailed as global consumer products**

Data processing of robot's infrastructures

The 20th century is about automobiles; the 21st about robots

"Information, Robots and Life" 1st lecture

Informatics in robots designed to emulate and surpass human capability

- Informatics in robots to emulate humans (the 1960's-1980's)

- Informatics in robots to surpass humans (the 1980's-2000)

"Information, Robots and Life"

Lecture 1, Part 1

Informatics in robots designed to emulate and surpass human capability

Part 1

- **Informatics in robots designed to emulate humans**
  - **A - History of intelligent robots（the 60s to 70's）**
  - **B - History of intelligent robots（the 70s to 80's）**

Part 2

- **Informatics in robots designed to surpass humans**

Our objective is to experience applications in robotics technology.

History of Intelligent Robots（1960's -70's）

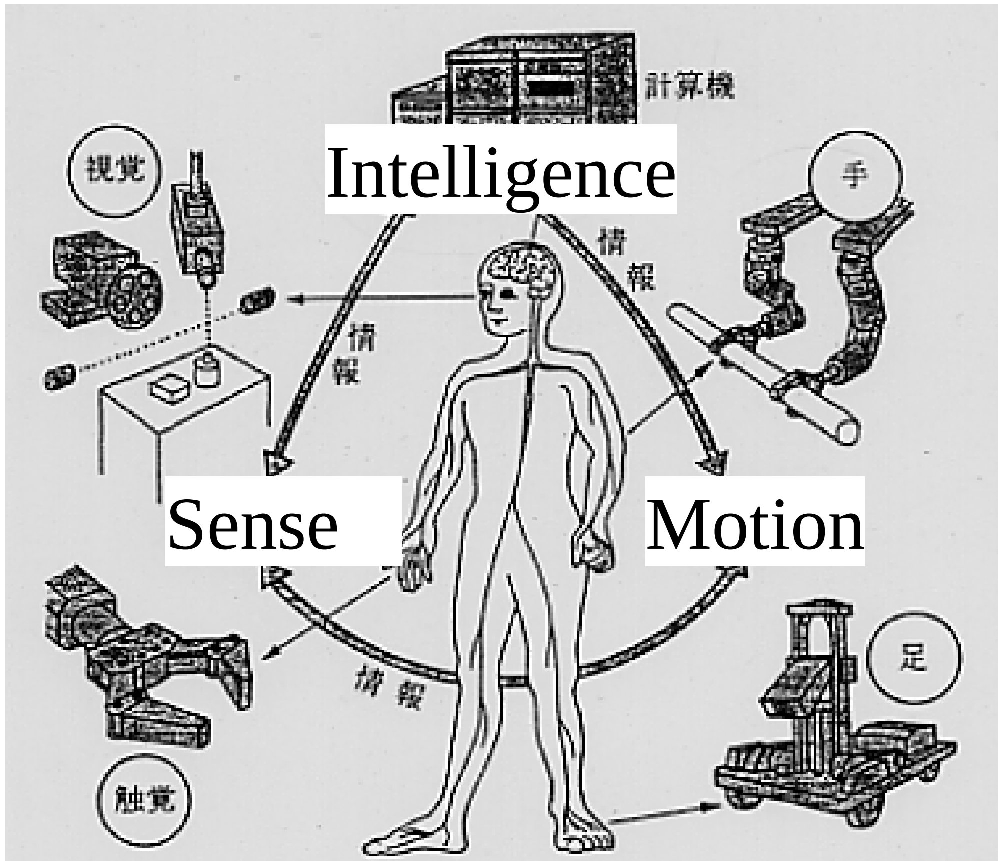
The Beginning of Artificial Intelligence
The Beginning of intelligent robot studies

● **The Age of Artificial intelligence**（from the 60's ）

With advances in computer technology, researchers grew familiar with computers, which encouraged them to use data processing capabilities to map human intellectual functions into robots.

With the successful study in data Processing of symbolic information and other areas of information mapping, natural language processing and problem solving have put expert systems to further practical use. **As part of the study of real-world intelligence, intelligent robots have been studied since the 60's.**

Initial Model of Human Data Processing



Seiji WAKAMATSU and Tomomasa SATO, “*chinō robotto – jisedai no robotto gijutsu -*”, (1984), Ohmsha, p.4 Fig.1-2 ‡

Sense | Planning | Behavior

Sense Planning Behavioral Model (vertical model)

What are “Robots”?
A Definition

Robots are

machines with human-like functions

↑

Motor functions, sensing functions and intelligent functions

Intelligent robots are

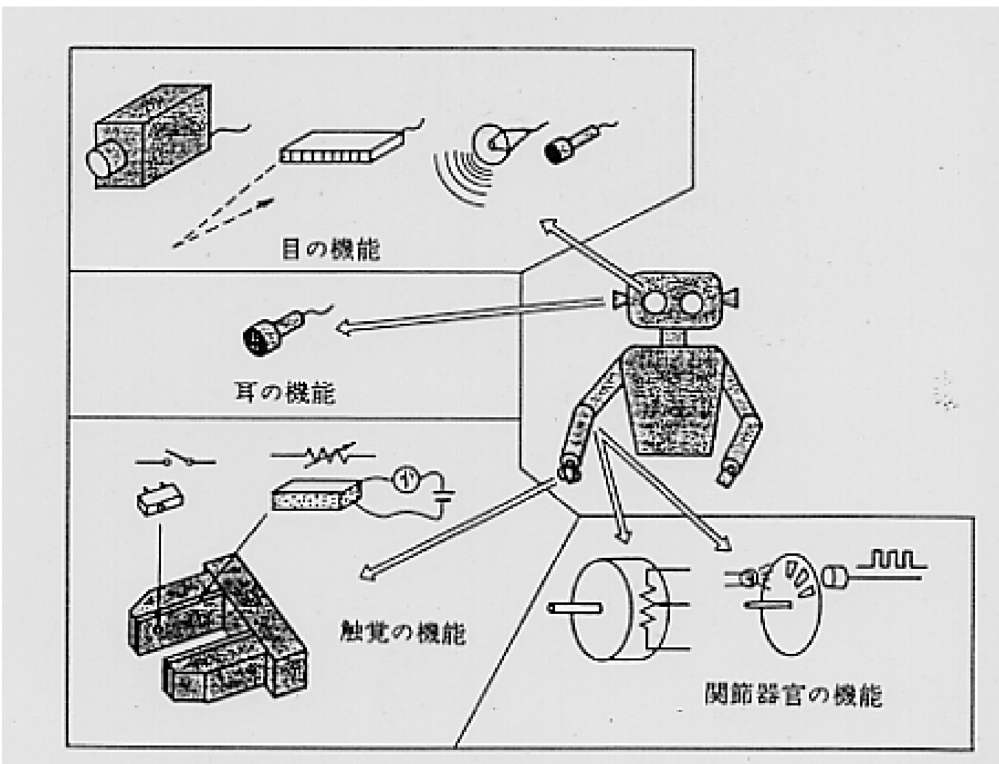
robots that adapt to the environment to work skillfully

I. Sensing Functions:

External sensors equivalent to a human's five senses

Internal sensors showing a robot's condition

- Informatics to input global information and process it well



Seiji WAKAMATSU and Tomomasa SATO, "*chinō robotto –jisedai no robotto gijutsu -*", (1984), Ohmsha, p.7 Fig.1-5

Pattern recognition study

‡ computer 8k words mini computer

Trailblazing Robots
ETL Robot MK-1 1970

Provided by National Institute of Advanced Industrial Science and Technology ‡

Intelligent robots with hands and eyes

The Current Status of Robots with Eyes（37 years later)
Urban Challenge (2007)

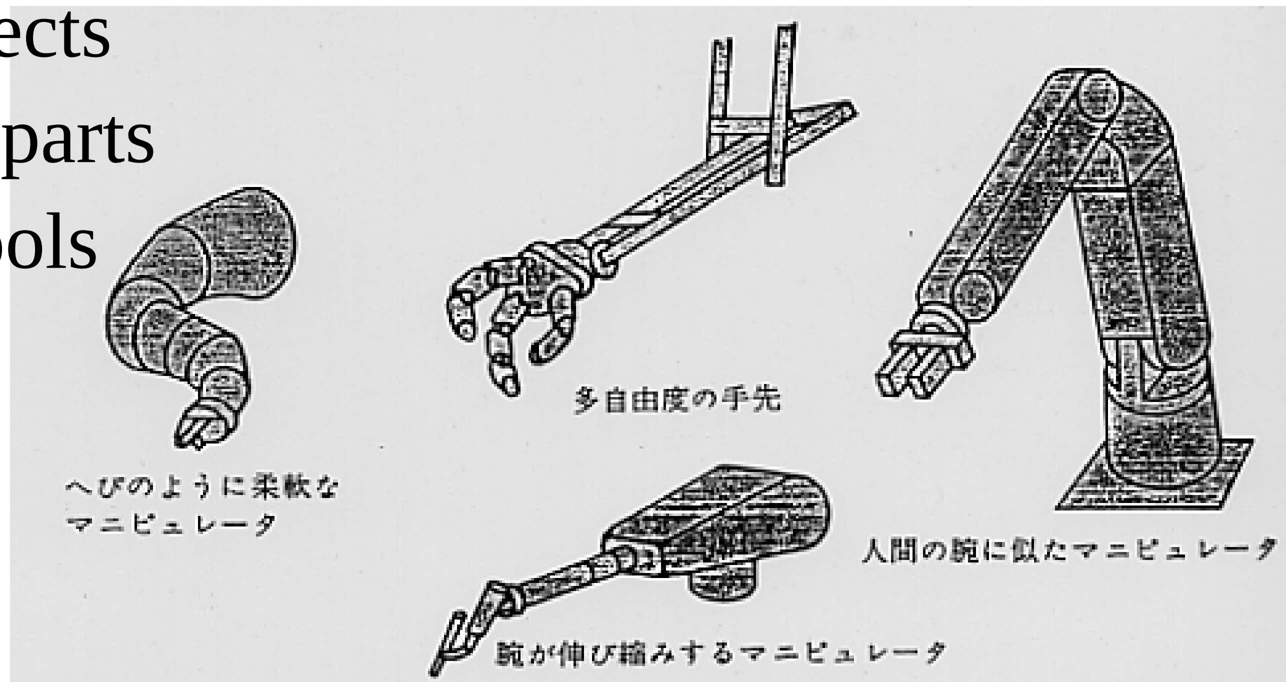
‡

Source: http://robot.watch.impress.co.jp/static/2007/11/08/uc_54.wmv
（http://robot.watch.impress.co.jp/cda/news/2007/11/08/733.html）

Automatic vehicle driving was realized in urban traffic, at intersections without signals and in avoiding parked cars.

II. Motor Functions　Part 1

1. Informatics to create manual functions (arms and fingers):
   - to move objects
   - to assemble parts
   - to operate tools

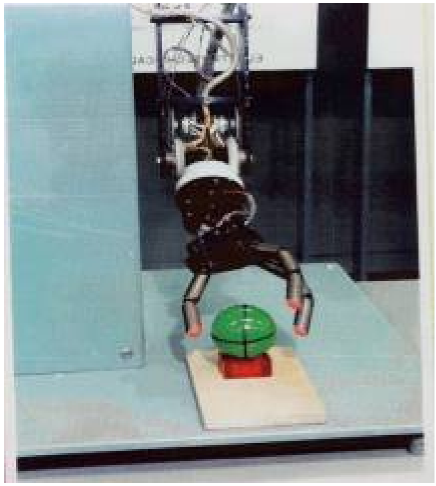


‡

Seiji WAKAMATSU and Tomomasa SATO, *"chinō robotto –jisedai no robotto gijutsu -"*, (1984), Ohmsha, p.6 Fig.1-3

Establishment of kinematics (particularly cymatics)

Three Finger Systems (1978)



Provided by Tokuji OKADA, Professor, Niigata University

- The three finger system

  Arms with 5 degrees of freedom (5DOF)

  Fingers with 11DOF (thumb 3, 2^{nd} finger 4, and 3^{rd} finger 4)

- Rope driving
- Work

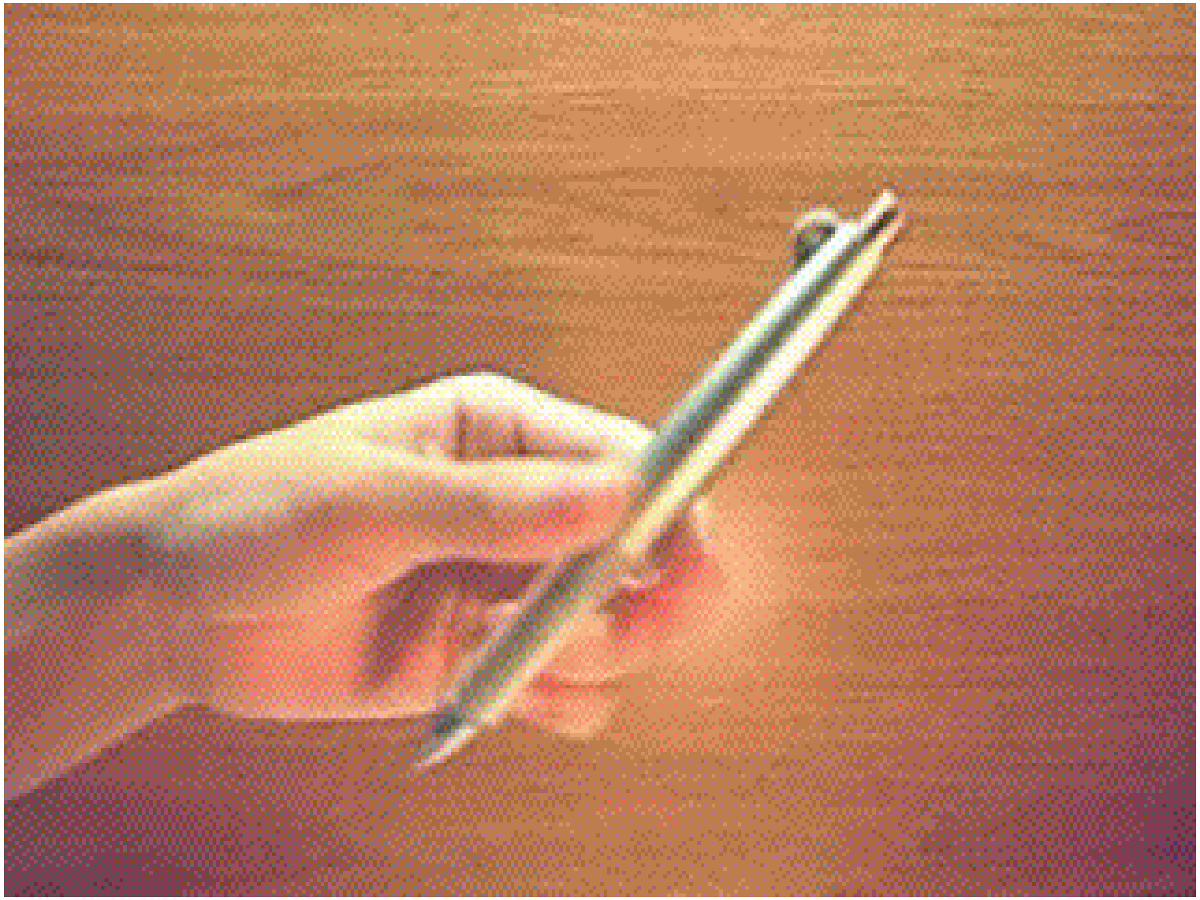
  Bar manipulation (teaching and playback)

  Nut mounting (trajectory planning)

The Finger Systems 1974

The figure is omitted due to copyright.

A man is fabulous



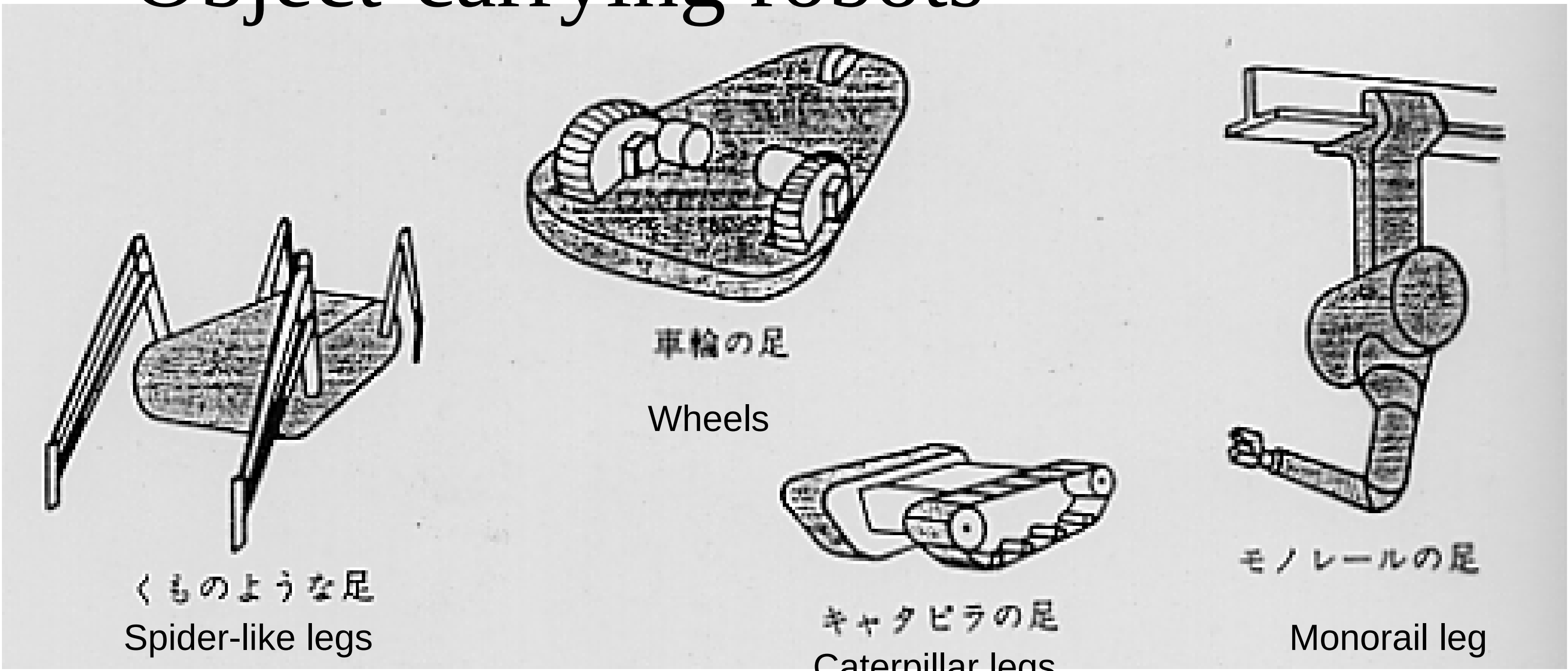
‡

Source: http://freestyle.penspinning.info/JapEn/japen1st.wmv
（http://freestyle.penspinning.info/JapEn/）

II. Motor Functions Part 2

2. Informatics to realize leg functions:

- Moving robots
- Object-carrying robots



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Seiji WAKAMATSU and Tomomasa SATO,
"*chinō robotto –jisedai no robotto gijutsu -*", (1984), Ohmsha, p.6 Fig.1-4

Trajectory study - path-planning method

Mobile-Handling Robots 1973

‡

Provided by National Institute of Advanced Industrial Science and Technology

Hopping Robots CMU（1984）

The figure is omitted due to copyright.

The Current Status of Hopping Robots (2006)

**Source: http://www.bostondynamics.com/dist/BigDog.wmv
http://www.bostondynamics.com/content/sec.php?section=BigDog**

BigDog is the alpha male of the Boston Dynamics family of robots. It is a quadruped robot that walks, runs, and climbs on rough terrain and carries heavy loads. BigDog is powered by a gasoline engine that drives a hydraulic actuation system.

Intelligent Robots (1960s - 70s)

In the toy world, robots were equipped with programs that work intelligently based on information gathered to activate intelligent functions.   By eliminating human intervention, robotic autonomy was pursued.

Incompleteness of computer statements and of real-world sensors and actuators revealed human multi-functional intelligence.

History of Intelligent Robots (1970's - 80's)

Intellectual functions

Informatics to activate

Functions that adapt to the environment

Functions that accomplish tasks skillfully

Functions that adapt to human beings

Let's study the intellectual functions above in some examples of how they work

Intelligent Robots until the Early 80s
- How They Worked -

1. Receiving the work request
2. Deciding the work sequence
3. Creating the work environment
4. Attaching parts (nuts) with arms
5. Pinching nuts
6. Screwing nuts
7. If the nut doesn’t rotate, try using a tool (wrench)

Computer 1 Mips super mini computer

Work Sequence 1

Humans vs. Intelligent robots

Humans	Intelligent robots
Receive a work request	Receive a work order in robotic language

Using words:

"Knock this down"

Using body language

Robotic languages

vocabulary, language with limited grammar

Pick valve1, Place box on table

Accept arm's motion → remote control

Environmental learning system

Remaining challenges： Adapting to human functions

→ Sensing a person's intensions by watching him/her

Remote Work Robots Manipulating Scenes

‡

July, 1982

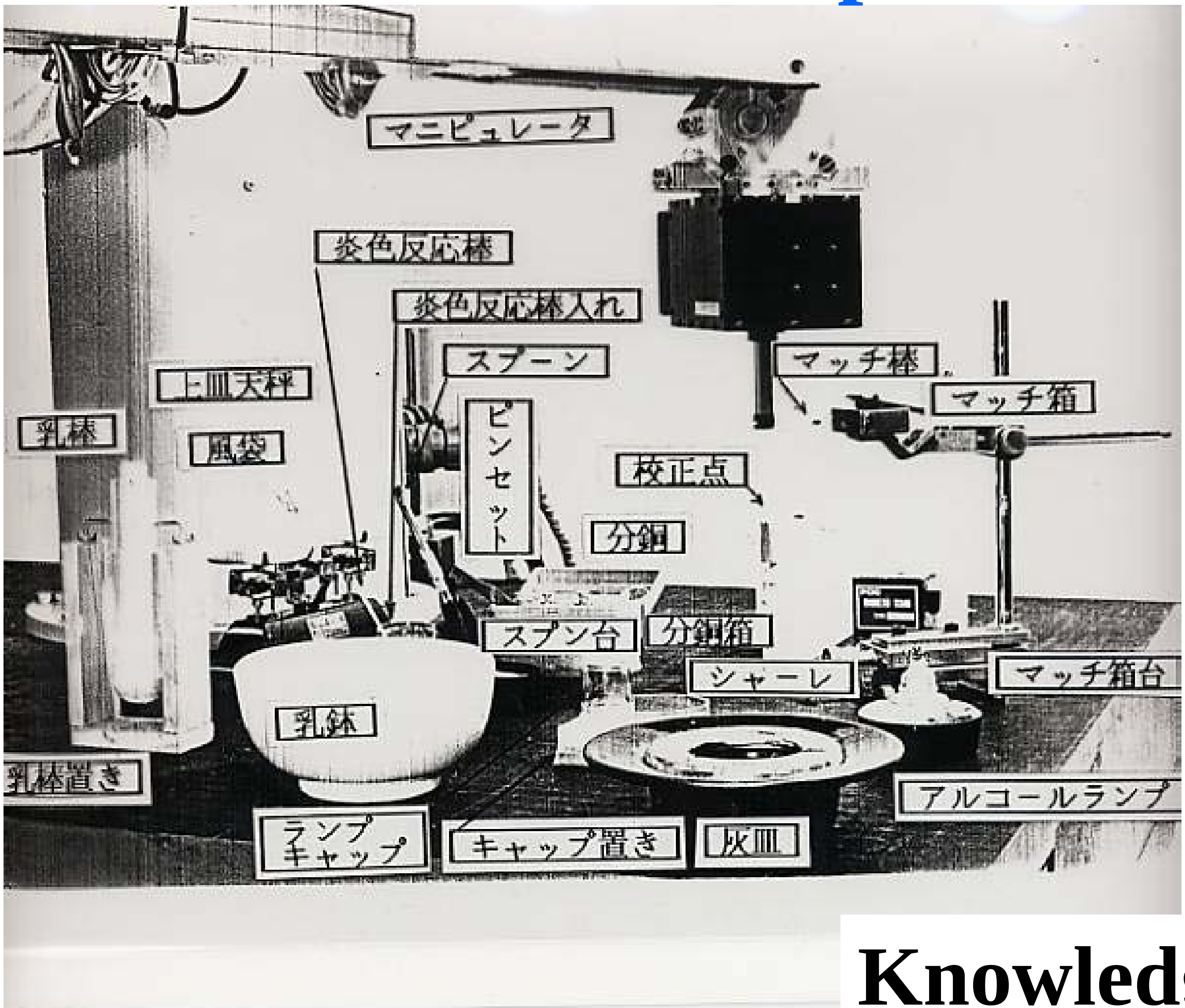
Provided by Shigeoki HIRAI, National Institute of Advanced Industrial Science and Technology

Intelligent Remote Work Robots MEISTER

‡

Provided by Shigeoki HIRAI, National Institute of Advanced Industrial Science and Technology

Ultimate Work Robots
MEISTER's Components



Provided by Shigeoki HIRAI, National Institute of Advanced Industrial Science and Technology

‡

Knowledge basis

Work Sequence 2

Humans vs. Intelligent Robots

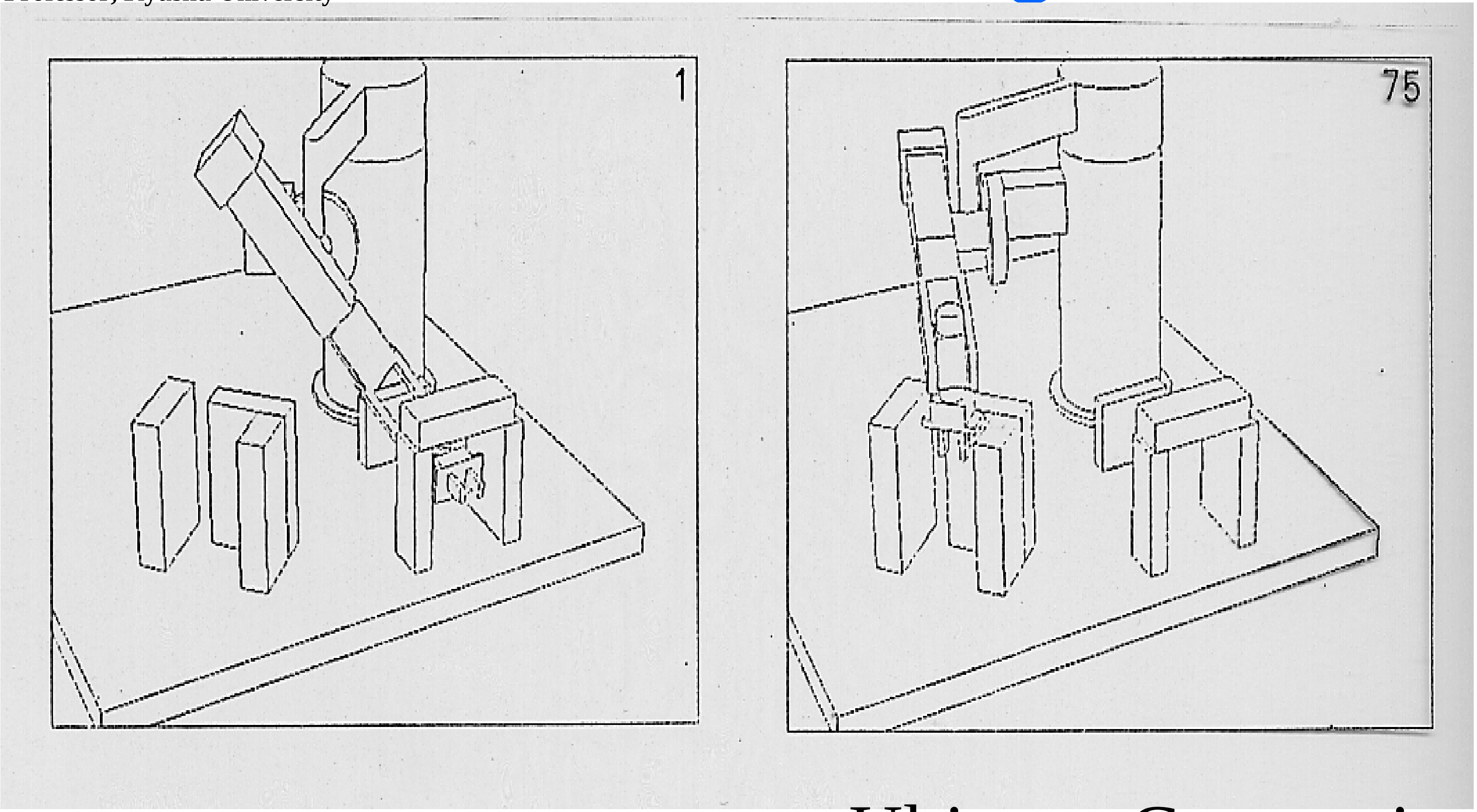
Humans	Intelligent Robots
Consider a work sequence	Plan a work sequence observing how the machine was assembled
Thinking over how to knock down while screwing bulbs	Planning the work sequence in advance

Remaining challenge: Ability to complete the work

→ making a work plan adopting abundant knowledge, experience and common sense

Provided by Tsutomu HASEGAWA,
Professor, Kyushu University

Motion Planning



Initial Geometric Model

Ultimate Geometric Model

Collision-avoidance Path Systems

Planning collision-avoidance behaviors using a manipulator

Challenge:

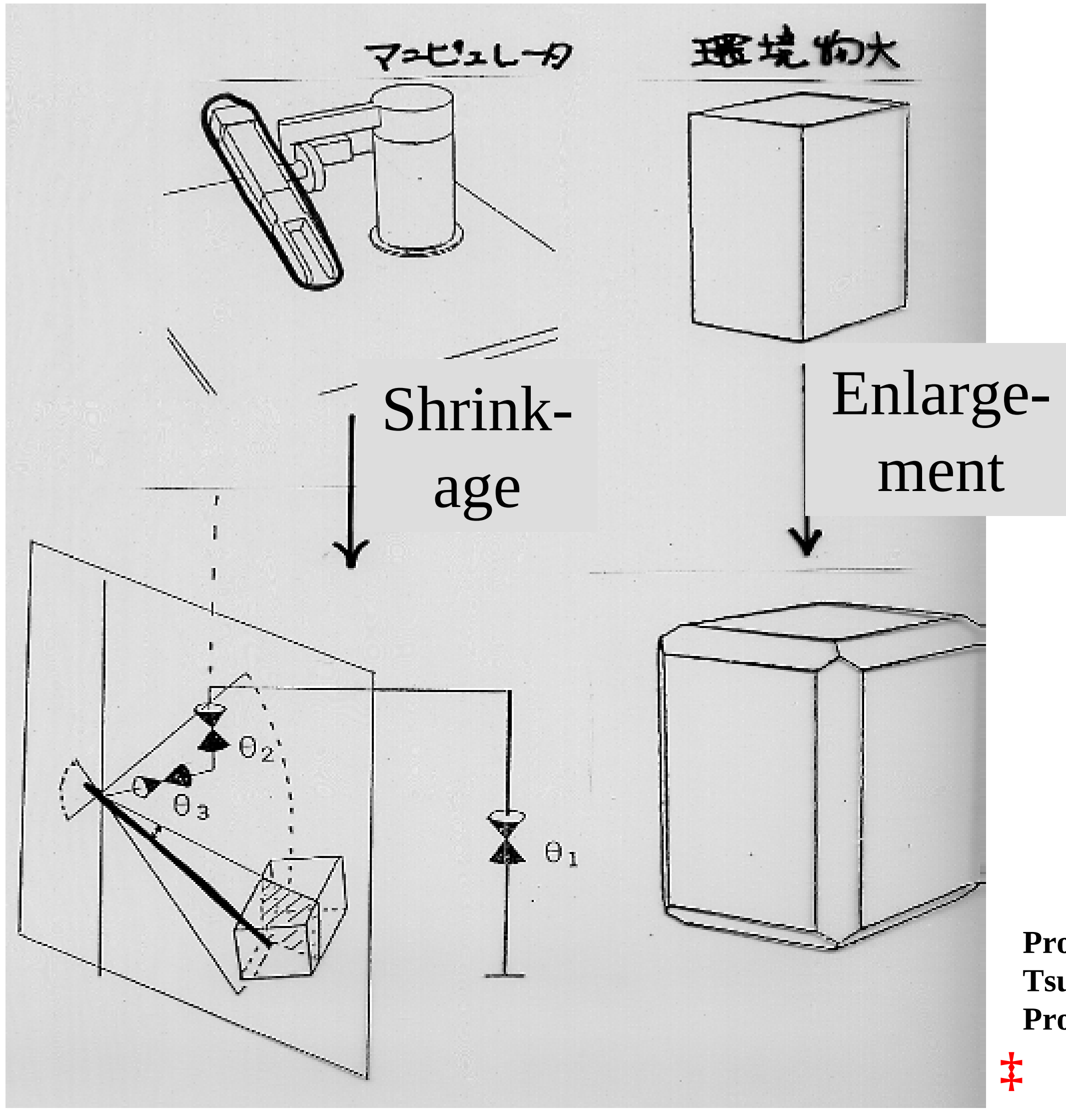
Find a trajectory for motion without colliding with any object in the environment from beginning to end.

Challenging environment

Find a space that has the same DOF dimensions as the manipulator's

Innovation makes motion planning possible

Simplification of Manipulators



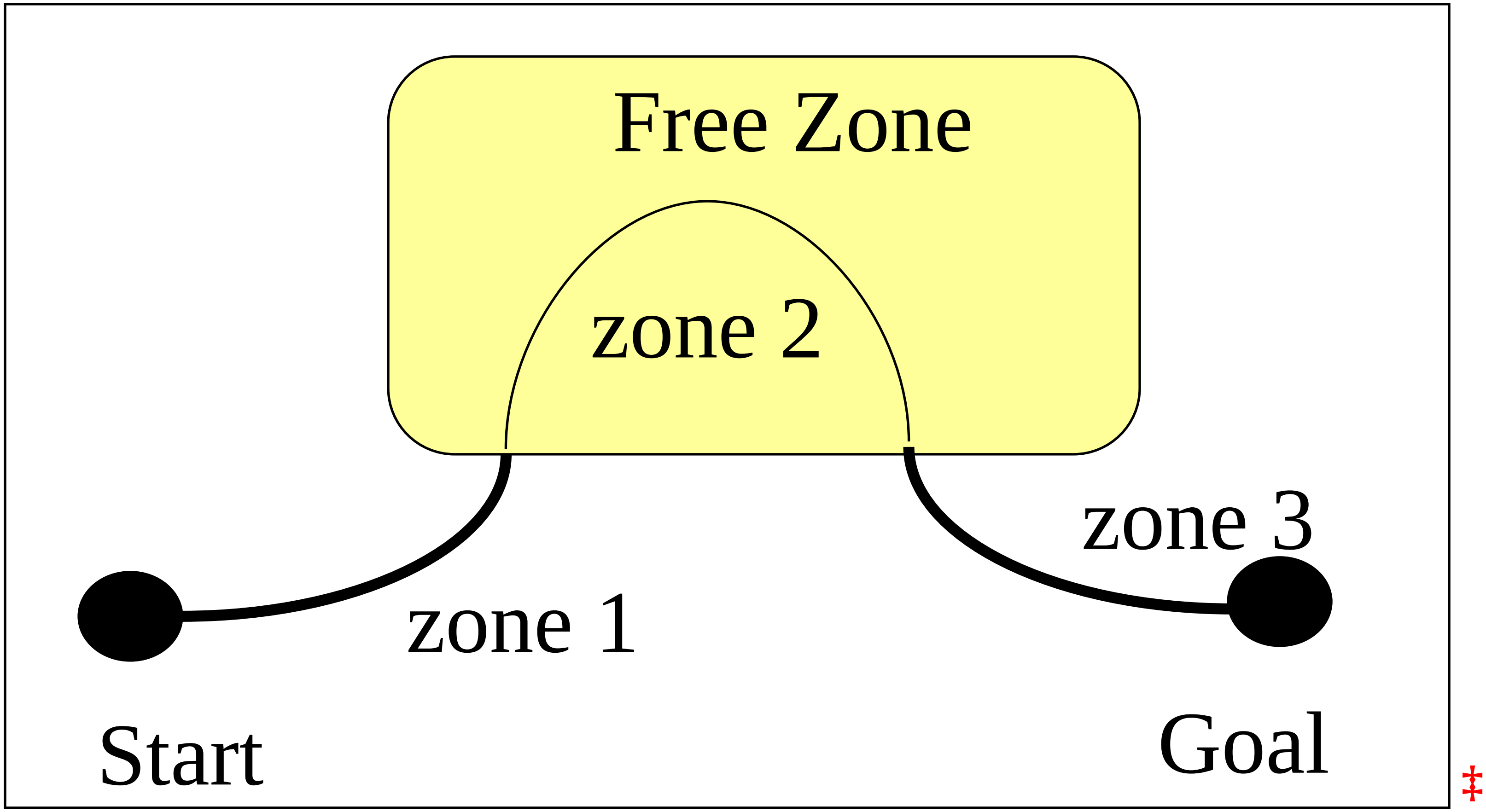
Provided by
Tsutomu HASEGAWA,
Professor, Kyushu University

‡

To speed up collision interference calculations

Innovation to make work planning possible

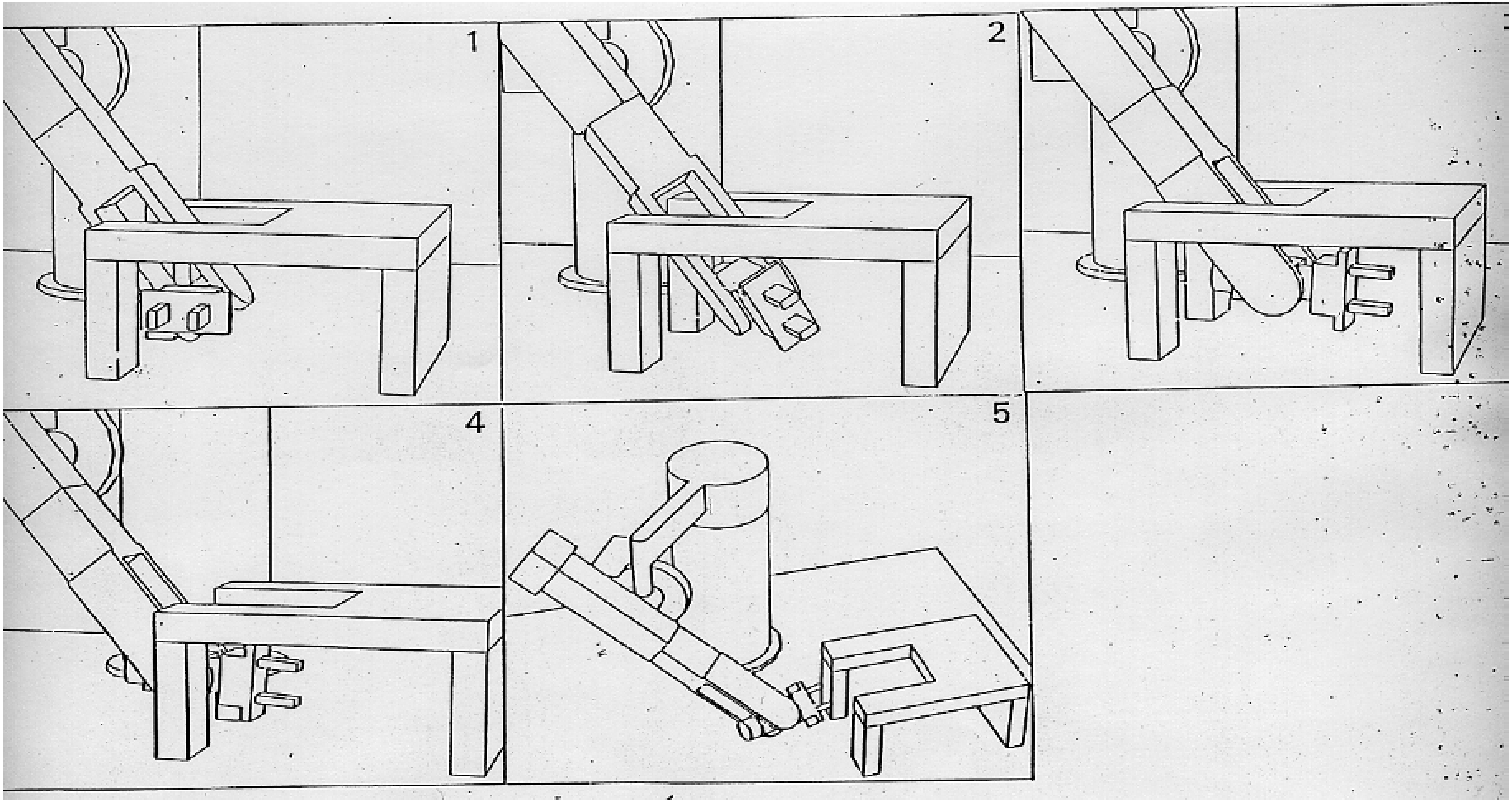
Divide and Conquer



Provided by Tsutomu HASEGAWA, Professor, Kyushu University

The most effective way to solve a complicated problem is to divide it into multiple simple problems and find a solution in their combination.

Planned arm movements



Provided by Tsutomu HASEGAWA, Professor, Kyushu University

Obstacle Avoidance Motion Videos

‡

Provided by National Institute of Advanced Industrial Science and Technology

Work Sequence 3

Humans vs. Intelligent Robots

Humans	Intelligent Robots
Set up a work environment	Plan a camera and lighting position
Immobilize the bulb in a good place with a vise	Active sensing plan
Move the head to see the bulb clearly	Camera positioning plan
Turn on a light when dark	Lighting angle positioning plan

Remaining challenge： adapting functions to the environment

→ Autonomous behaviors in configuring the work environment and in planning and implementing sensors.

HEAVEN Sensing-Planning Systems

Shigeyuki SAKANE, Professor, Chuo University

‡

Work Sequence 4

Humans vs. Intelligent Robots

Humans	Intelligent Robots
Move the hand toward the part (a nut)	Measure the nut position and move the hand toward it
While watching the nut,	Understand the graphic image Find the nut Verify vision Measure the location of the nut
Move the hand over it	Plan a trajectory Plan a path not to collide with any obstacles Move the hand along the path

Remaining challenge : Flexible functions interdependent with the environment

→ Instantaneous understanding and judgment of the environment and prompt response actions.

Work Sequence 5

Humans vs. Intelligent Robots

Humans	Intelligent Robots
Pinch the nut	Position the fingers on the nut and close them

Visual feedback

Position the hand using visual information

Force Feedback

Keep closing the fingers until they acquire a certain force

Remaining challenge : Functions to accomplish work using sensors → Development of the five-sense sensors of vision, force, touch, slip and taste, and their utilization with sensory feedback.

Hand- Eye Systems

Provided by National Institute of Advanced Industrial Science and Technology

‡

Light-plane-intersecting Method, Verification of a Vision and Knowledge Basis

Work Sequence 6

Humans vs. Intelligent Robots

Humans	Intelligent Robots
Twist the nut	Torque the nut around the pivot
With 5 fingers,	Force control
Twist gently	Rotate the arms

Remaining challenge : Skillful Functions

→ Subtle adjustments in control of force

Work Sequence 7

Humans vs. Intelligent Robots

When the nut doesn't move,

Think "I'm going to use a tool (wrench)"

Measure rotation angle of the nut and try to twist it.

When it doesn't rotate,

call up an error recovery process routine.

Error detection

Error analysis

Error recovery

Remaining challenge : Functions to recover errors and accomplish the task → Error recovery functions to deal with various situations and complete the work.

Humans vs. Robots

1. Receive a task request	**Work Order**
2. Consider a process	**Work planning**
3. Set up the environment	**Work environment planning**
4. Move arms to parts (nut)	**Visual Feedback**
5. Pinch the nut	**Manipulation**
6. Twist the nut	**Force control**
7. Use a tool (wrench) when the nut doesn't turn.	**Error recovery**

Fields of study are created for each function

Intelligent Robots up to the Early 80's Model-Based Robotics

Based on geometric and work models, arithmetic processing implements intelligent functions.

- **Geometric models advance to computational geometry. Two challenges remain: model's incompleteness, and adaptation to a wide variety of real environments.**

→ The age of behavior-based robotics in the 90's

→ The age of car navigation systems.

- **Humans adopt the role of teachers → as objects to be supported (in the 90's).**
- **These studies clarified man's excellent capability.**

Then computers became Workstations

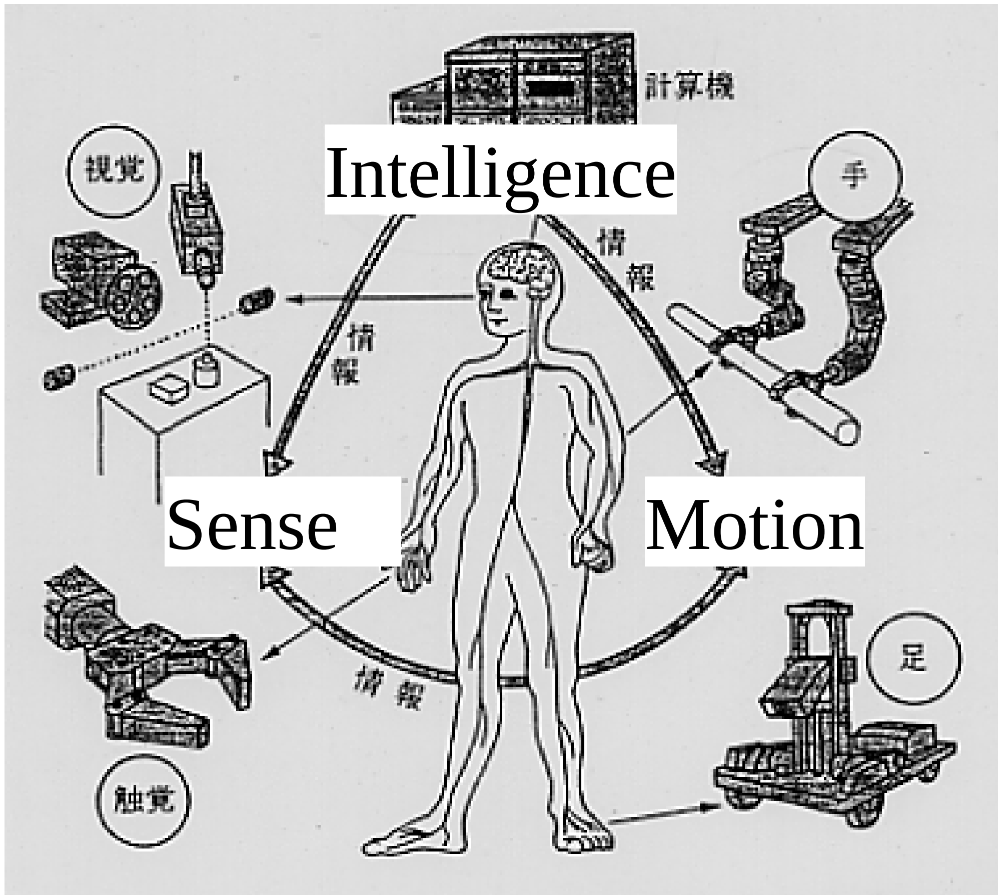
Robots aspiring to emulate Humans (1960's - 80's) Summary

Robots aspiring to emulate humans (from the 60's) : Robots aiming at implementing human's intellectual activities and physical capabilities, and their informatics.

- **Background ideas :** Computers were expensive in the 60s. When researchers began to use computers, they started to study artificial intelligence which can think for itself. As an extension of this research, robots were programmed and tested to study materials and work with hands.
- **Robots realized :** Various robots were designed – robots to distinguish objects on a table, carpentry robots that work with both hands, mobile robots that have flexible fingers, hands and eyes, robots that can locomote by jumping. It is not too much to say that all prototypes of the currently existing robots were experimented on in this age. However, this study revealed that humans were far more capable than robots. Industrial robots, on the other hand, became widely used at factories because of their high repeatability index that humans cannot match.
- **Supporting Technology :** Fundamental fields in robotics such as computer vision, kinematics and path-planning of mobile robots became clear in this age.

Reconsideration on the model

Initial Model of Human Information Processing



Seiji WAKAMATSU
and Tomomasa SATO,
"chinō robotto –jisedai no robotto gijutsu -",
(1984), Ohmsha, p.4 Fig.1-2

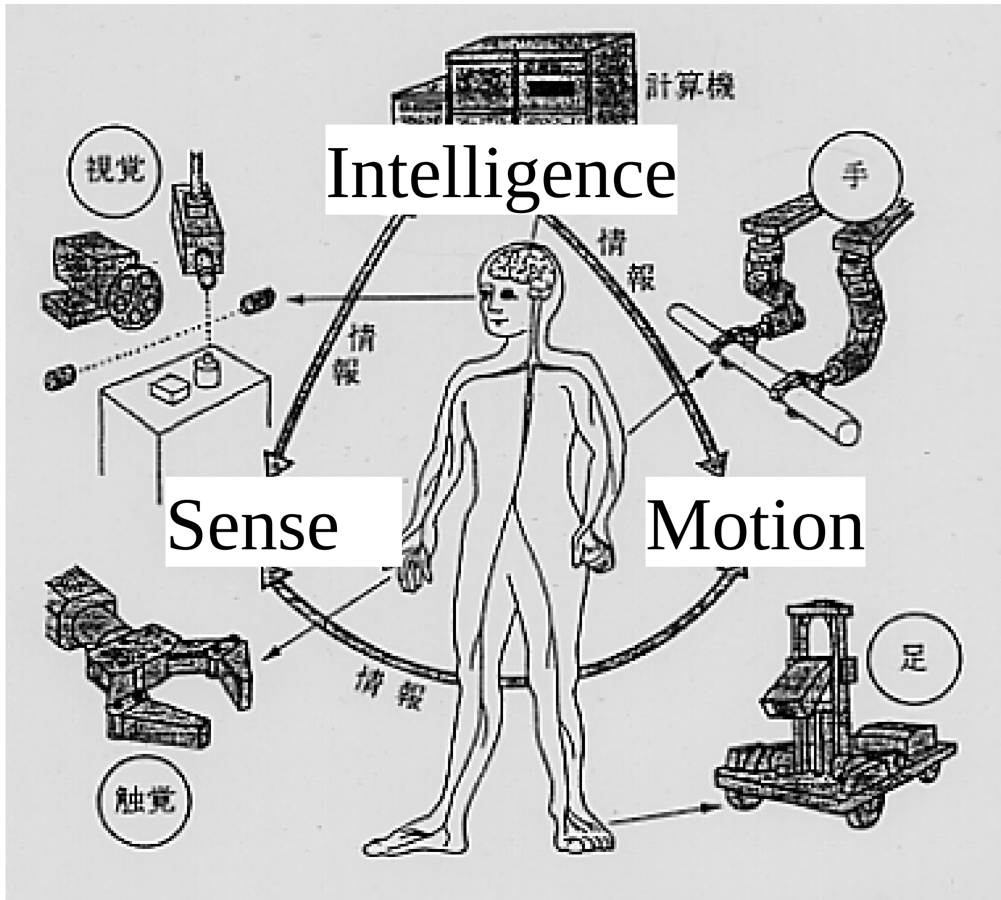
Sense | Planning | Behavior

‡

Sense Planning Behavioral Model

(vertical model)

Later Model of Human Information Processing



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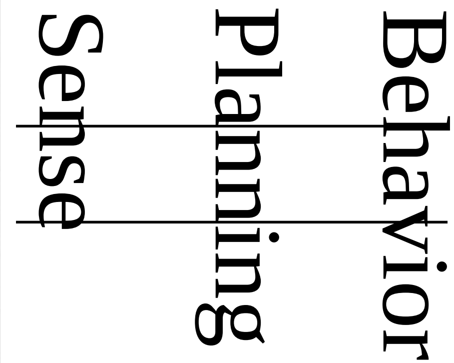


Dispersed Parallel Model (horizontal model)

"Information , Robots and Life"
Lecture 1 – Part 2

Informatics in robots designed to emulate and surpass human capability

Part 1 Informatics in robots designed to emulate humans

Part 2 Informatics in robots designed to surpass humans

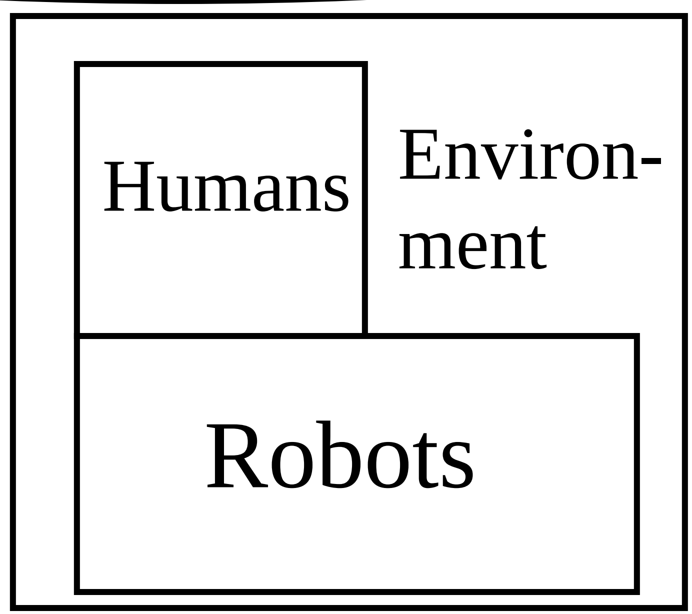
- **A - Robotic systems model**
- **B - Robotic systems – work contents scope 1**
- **C - Robotic systems - work object sizes scope 2**
- **D - Robotic systems – dimensions and wider applications scope 3**

The objective is to refresh the robot's image

Part 2 Informatics in robots designed to surpass humans

A - Robot system model (Robots between the 1980's and 2000)

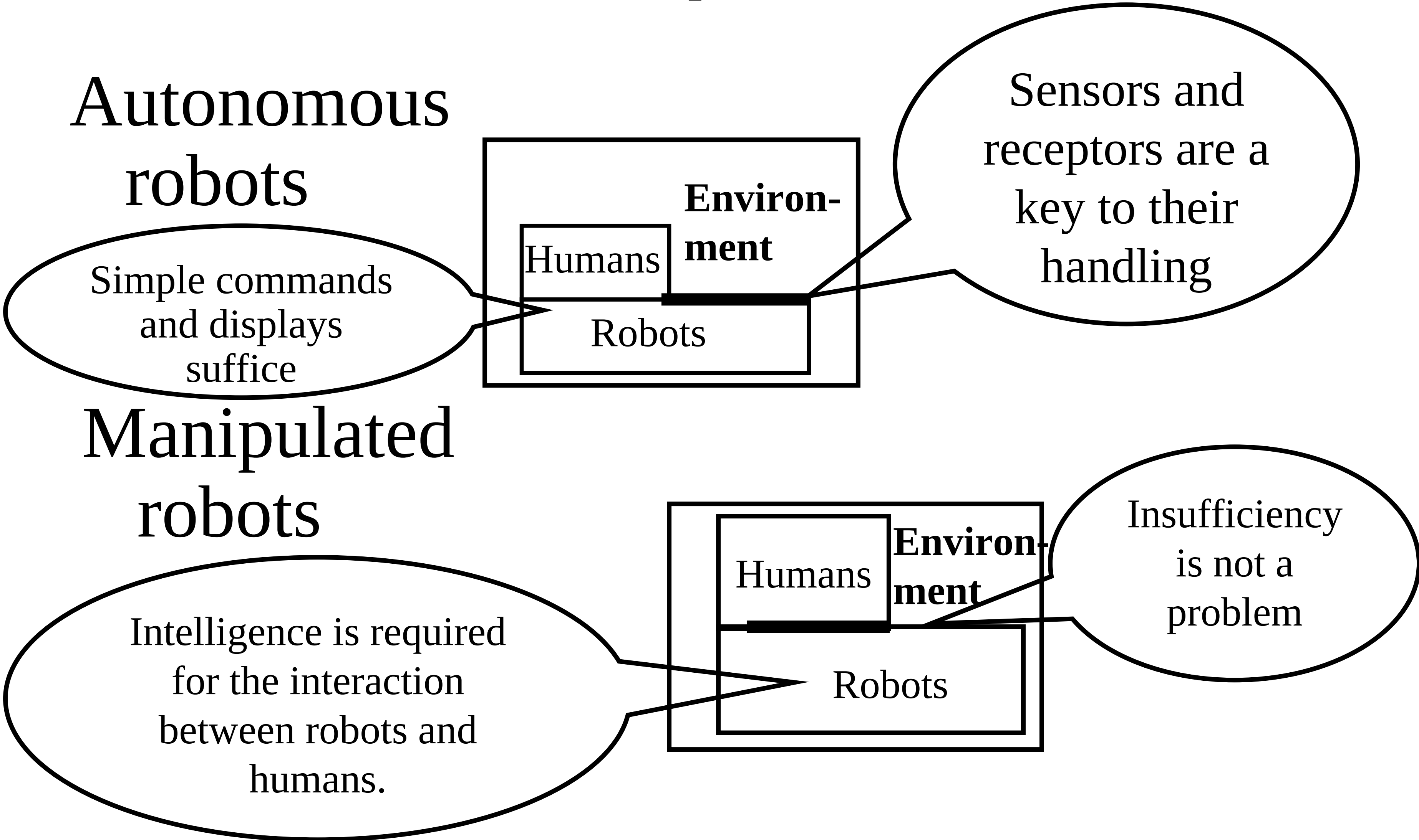
This model perceives a robot as a system comprised of these elements



Robot system model

Robots and Humans, Differences in how they deal with the environment 1/2

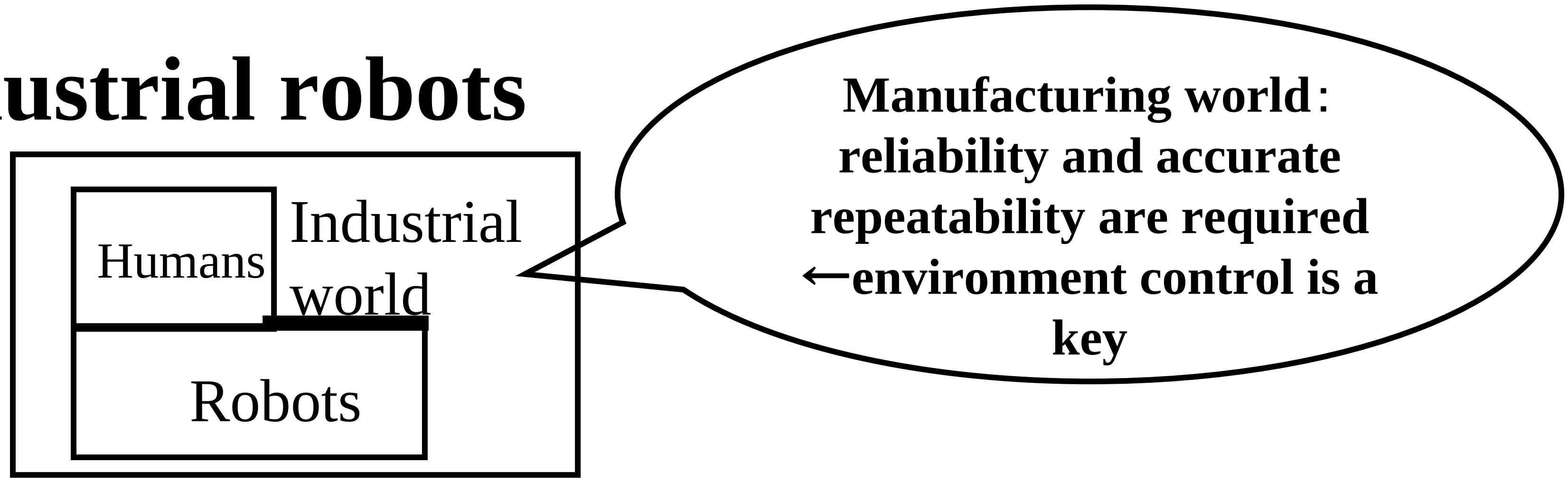
Autonomous robots and manipulated robots



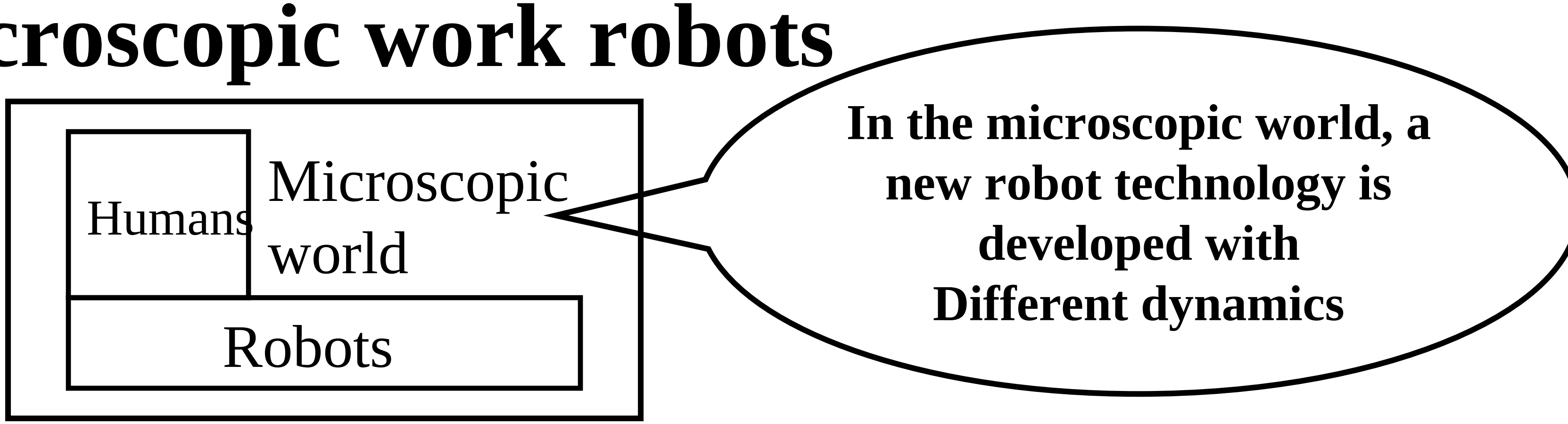
Different worlds where robots live 2/2

Industrial robots vs. microscopic work robots

Industrial robots



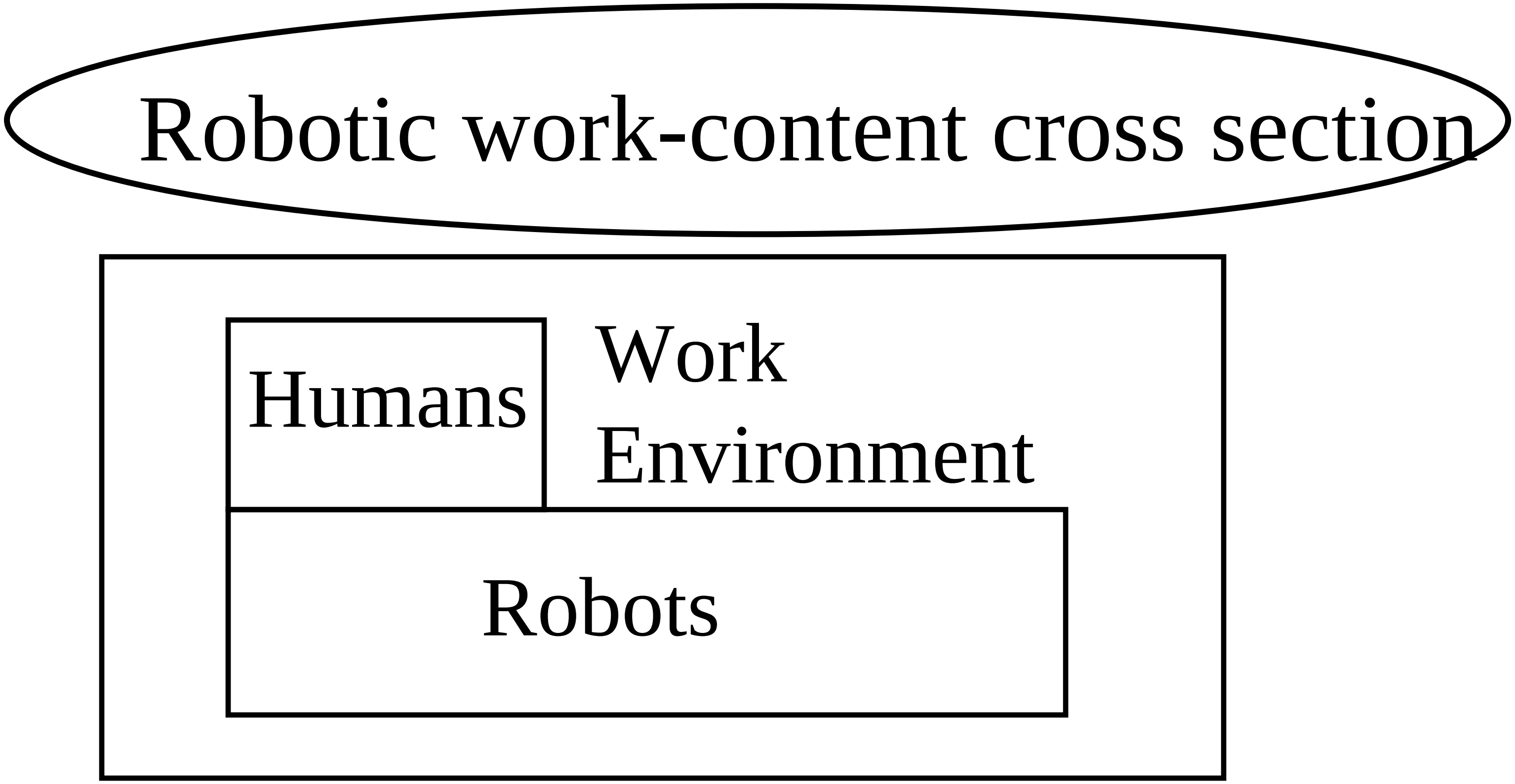
Microscopic work robots



Their Scope from a Work-content Perspective

Robot System Scope 1

Scope from a work-content Perspective



All of our activities and far beyond become the contents of robot's work objects

Verb 1: Manufacturing

Analyze（分析する）
Assemble（組み立てる）
Disassemble（分解する）
Repair（修理する）
Build（建てる）
Machining（加工する）
Measure（計測する）
Operate（手術する）
Produce（生産する）
Sense（検知する）
Test（試験する）

Genre of robots ‡

References: TAKASE, Kunikatsu (1985)
“Ultimate Work Robots Study Results : A Brief summary” (p. 13)

Verb 2: Process adding Behaviors

Punch（たたいて穴をあける）
Drill（ドリルで穴をあける）
Saw（のこでひく）
Cut（切る）
Cut-out（切り抜く）
Whet（研ぐ）
Sharpen（とがらせる）
Shave（削る）
Plane（かんなで削る）
Whittle（ナイフで削る）

Polish（みがく）
Grind（研磨する）
Weld（溶接する）
File（やすりをかける）
Squeeze（押し潰す）
Powder（粉にする）
Scratch（ひっかく）
Drive-nail（釘を打つ）
Unnail（釘を抜く）
Dig（ほる）

‡

References: TAKASE, Kunikatsu (1985)
“Ultimate Work Robots Study Results : A Brief summary” (p. 13)

Verb 3: Flexible-object Operational Actions

Wash（洗う）
Squeeze（絞る）
Wind（巻く）
Tic（むすぶ）
Wire（配線する）
Spread（張る）
Bend（曲げる）
Fold（折る）
Wrap（つつむ）
Saw（縫う）
Knead（もむ）
Tear-off（はがす）

‡

References: TAKASE, Kunikatsu (1985) “Ultimate Work Robots Study Results : A Brief summary” (p. 13)

Verb 4: Collective- object (e.g. Liquid and Powder) Handling Behaviors

Pour（注ぐ）
Paint（塗る）
Plaster（しっくいを塗る）
Spray（散布する）
Distribute（まく）
Sift（ふるいにかける）
Fill（充填する）
Lubricate（油をやる）
Stuff（ねり物をつめる）

Mix（まぜる）
Wipe（ふく）
Gather（かき集める）
Draw，Pump（汲む）
Scoop（すくう）
Laddle（柄杓ですくう）
Clean（掃除をする）
Write（書く）

‡

References: TAKASE, Kunikatsu (1985)
“Ultimate Work Robots Study Results : A Brief summary” (p. 13)

Verb 5: Locomotion and Connecting / Disconnecting Behaviors

Transfer（運ぶ）
Throw（投げる）
Place（置く）
Put-on（のせる）
Arrange（配列する）
Lean（たてかける）
Hang（つるす）
Insert（挿入する）
Combine（結合する）
Screw（ねじ込む）

Unscrew（ねじをぬく）
Separate（分離する）
Extract（引き抜く）
Attach（取付ける）
Set（合わす）
Lock（締める）
Unlock（ゆるめる）
Pack（つめる）
Unpack（取り出す）

‡

References: TAKASE, Kunikatsu (1985)
“Ultimate Work Robots Study Results
: A Brief summary” (p. 13)

Verb 6: Sheer Movement and Force Effect Actions

Move（動かす）
Incline（傾ける）
Pull（引っ張る）
Lift（持ち上げる）
Turn（まわす）
Twist（ねじる）
Push（押す）
Support（支える）
Shake（振る）
Vibrate（振動する）

Swing（ゆらす）
Impact（衝撃力を加える）
Strike（打つ）
Fit（あてる）
Slide（すべらす）
Grasp（にぎる）
Pick（つまむ）
Release（はなす）

‡

References: TAKASE, Kunikatsu (1985)
"Ultimate Work Robots Study Results : A Brief summary" (p. 13)

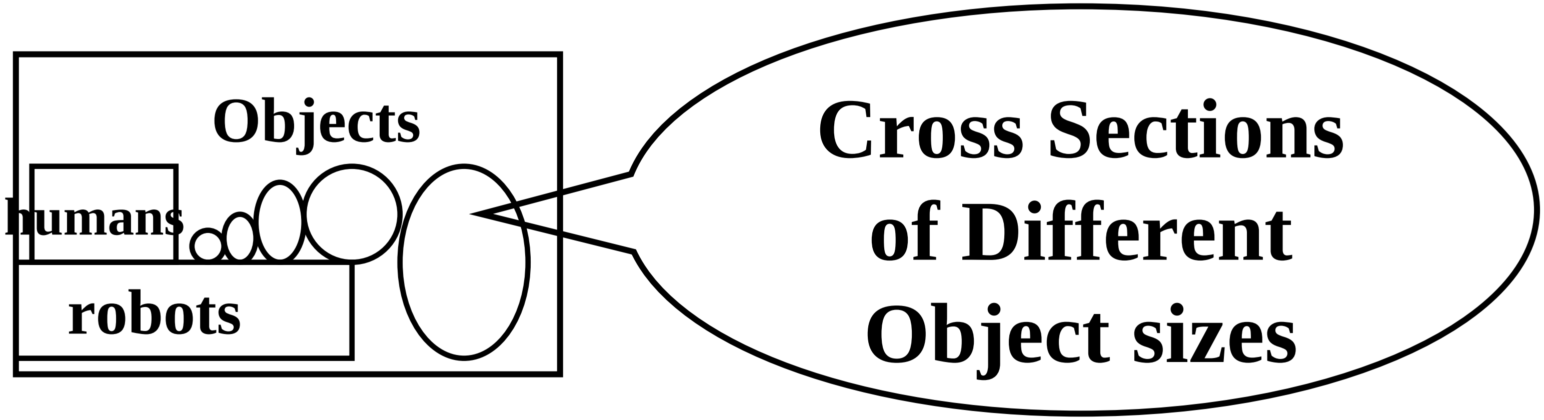
The 2nd half ● Informatics in Robotics designed to surpass human capability

The 2nd half C ● Robotic System Scope 2
The Dimensions of work Objects

The Scope of Test Object Sizes

Robotic System Scope 2

The Scope of Object Sizes to Handle

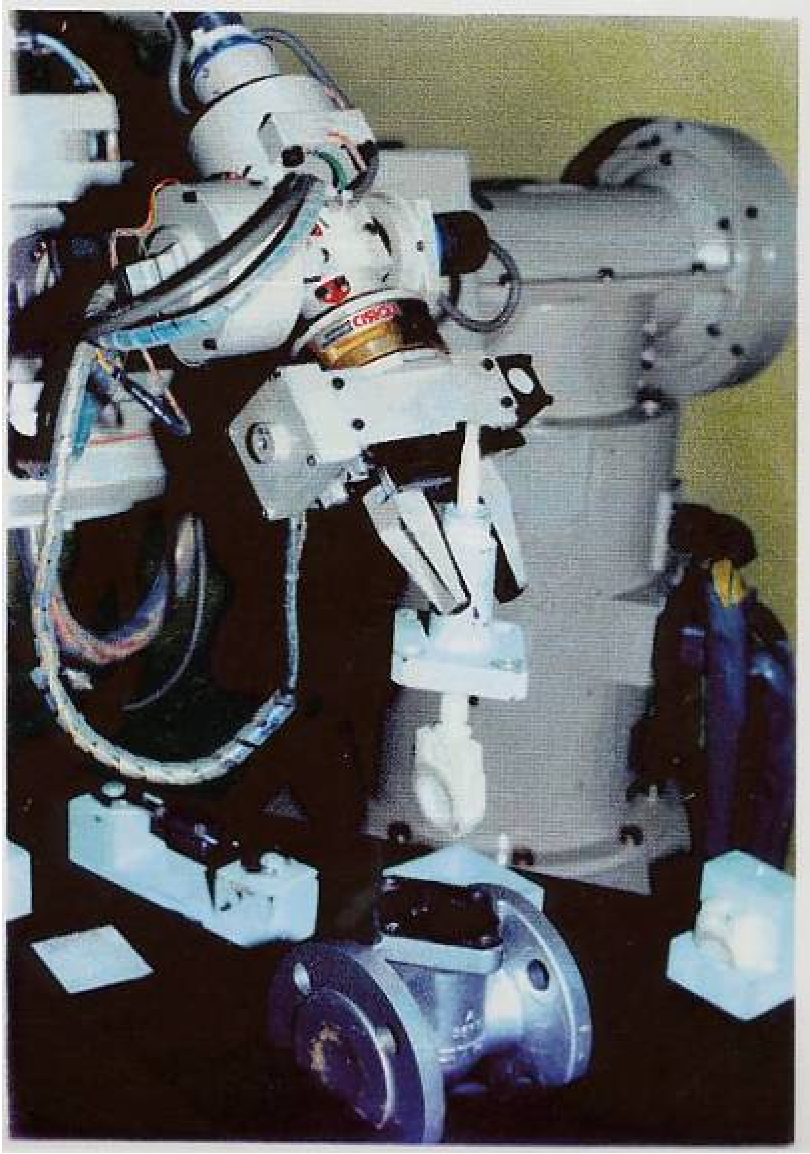


The dimensions of work objects vs. robots

- **Enormous-object-handling robots**
- **Space robots**
- **Industrial robots**
- **Daily-object-handling robots**
- **Microscopic-work robots**
- **Ultimate microscopic-object-handling robots**

System structures and usages vary depending on object sizes

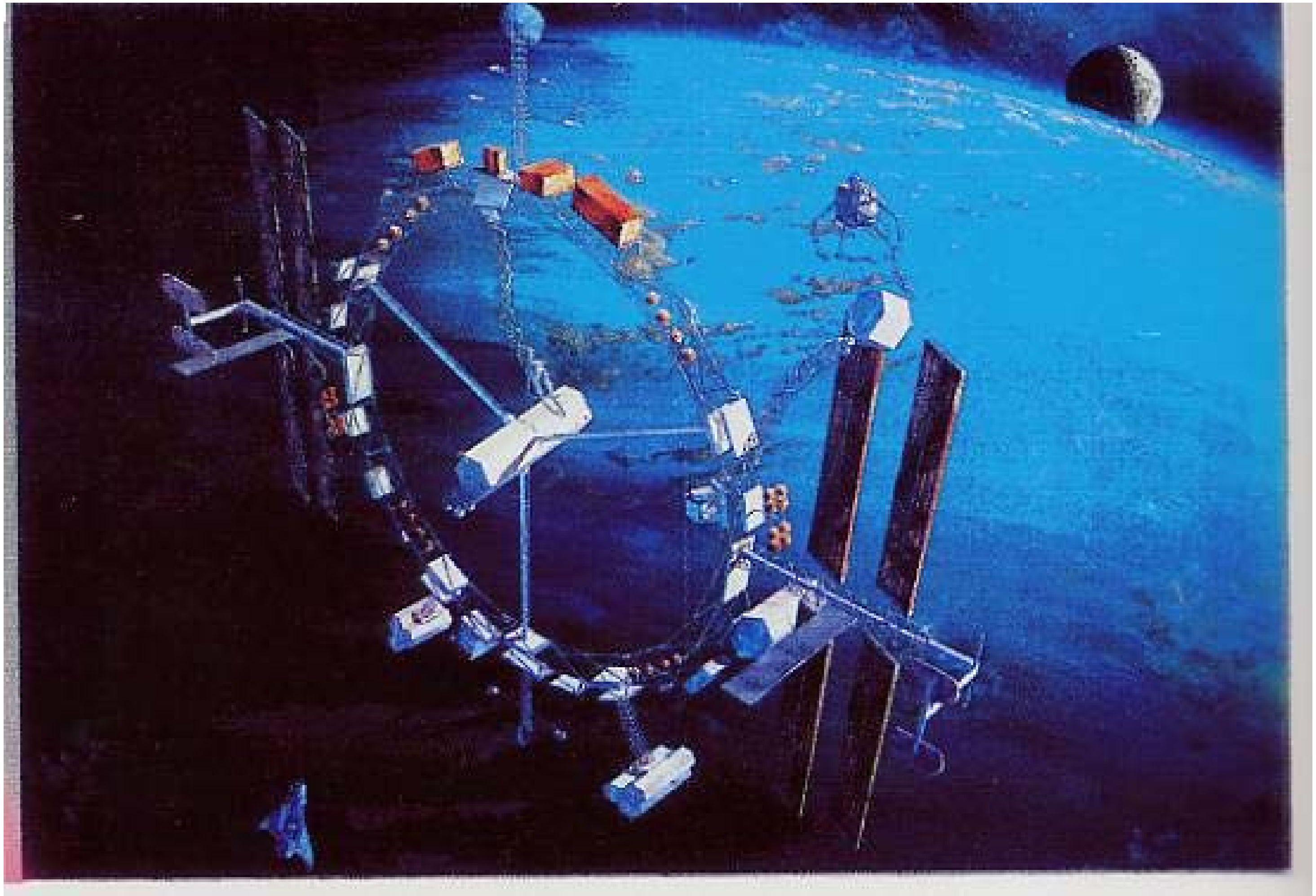
Daily-commodity-handling Robots



Provided by Kunikatsu TAKASE, Professor, The University of Electro-Communications

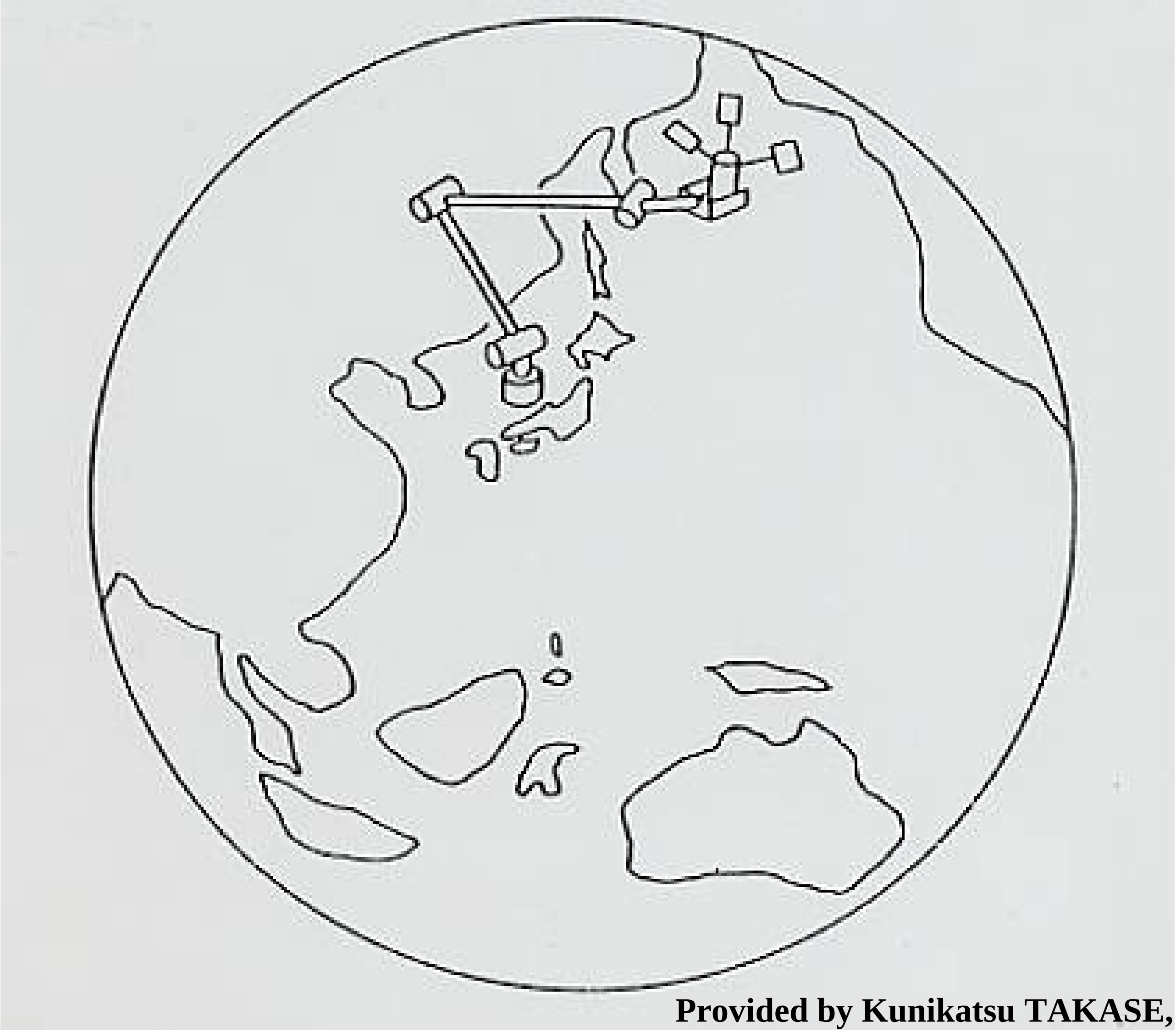
Balloon your Imagination toward bigger objects

Space-structure-handling robots



Journal of SICE *"keisoku to seigyo"* Vol.28, No.12, cover, 1989 ‡

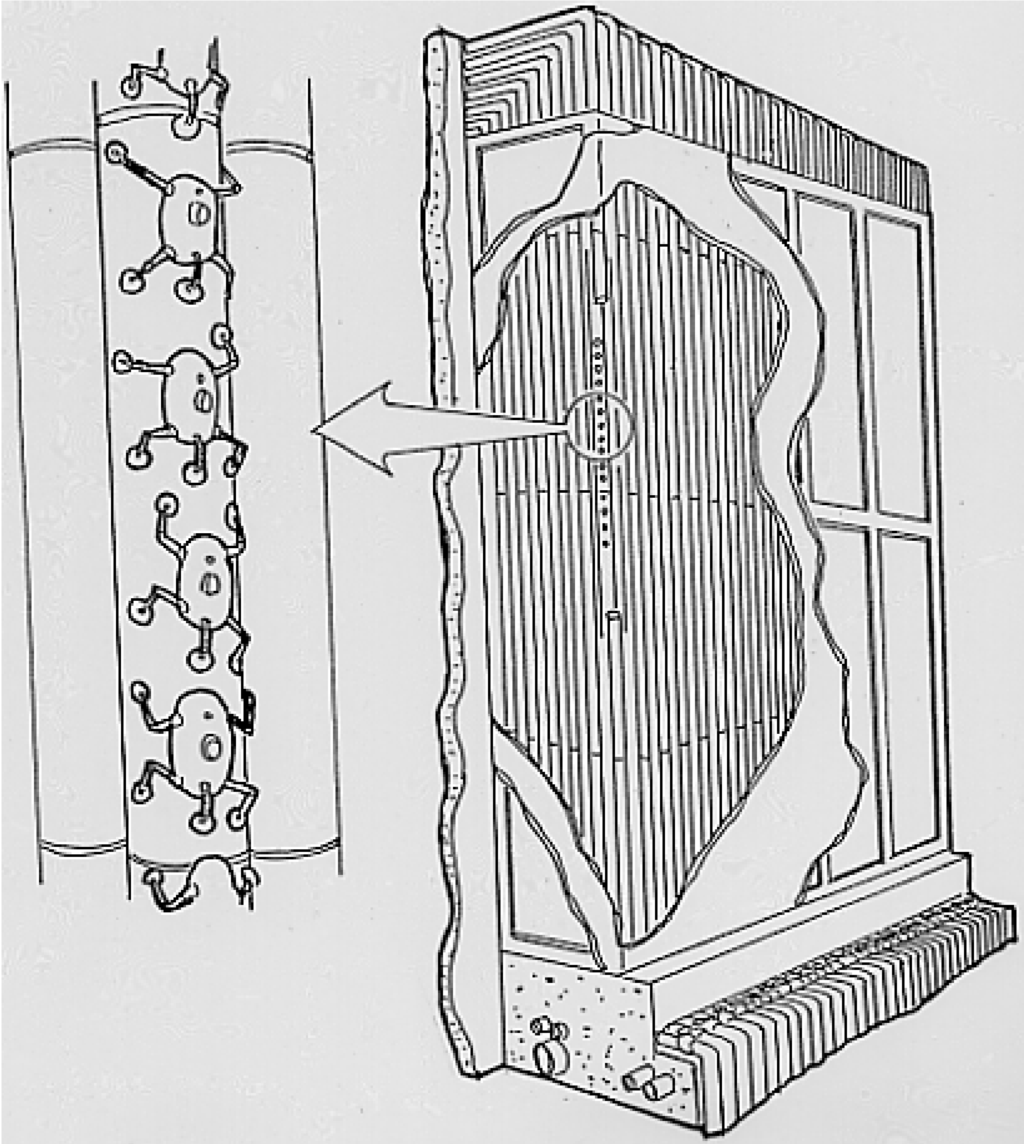
Ultimate Gigantic Robots



Provided by Kunikatsu TAKASE, ‡
Professor, The University of Electro-Communications

Expand your Imagination toward smaller objects:

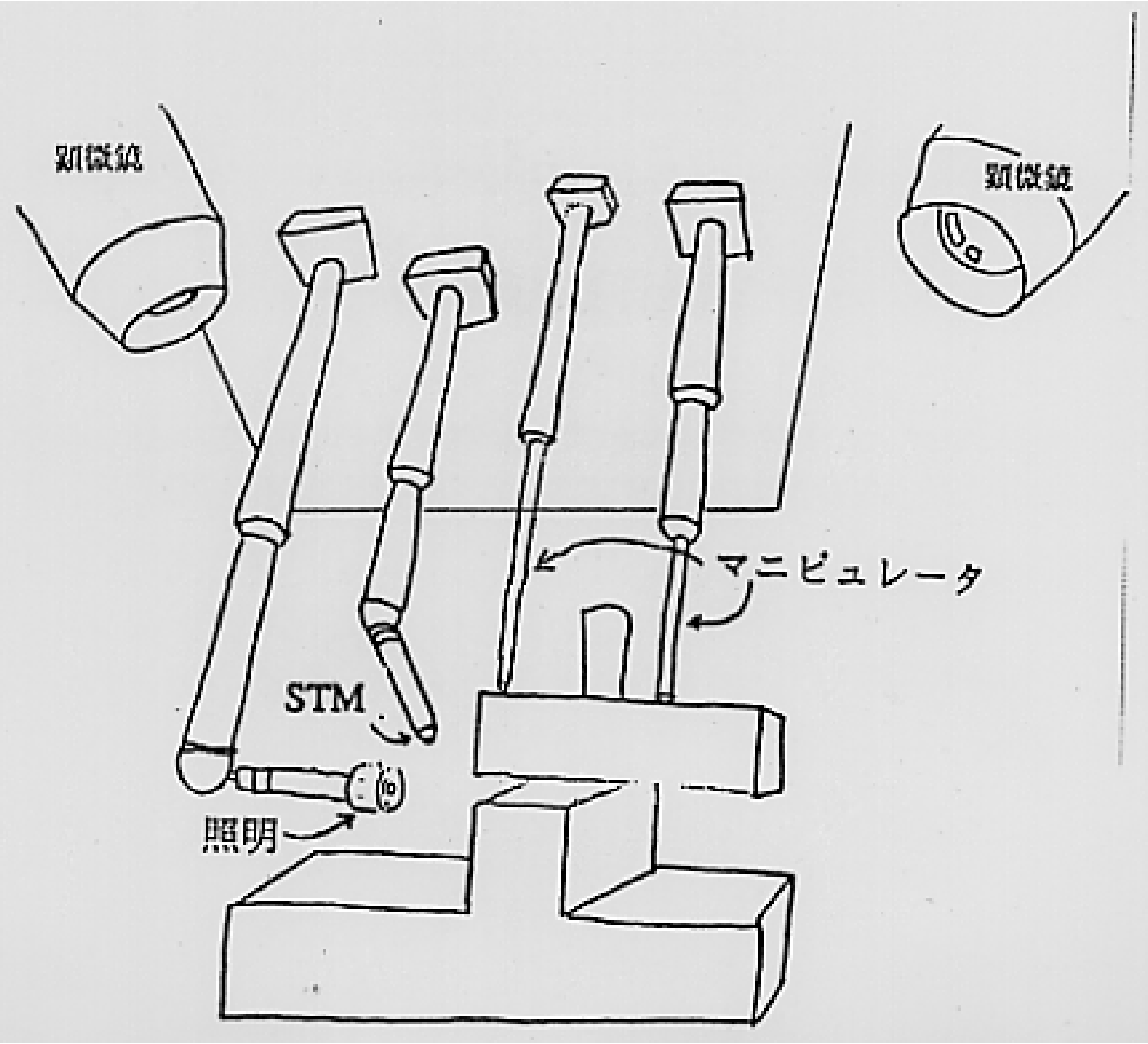
Robots for narrow work spaces



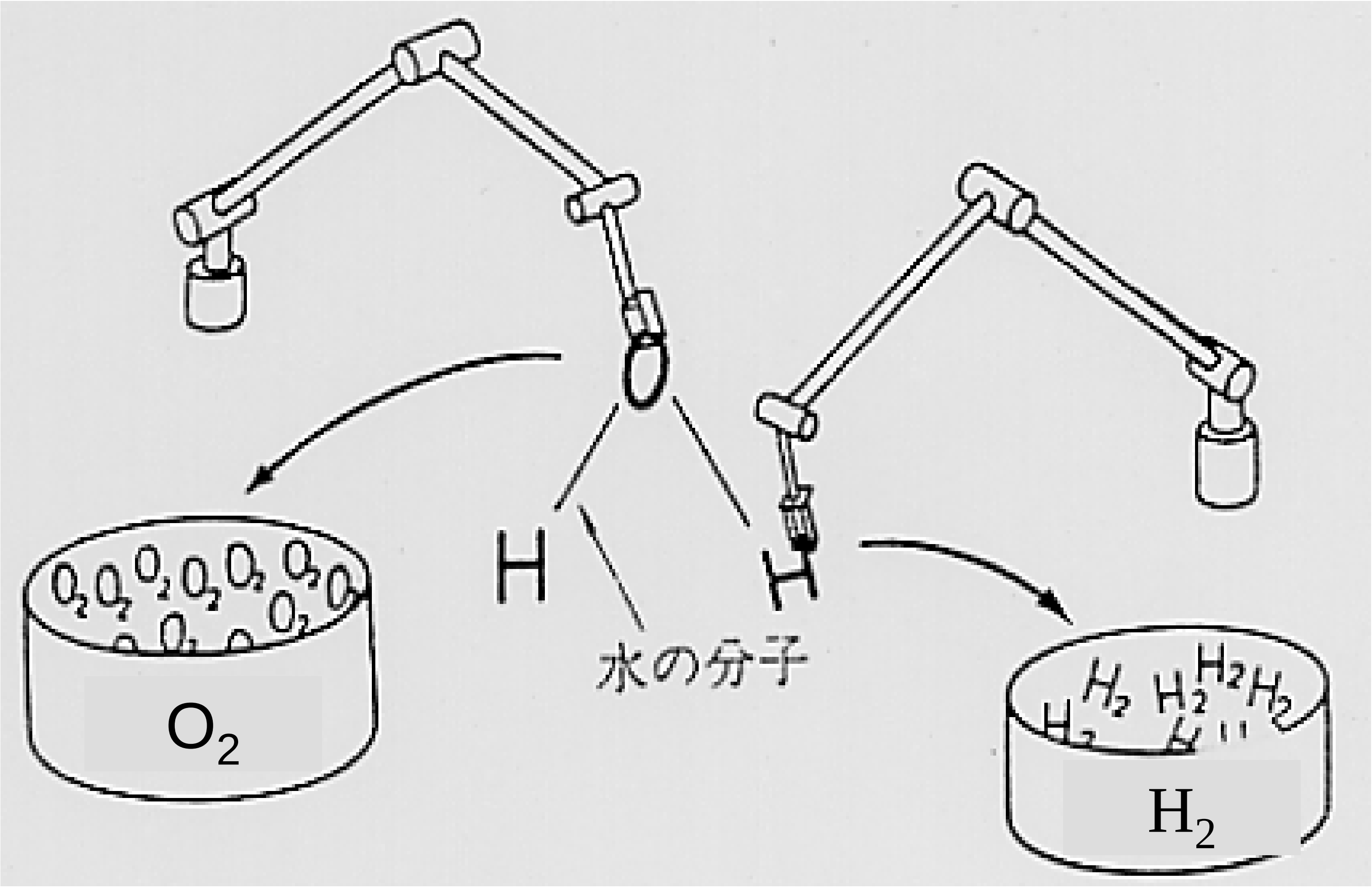
‡

Provided by Shigeoki HIRAI, National Institute of Advanced Industrial Science and Technology

Microscopic Work Robots

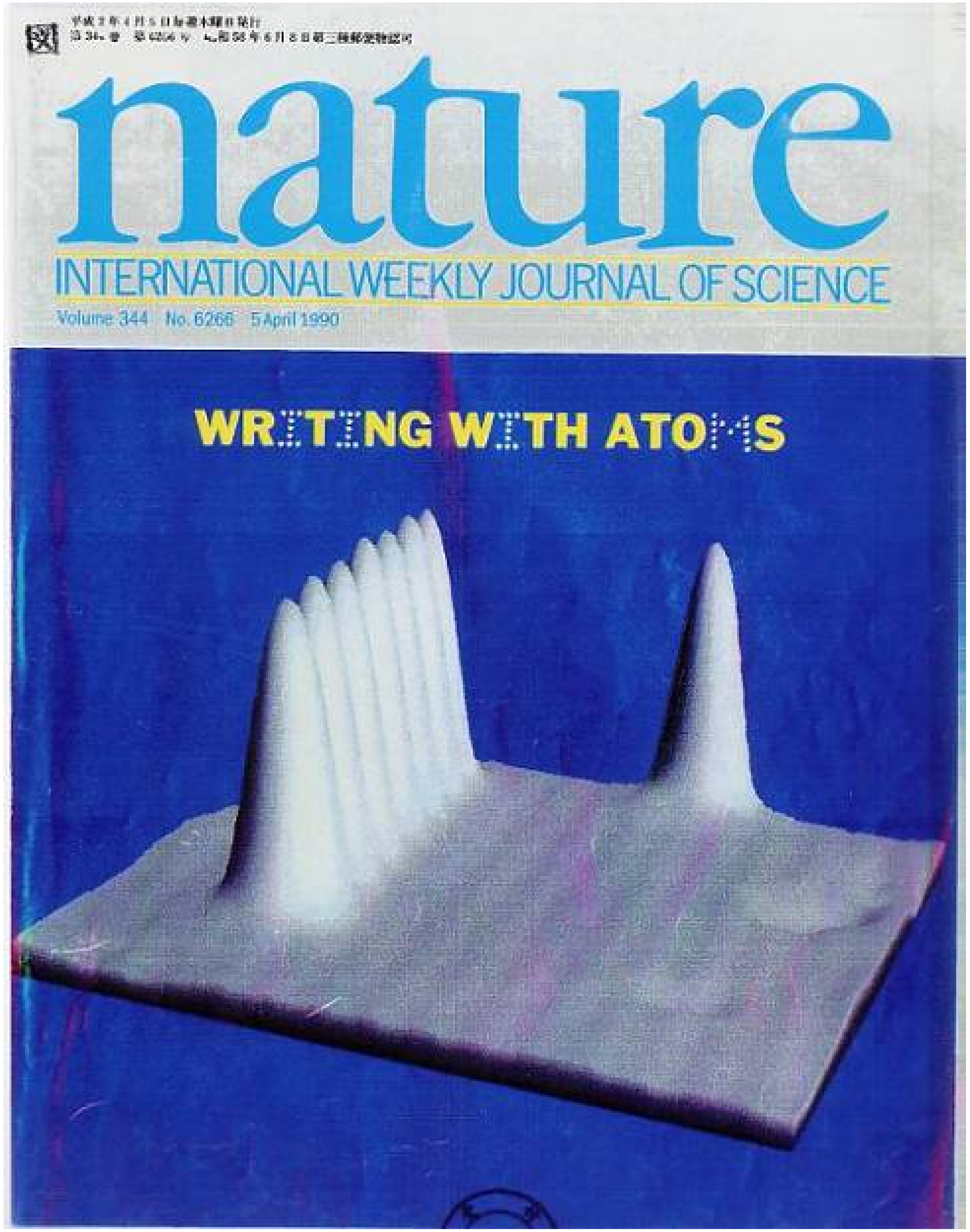


Ultimate Microscopic-object-handling Robots



Provided by Kunikatsu TAKASE, Professor, The University of Electro-Communications

Nature’s Front Page（April, 1991）



Photos from Nature
The world smallest business cards

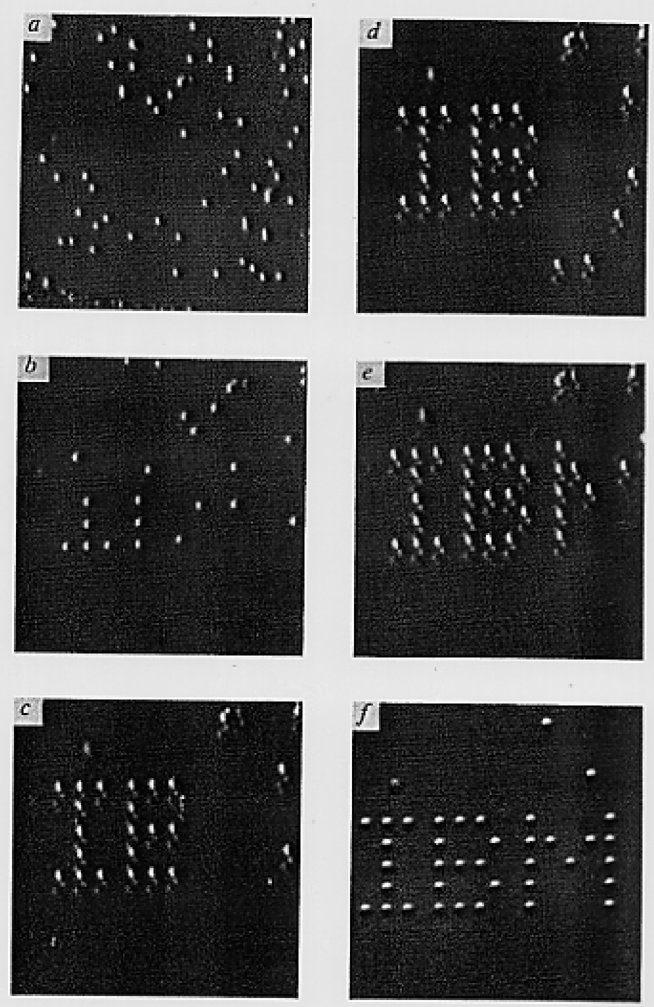


FIG. 1 A sequence of STM images taken during the construction of a patterned array of xenon atoms on a nickel (110) surface. Grey scale is assigned according to the slope of the surface. The atomic structure of the nickel surface is not resolved. The $\langle 1\bar{1}0\rangle$ direction runs vertically. *a*, The surface after xenon dosing. *b–f*, Various stages during the construction. Each letter is 50 Å from top to bottom.

D. M. Eigler, & E. K. Schweizer,
Positioning single atoms
with a scanning tunnelling microscope.
Nature 344, 524 - 526 (05 Apr 1990)
Fig.1

‡

A figure from Nature
Atom manipulation method

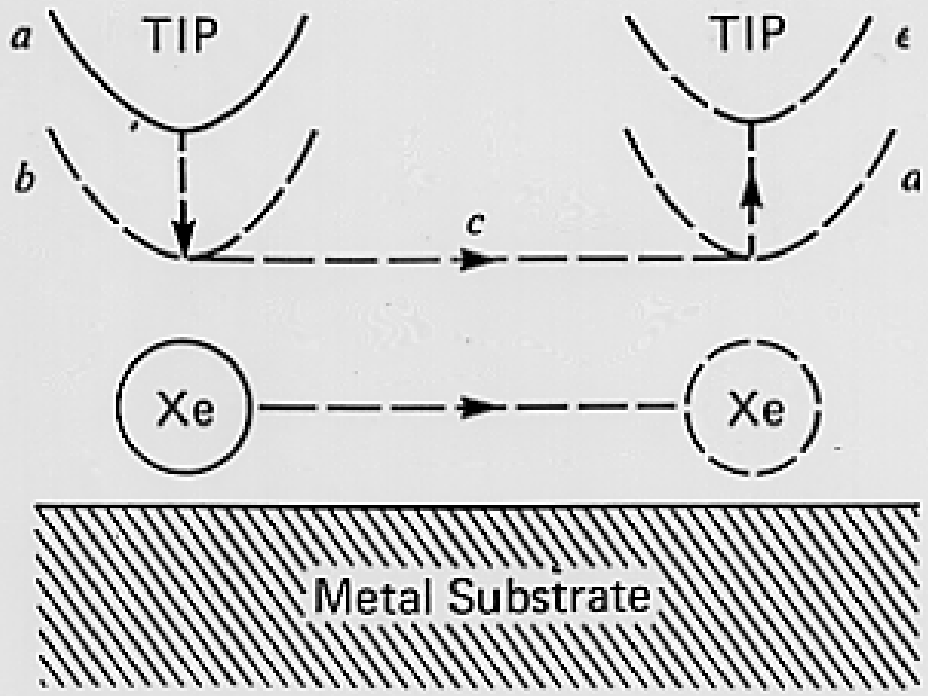
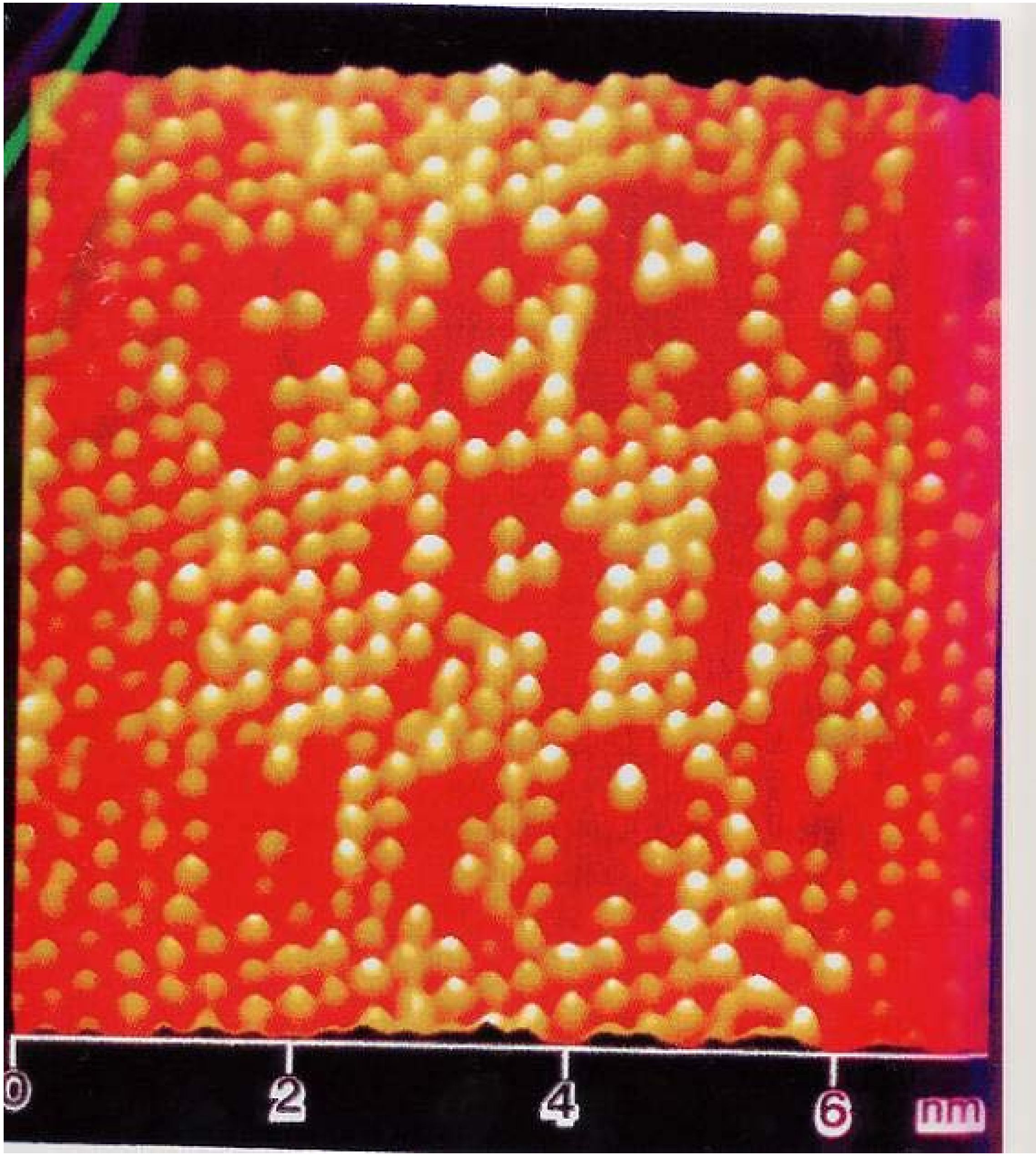


FIG. 2 A schematic illustration of the process for sliding an atom across surface. The atom is located and the tip is placed directly over it (*a*). Th tip is lowered to position (*b*), where the atom–tip attractive force is sufficier to keep the atom located beneath the tip when the tip is subsequentl moved across the surface (*c*) to the desired destination (*d*). Finally, the ti is withdrawn to a position (*e*) where the atom–tip interaction is negligible leaving the atom bound to the surface at a new location.

D. M. Eigler, & E. K. Schweizer,
Positioning single atoms with
a scanning tunnelling microscope.
Nature 344, 524 - 526 (05 Apr 1990)
Fig.2

‡

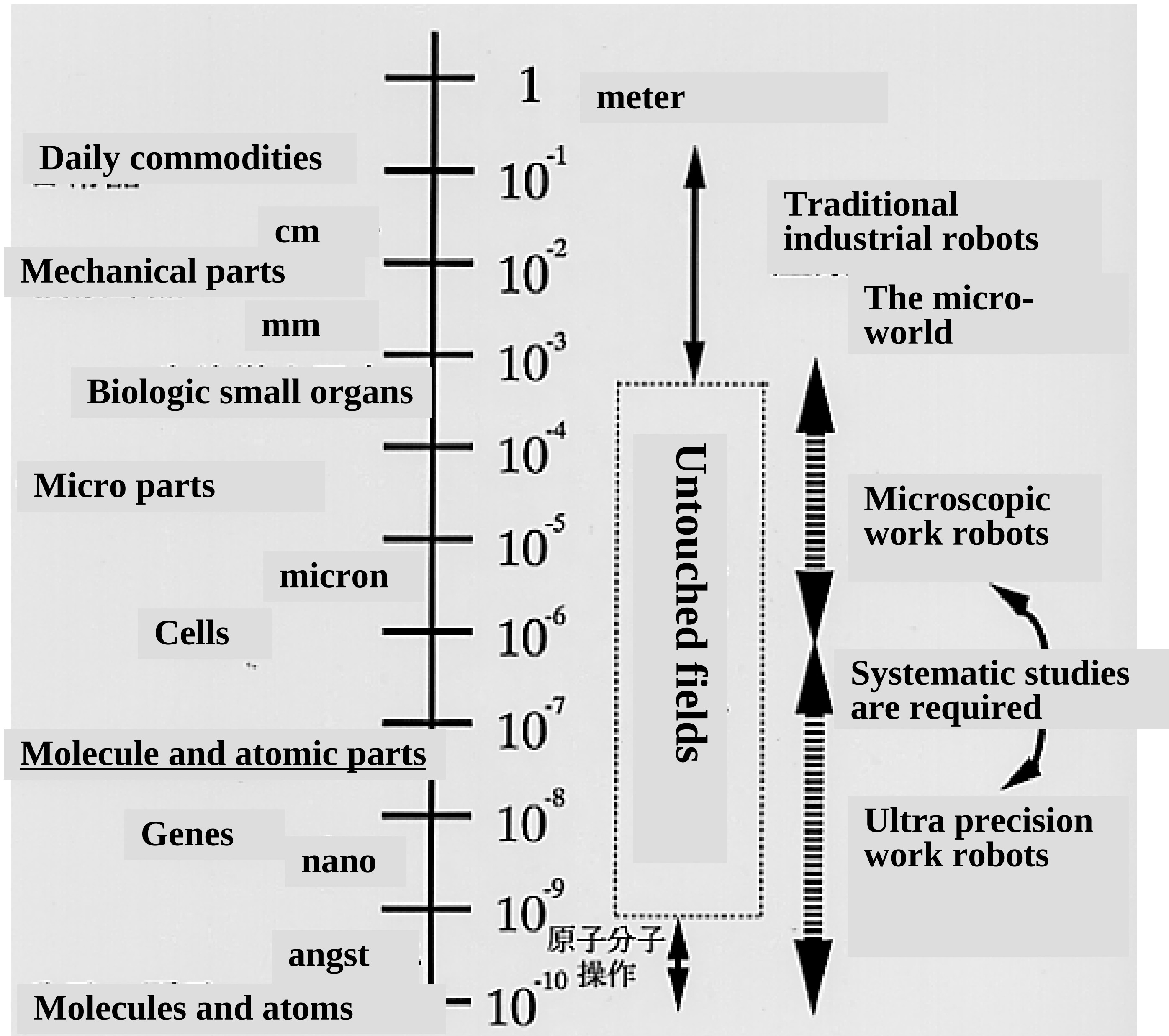
Letters of Hitachi, Ltd.



Provided by
Central Research Laboratory,
Hitachi, Ltd

‡

Object Sizes and Work Robots



World of Manipulation Work

Verb1：作業
Analyze（分析する）
Assemble（組み立てる）
Disassemble（分解する）
Repair（修理する）
Build（建てる）
Machining（加工する）
Measure（計測する）
Operate（手術する）
Produce（生産する）
Sense（検知する）
Test（試験する）

Verb2：加工を加える動作
Punch（たたいて穴をあける）
Drill（ドリルで穴をあける）
Saw（のこでひく）
Cut（切る）
Cut-out（切り抜く）
Whet（研ぐ）
Sharpen（とがらせる）
Shave（削る）
Plane（かんなで削る）
Whittle（ナイフで削る）
Polish（みがく）
Grind（研磨する）
Weld（溶接する）
File（やすりをかける）
Squeeze（押し潰す）
Powder（粉にする）
Scratch（ひっかく）
Drive-nail（釘を打つ）
Unnail（釘を抜く）
Dig（ほる）

Verb3：柔軟物を操作する動作
Wash（洗う）
Squeeze（絞る）
Wind（巻く）
Tic（むすぶ）
Wire（配線する）
Spread（張る）
Bend（曲げる）
Fold（折る）
Wrap（つつむ）
Saw（縫う）
Knead（もむ）
Tear-off（はがす）

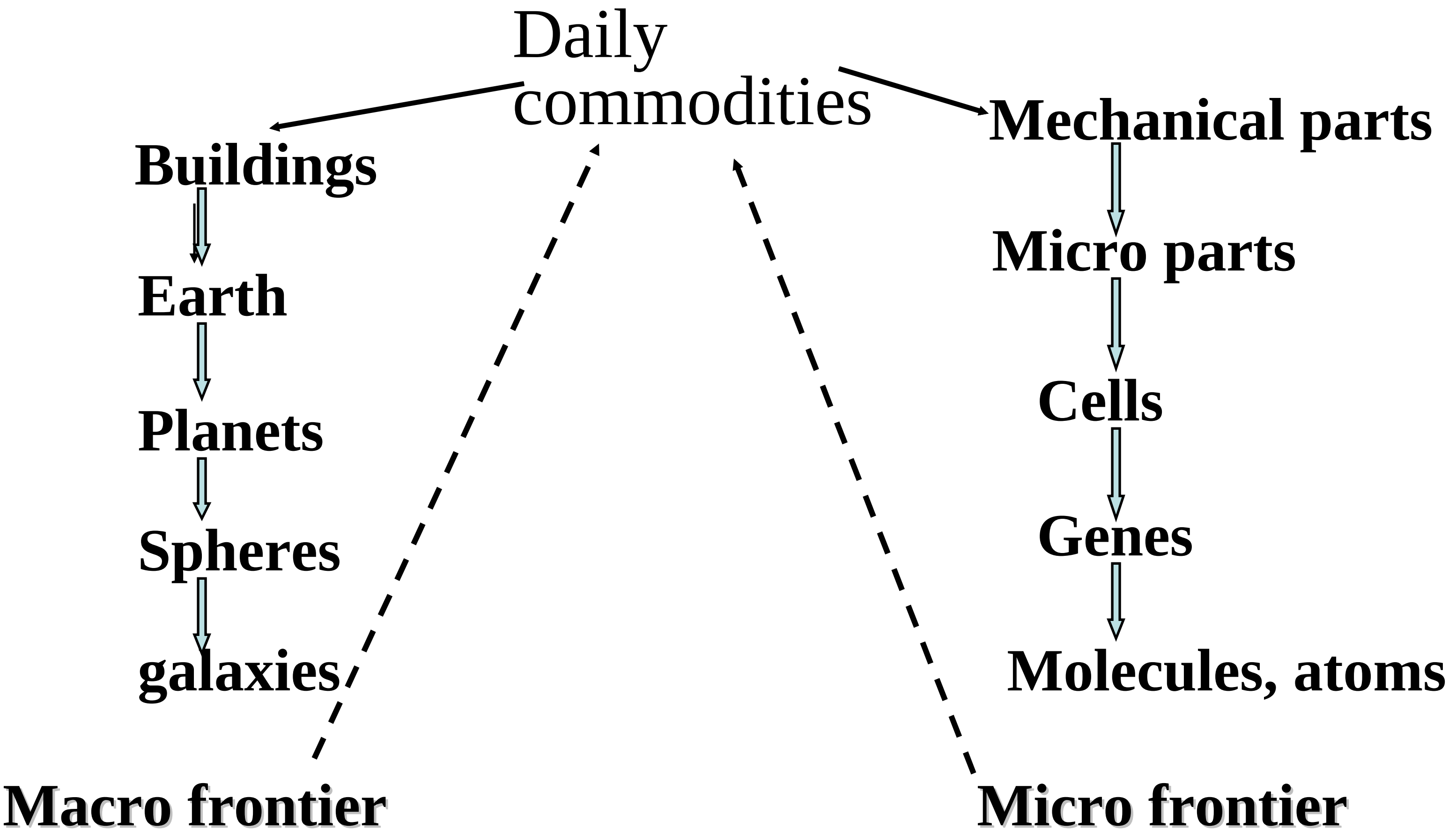
Verb4：集合体（液や粉）を扱う動作
Pour（注ぐ）
Paint（塗る）
Plaster（しっくいを塗る）
Spray（散布する）
Distribute（まく）
Sift（ふるいにかける）
Fill（充填する）
Lubricate（油をやる）
Stuff（ねり物をつめる）
Mix（まぜる）
Wipe（ふく）
Gather（かき集める）
Draw，Pump（沈む）
Scoop（すくう）
Laddle（柄杓ですくう）
Clean（掃除をする）
Write（書く）

Verb5：移動、結合を変化させる動作
Attach（取付ける）
Arrange（配列する）
Combine（結合する）
Deposit，Pile（積む）
Extract（引き抜く）
Fly（飛ばす）
Hang（つるす）
Insert（挿入する）
Interconnect（結合する）
Lean（たてかける）
Lock（締める）
Pack（つめる）
Place（置く）
Pull（引っ張る）
Put-on（のせる）
Rotate（回す）
Screw（ねじ込む）
Set（合わす）
Separate（分離する）
Transfer（運ぶ）
Throw（投げる）
Unscrew（ねじをぬく）
Unlock（ゆるめる）
Unpack（取り出す）

Verb６：単なる動きや力作用動作
Move（動かす）
Incline（傾ける）
Pull（引っ張る）
Lift（持ち上げる）
Turn（まわす）
Twist（ねじる）
Push（押す）
Support（支える）
Shake（振る）
Vibrate（振動する）
Swing（ゆらす）
Impact（衝撃力を加える）
Strike（打つ）
Fit（あてる）
Slide（すべらす）
Grasp（にぎる）
Pick（つまむ）
Release（はなす）

Robots can work in these micro- and nano- work environments, and at the same time these are realized in huge environments.

Object sizes that robots can handle



What Humans cannot do provides a key

The figure is omitted due to copyright.

New frontiers exist which people can’t touch

What Humans cannot do provides a Key 1/3

Industrial Robots

The figure is omitted due to copyright.

Accurately repeat the same task

What Humans cannot do provides a key 2/3

Ultimate work robots（from the 80's）

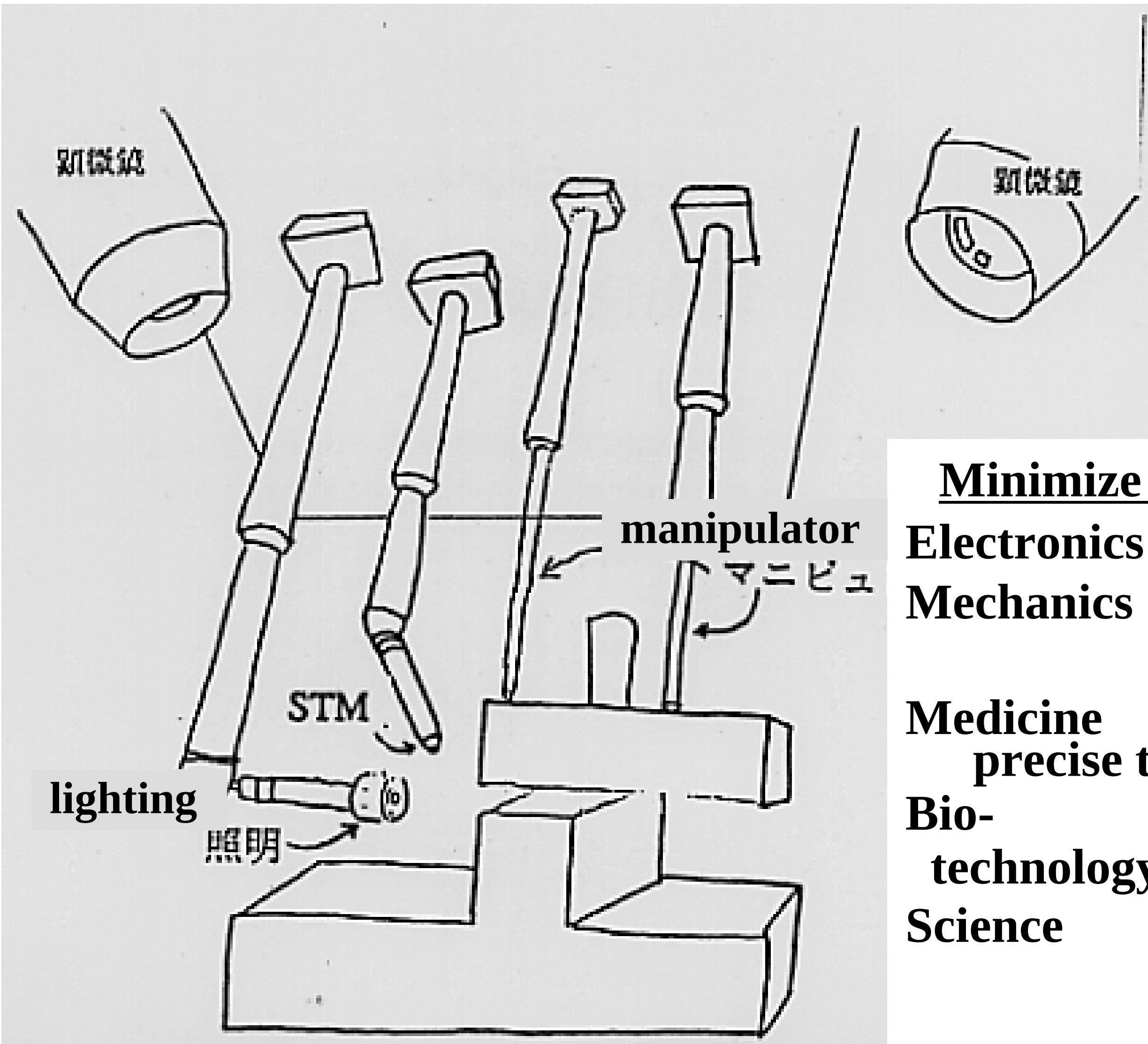
Work where people cannot enter

‡

Provided by Shigeoki HIRAI, National Institute of Advanced Industrial Science and Technology

What Humans cannot do provides a Key 3/3

Microscopic work robots (from the 90's)



Provided by Shigeoki HIRAI, National Institute of Advanced Industrial Science and Technology

<u>Minimize the object world</u>

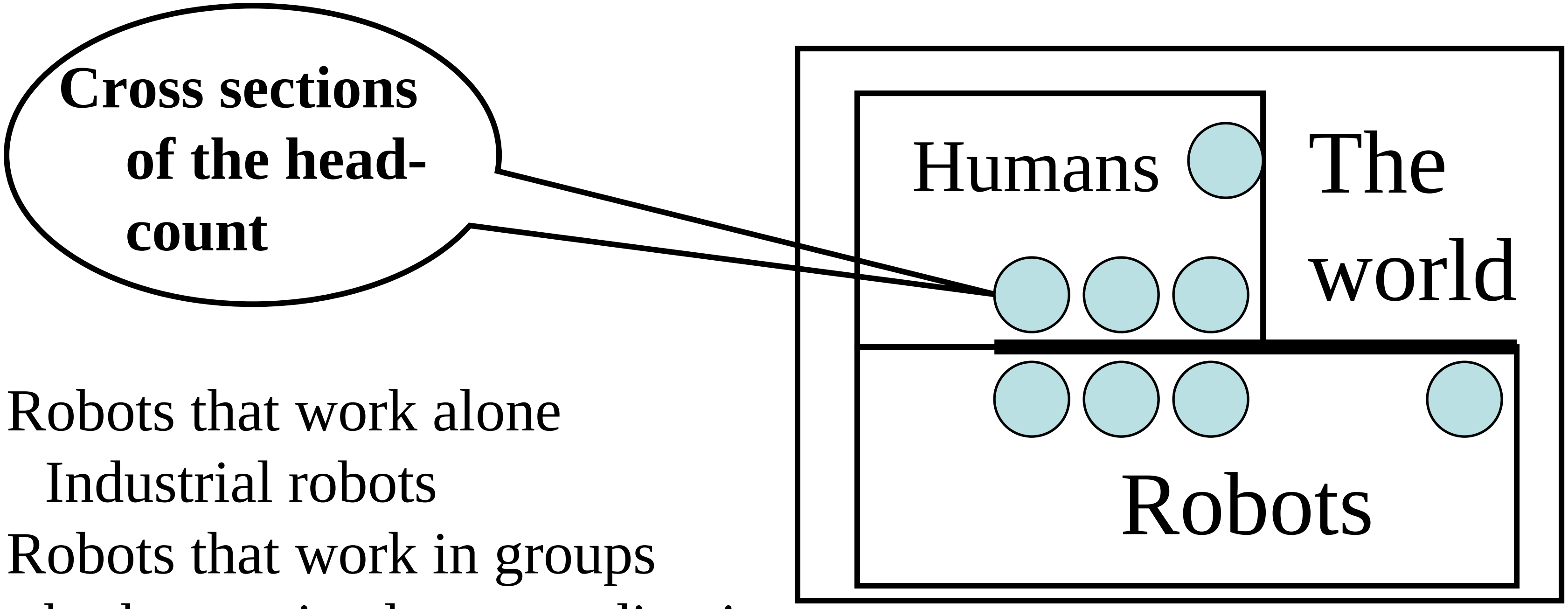
Electronics	Refinement of patterns
Mechanics	Refinement of structures
Medicine	Less invasive more precise treatment
Bio-technology	Organic, cellular level assessment
Science	Minimization of target

Part 2 - Informatics in Robots designed to surpass humans
D - Robotic Systems – Dimensions and Applications - Scope 3

The Scope of a robot’s size and its applications

Robotic Systems Scope 3

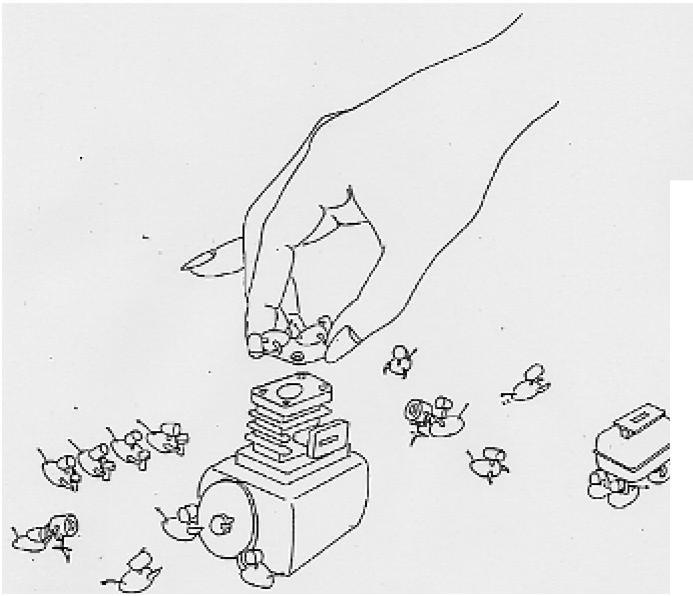
The Scope of a number of robots

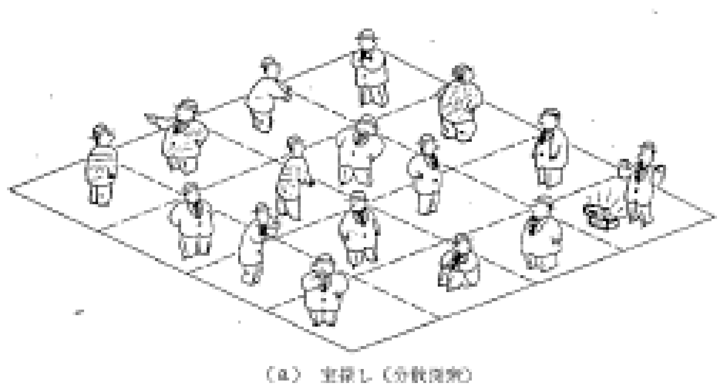


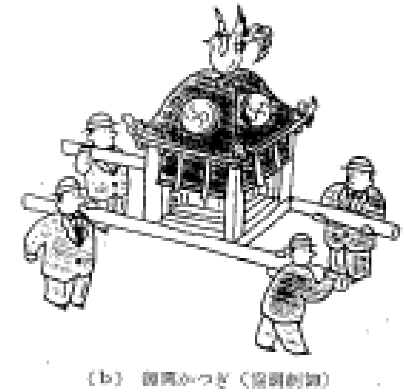
- Robots that work alone
  - Industrial robots
- Robots that work in groups
  - both arms in close coordination
  - three fingers
  - five fingers
  - multi-robots (swarm robots)
  - environmental robots
  - networking robots

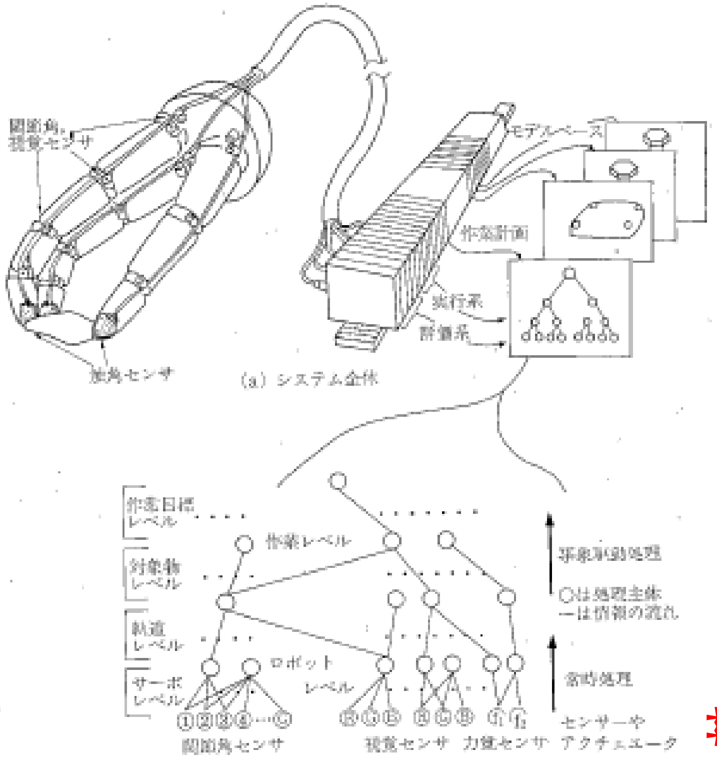
The headcount of humans and robots modifies the characteristics of the systems

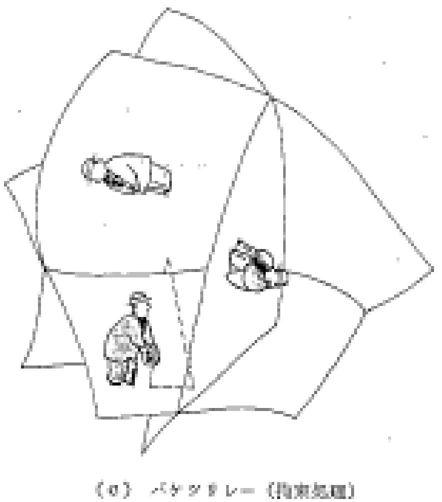
Multi-robotic System

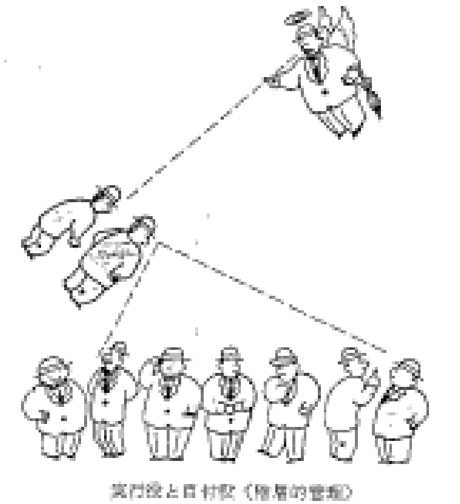












Provided by Kunikatsu TAKASE, Professor,
The University of Electro-Communications

‡ Merits of multi-robotic systems

Networking Digital Home Appliance Group

Networking machines and electronics devices
that closely interact with humans

The figure is omitted due to copyright.

Advantages for users, manufacturers and electric power suppliers

Necessary and Useful things

The Boundary between robots and humans
Robotic and human worlds variously interact

・Invasive neural boundaries： The study of humans and robots in their bodies and inner neural workings (e.g., studies of the boundaries between neural structures and robots, brains and robots）

Medical robots → used for advanced medicine

・Physical boundaries: The study of humans and robots in physical contact (e.g., the boundaries between humans and exoskeletal robots）

・Individual boundaries: The study of humans and robots in individual spaces and on living things (e.g., individual spatial boundaries, and the boundary between humans and humanoid)

・Social and environmental boundaries: The study of humans and robots in social interaction and the human environment.
(environmental boundary study, boundary studies of humans and ubiquitous robots, studies in robotic social science & technology, social intelligence studies.）

Robotic worlds working for human's lifetime

Fetus stage : Robots that watch over a mother and a baby (watch robots) providing care and support for the mother in her social activities (carriage robots, power-assistant robots)

Infant stage : Robots that assist un-experienced couples and promote a mother's role in her participation in social activities (nurse robots)

Toddler stage : Robots that care for children (child-rearing robots) and assist parents who are gradually going back to work (housekeeping support robots)

School age : Robots that can help create a child's own society and study routines (network robots) and robots that make safe commuting to school possible (systems including vender machines)

Puberty : Robots that can open a child's eyes to the society (communication support robots)

Adolescence : Robots that chide a child not to go wrong (companion robots)

Bachelorhood : Hobby robots obsess the young and goods robots satisfy a desire for quality

Guardian stage : Robots that can connect the family and build family unity in the society (family robots)

Maturity stage : Robots that assist housework and business. Housekeeping robots (sweeping, washing, cleaning, **tidying up after meals and tea, etc.), industrial robots that supplement an insufficient work force (robotic cell-production systems)**

Nursing stage : **Assistant robots for nursing care givers** （nursing care robots that support two nursing care givers for one senior)

Pre-senior stage : Robots that help to overcome physiological changes in life, offer comfort and ease tiredness (power assist robots)

Retiree stage : Robots that activate and manage a new life after retirement (brain activation robots)

Senior couple stage : Robots that give a purpose in life like grandchildren do (mental commitment robots) and robots that care for a couple's health (intelligent rooms, intelligent beds)

Solitary senior stage : Robots that support a senior citizen's independent lifestyle for a long time (personal care support robots)

Care receiver stage : Robots that can learn how a care receiver wants to be taken care of and convey it to assist care givers (information terminal robots)

Posthumous message stage : Robots that record and save the deceased person's words, deeds and data for the bereft families and the future society. **(action-record and social heritage conveyance robots)**

Robotic Worlds Imagined from the Robot Index

● Robot vs. human count（Robot Attendance Index）

Now 35.6 robots/ 12 Million people＝2.8×E-2

（for industrial robots by Japan Robot Association）

As many as cars →7470 vehicles/1.2 million people＝0.59car/person

As many as CPUs in cars

⇒30×0.59＝17.6 units/person

（**combination : quantitative explosion**）

● Robot Density Index

At present 35.6 robots/370000㎡＝1 robot/K㎡

As many as cars（20 years later）

→ 7470vehicles/ 370000㎡ =200 cars/K㎡

As many as CPUs equipped in cars

⇒30×200＝6000 units/k㎡

（**combination:density explosion**）

●Robot Supporting time Index

As long as cars 10 minutes/(24×60 minute) ＝ 0.7% /day

As long as a PCs → 72 minutes/ (24×60 minute) ＝ 5% /day

Ubiquitous → 720 minutes/ (24×60 minute) ＝ 50% /day

Robots designed to exceed human capacity (1980 - 2000) Conclusion

Robots designed to exceed human capacity（from the 1980's）：

Robots and informatics aimed at surpassing human work capability

- **Background ideas：**
  Robots have been designed to carry out work that humans cannot do and work where humans cannot set foot (e.g., in outer space, under the ocean, in nuclear power plants and in the microscopic world.) Those robots are required to have superior capability exceeding human ability.
- **Robots created with human features ：**
  While an intelligent work robot controllable from a distance to help create the ultimate environment is being realized, robotic studies are being promoted with global geometric models for intelligent robots, choreographing sequences such as robotic hand movement and offering a perspective on how environmental complicity gives robots intelligence.
- **Supporting technology：**
  Model-based robotics, architectural robot technology

We are in an epoch in which robots can coexist with humans（the 21st century and on）

For Conclusion 1

"Information, Robots and life" 1st lecture

Informatics in robots that aspire to exceed human capacity

Part 1 - Informatics in robots aspiring to human capacity

- **A - History of Intelligent Robots（1960's - 1970's）**
- **B - History of Intelligent Robots（1970's – 1980's）**

To gauge developments in technology

Part 2 - Informatics in robots exceeding human capacity

- **A - Models of Robotic Systems**
- **B - Robotic Systems – Work Contents Scope 1**
- **C - Robotic Systems – Work Objects Size Scope 2**
- **D - Robotic Systems – Robots Size and widescale applications Scope 3**

To change the image of robots

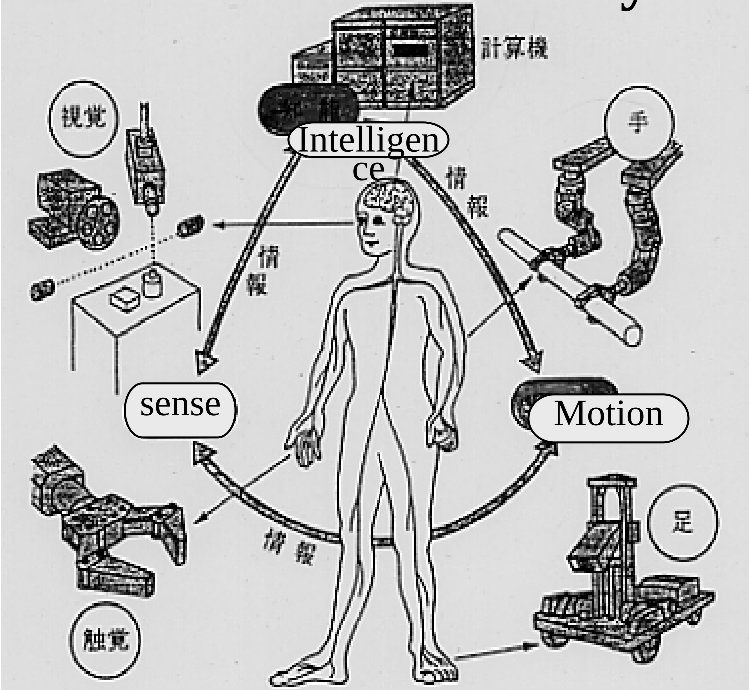
For Conclusion 2

Information, Robots and Life Informatics in robots that aspire to exceed human capacity

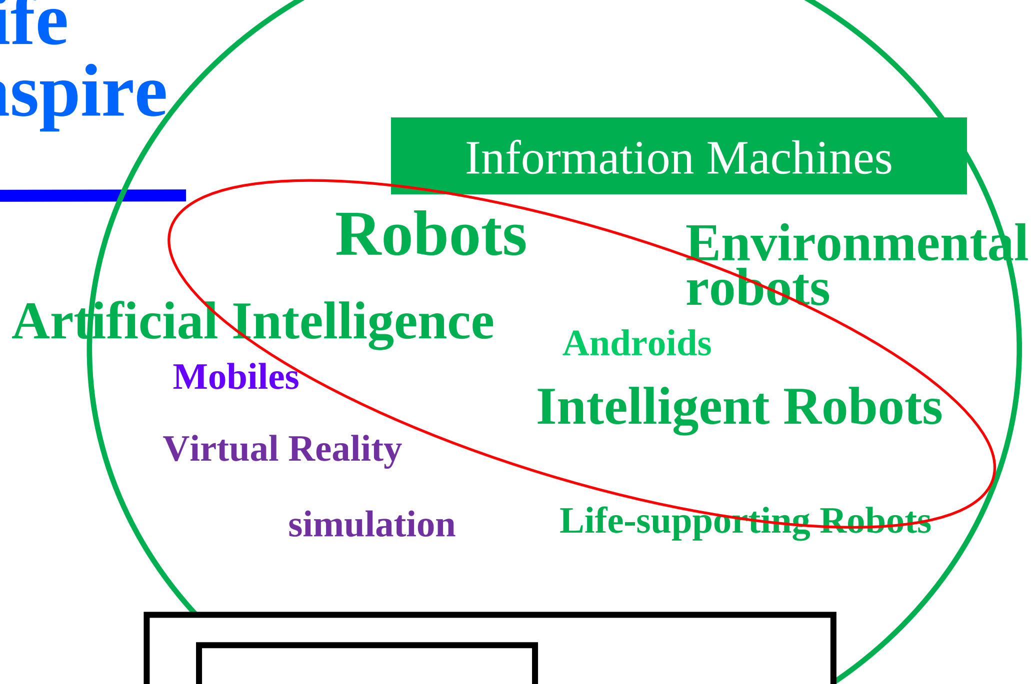
～Tomomasa Sato～

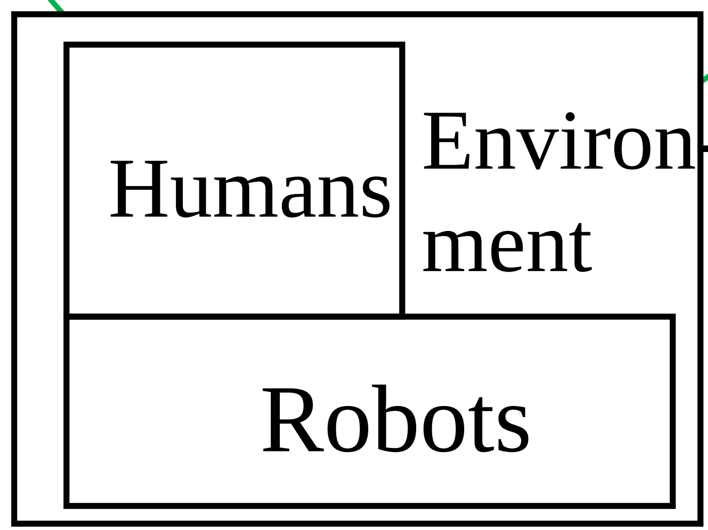
History of intelligent robots

（Video of robots from the 1960’s to 2000 and beyond）



Seiji WAKAMATSU and Tomomasa SATO, *“chinō robotto –jisedai no robotto gijutsu -”*, (1984), Ohmsha, p.4 Fig.1-2





Sense-Plan-Execute Model → Expansion in robotic technology

Humans – Robots – Environmental Model → Spread of Robots

END