The Sixteenth International Symposium on Artificial Life and Robotics 2011(AROB 16th '11),
B-Con Plaza, Beppu, Oita, Japan, January 27-29, 2011

Micro Nano Robotics

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Micro nano robotics, Tatsuo arai, Osaka University, Japan

MICRO NANO ROBOTICS, Tatsuo ARAI, OSAKA University

Micro Nano Robotics

Tatsuo ARAI
OSAKA University

16th International Symposium on Artificial Life and Robotics, Oita, JAPAN, January 28, 2011

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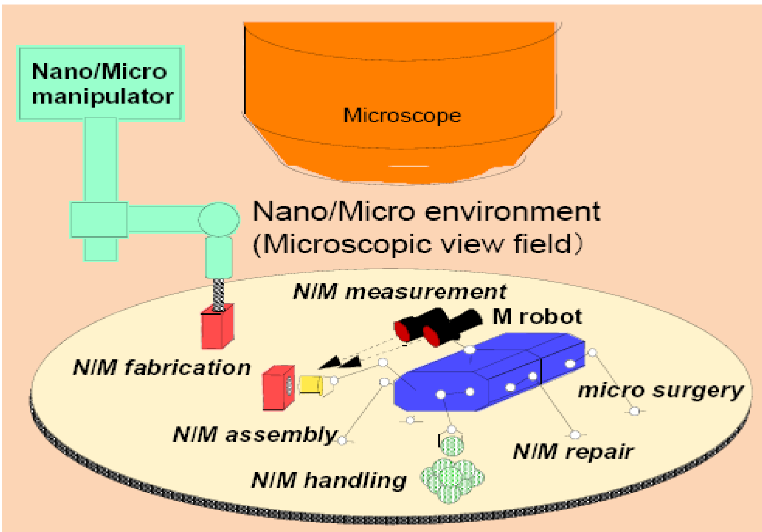
What is Micro Nano Robotics?

Fabrication, mechanization, automation, and system integration, targeting 1milli(10^{-3}) – 1nano (10^{-9}) scale in size and force.
1mm - 1nm
1mN - 1nN(pN)



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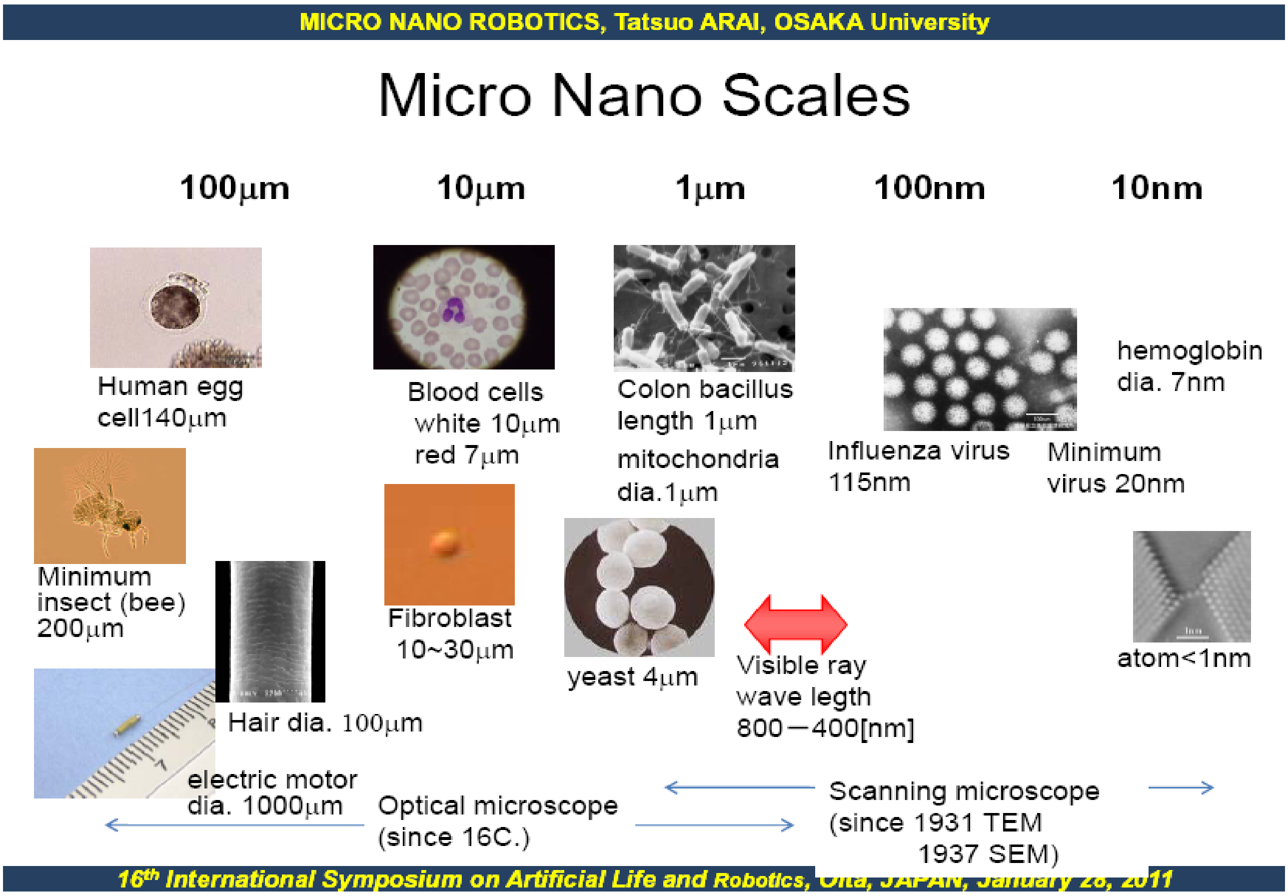
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Micro Nano Scales
100μm
10μm
1μm
100nm
10nm
Human egg cell140μm
Blood cells white 10μm red 7μm
Colon bacillus length 1μm
mitochondria dia.1μm
Influenza virus 115nm
hemoglobin dia. 7nm
Minimum virus 20nm
Minimum insect (bee) 200μm
Hair dia. 100μm
Fibroblast 10~30μm
yeast 4μm
Visible ray wave legth 800—400[nm]
atom<1nm
electric motor dia. 1000μm
Optical microscope (since 16C.)
Scanning microscope (since 1931 TEM 1937 SEM)
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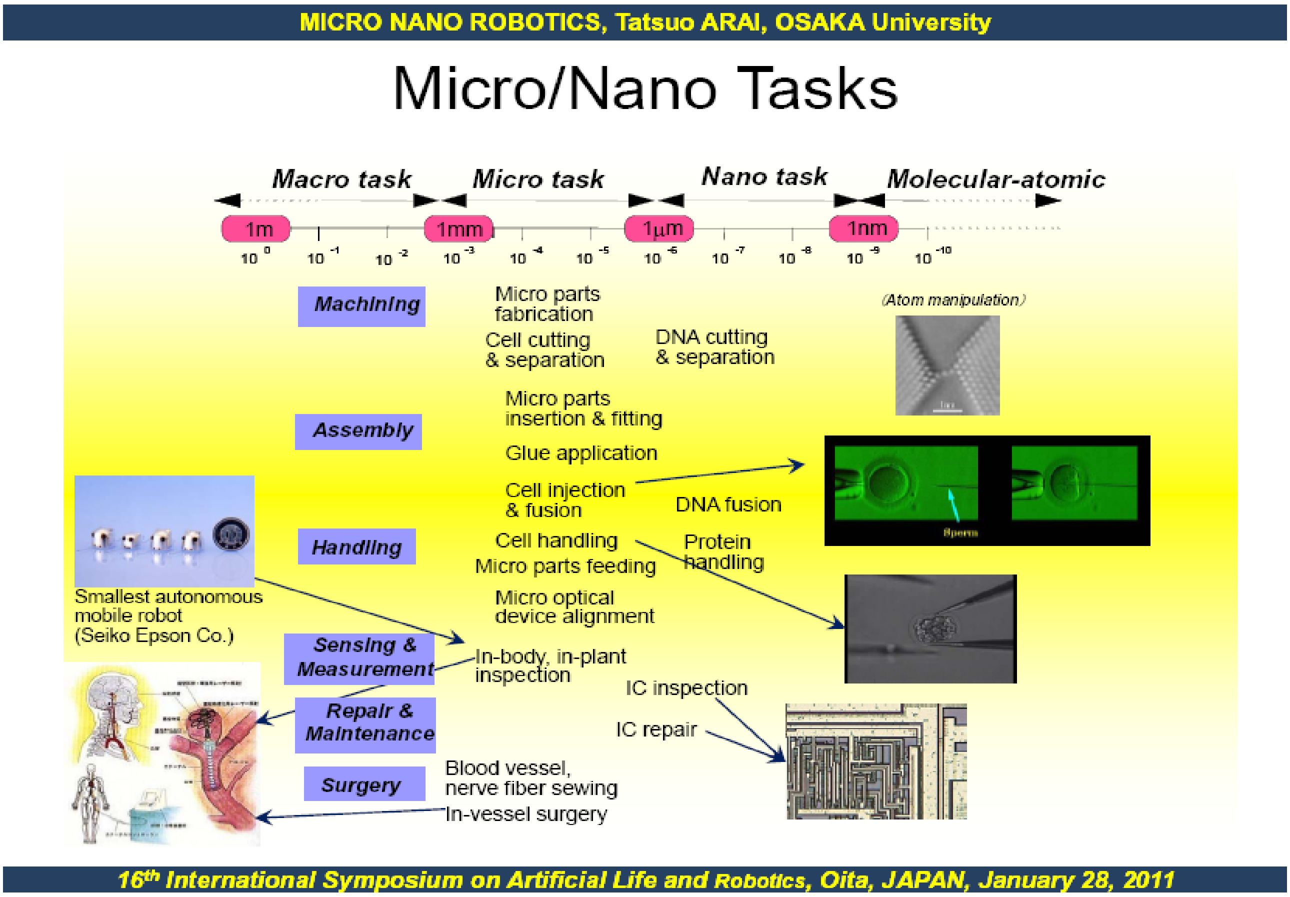
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Micro/Nano Tasks
Macro task
Micro task
Nano task
Molecular-atomic
1m
1mm
1μm
1nm
10^0 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10
Machining
Micro parts fabrication
Cell cutting & separation
DNA cutting & separation
(Atom manipulation)
Assembly
Micro parts insertion & fitting
Glue application
Cell injection & fusion
DNA fusion
Handling
Cell handling
Micro parts feeding
Protein handling
Micro optical device alignment
Smallest autonomous mobile robot (Seiko Epson Co.)
Sensing & Measurement
In-body, in-plant inspection
IC inspection
Repair & Maintenance
IC repair
Surgery
Blood vessel, nerve fiber sewing
In-vessel surgery
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Physical property in M/N environment

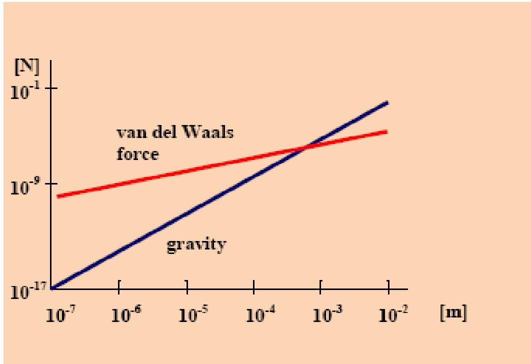
Scale effect:

- surface/volume comes to larger.
- friction, viscosity, surface force, electrostatic force appear dominantly.

  Ex.) 1um³ copper

  -gravity: 8.7 × 10-2 pN

  -van del Waals force: 2.1 × 10 pN



- Higher resonance frequency.
- Smaller heat capacity.
- Smaller Reynolds number.

$$Re = \frac{UL}{(\mu/\rho)} \quad (U: \text{velocity}, L: \text{distance}, \ \mu: \text{viscosity}, \ \rho: \text{density})$$

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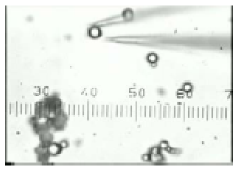
Advantages and disadvantages

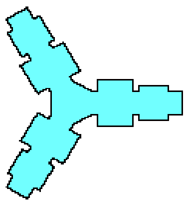
•Micro objects will stick to everything.



➡Manipulation problem.

•Much friction in rubbing motions.

➡No rotational motion, no revolute joint.



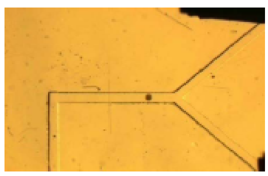
•Inertia has no effect in under-liquid propelling.

•High speed in motion, heat response.

•Low energy consumption.

•Small Reynolds number.

➡ Stable laminar flow in micro channel.



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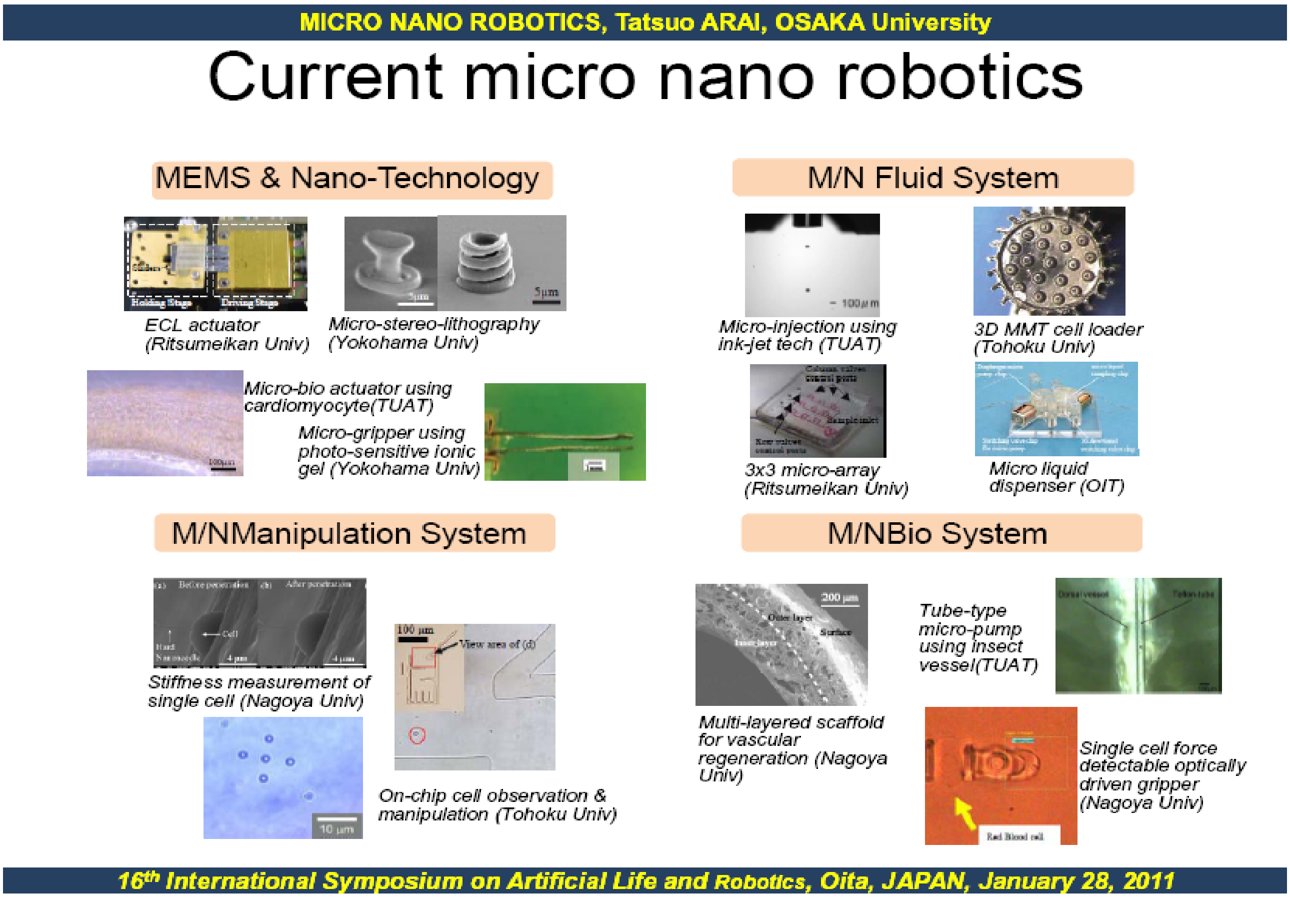
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Current micro nano robotics
MEMS & Nano-Technology
ECL actuator (Ritsumeikan Univ)
Micro-stereo-lithography (Yokohama Univ)
Micro-bio actuator using cardiomyocyte(TUAT)
Micro-gripper using photo-sensitive ionic gel (Yokohama Univ)
M/N Fluid System
Micro-injection using ink-jet tech (TUAT)
3D MMT cell loader (Tohoku Univ)
3x3 micro-array (Ritsumeikan Univ)
Micro liquid dispenser (OIT)
M/NManipulation System
Stiffness measurement of single cell (Nagoya Univ)
On-chip cell observation & manipulation (Tohoku Univ)
M/NBio System
Multi-layered scaffold for vascular regeneration (Nagoya Univ)
Tube-type micro-pump using insect vessel(TUAT)
Single cell force detectable optically driven gripper (Nagoya Univ)
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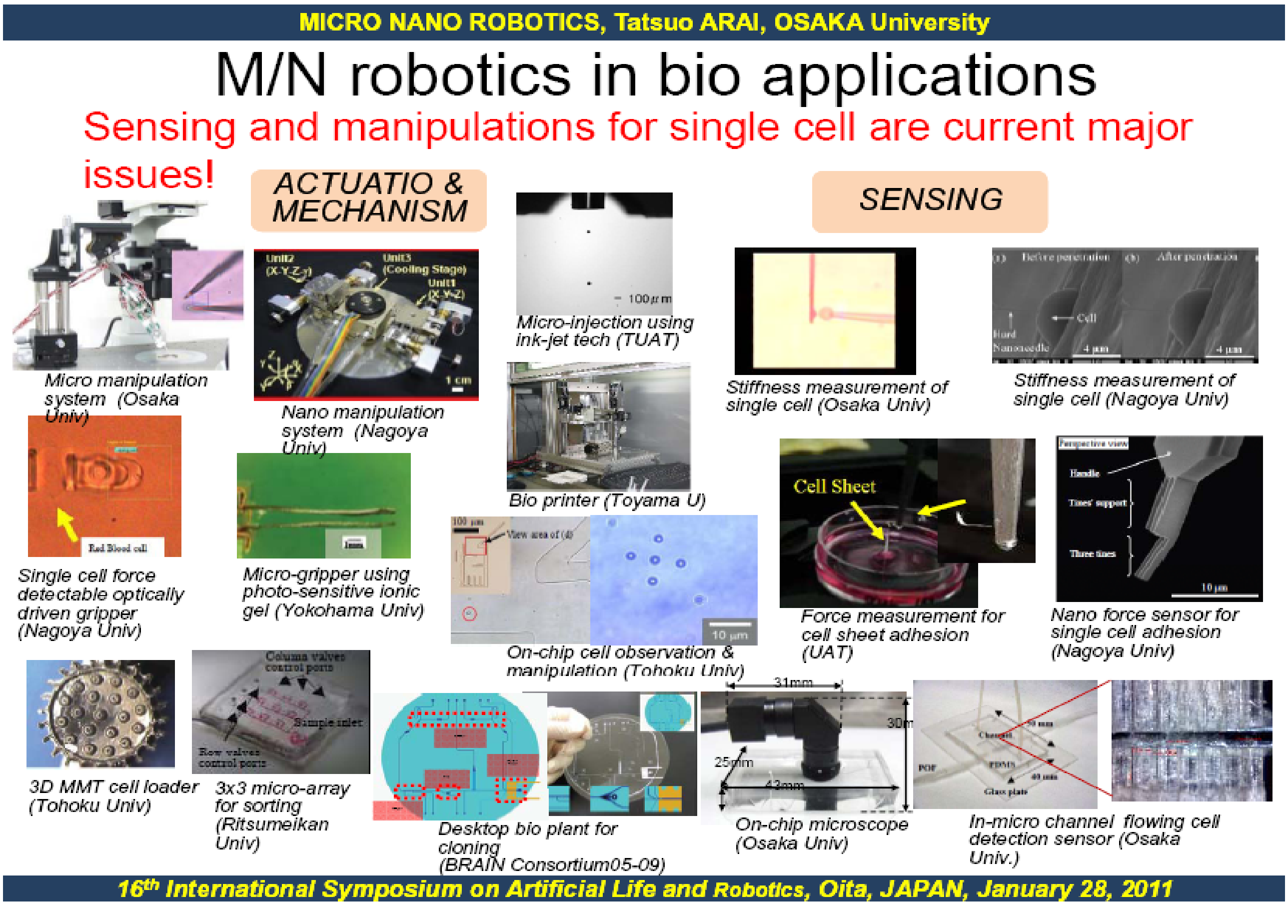
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M/N robotics in bio applications
Sensing and manipulations for single cell are current major issues!
ACTUATIO & MECHANISM
SENSING
Micro manipulation system (Osaka Univ)
Nano manipulation system (Nagoya Univ)
Micro-injection using ink-jet tech (TUAT)
Bio printer (Toyama U)
Stiffness measurement of single cell (Osaka Univ)
Stiffness measurement of single cell (Nagoya Univ)
Single cell force detectable optically driven gripper (Nagoya Univ)
Micro-gripper using photo-sensitive ionic gel (Yokohama Univ)
On-chip cell observation & manipulation (Tohoku Univ)
Cell Sheet
Force measurement for cell sheet adhesion (UAT)
Nano force sensor for single cell adhesion (Nagoya Univ)
3D MMT cell loader (Tohoku Univ)
3x3 micro-array for sorting (Ritsumeikan Univ)
Desktop bio plant for cloning (BRAIN Consortium05-09)
On-chip microscope (Osaka Univ)
In-micro channel flowing cell detection sensor (Osaka Univ.)
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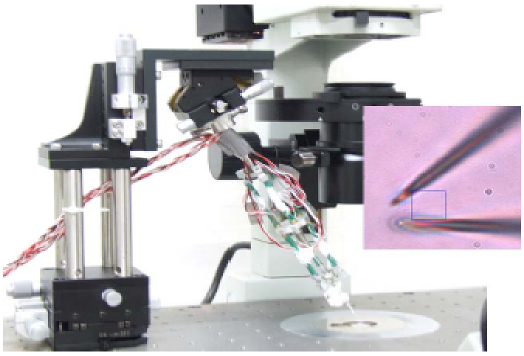
Topic 1: Dexterous micro manipulation

1. Motivations
2. Designing and prototyping two-finger hand
3. Sensors and controls
4. Demonstrations



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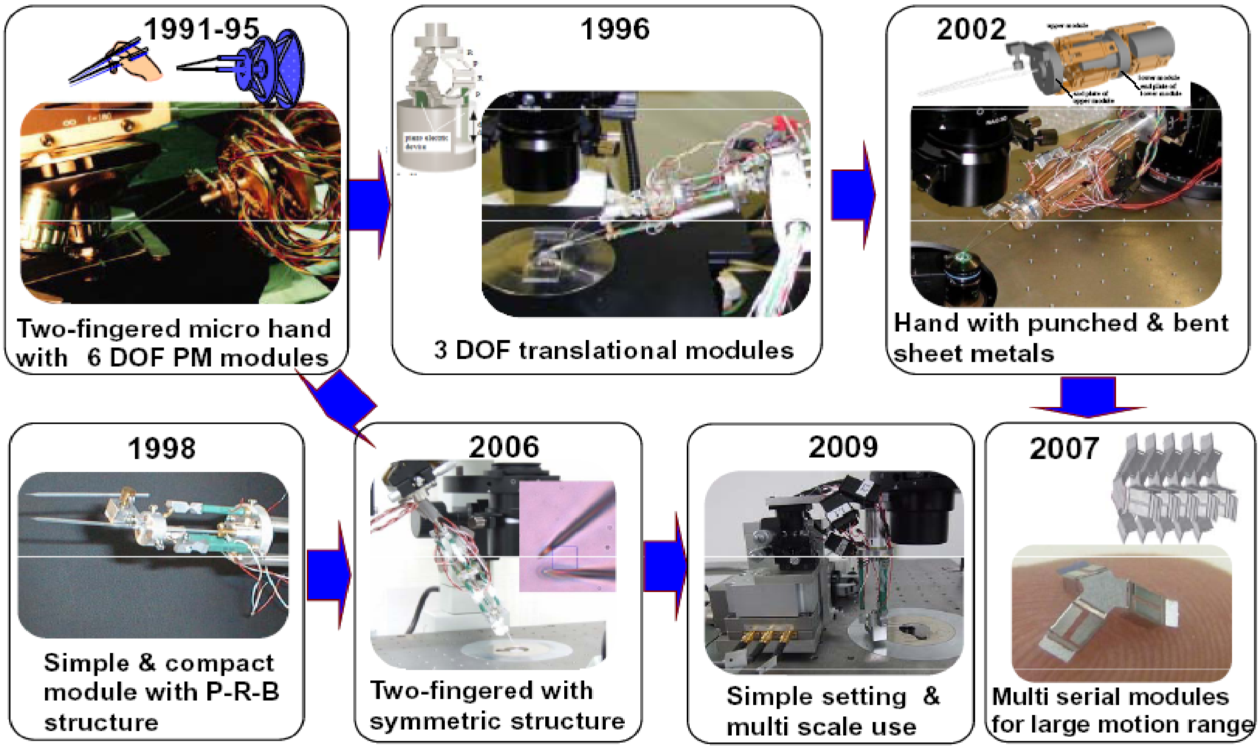
Our micro hand developments in 20 years



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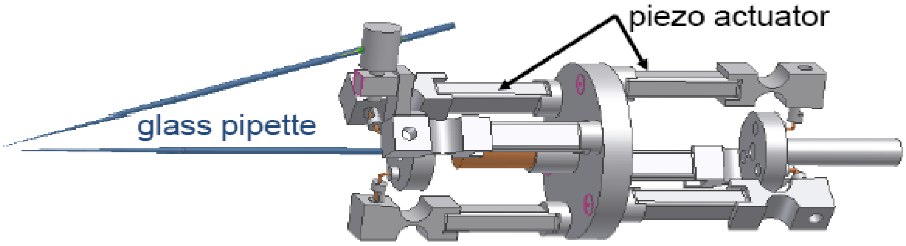
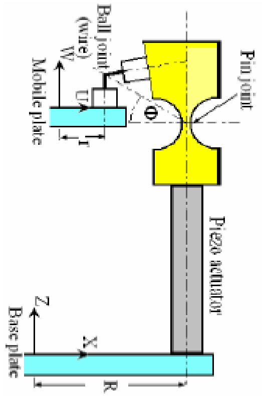
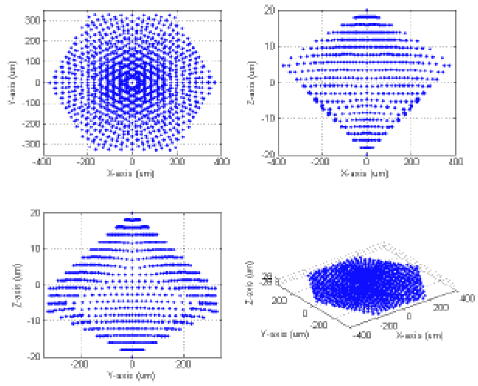
2006 Model

Symmetric and straight configurations aiming at compactness and large workspace.







CAD model for R = 10 mm, r = 3.5 mm, Φ = 35

Xmin	-370.92 µm	Xmax	370.83 µm
Ymin	-330.49 µm	Ymax	330.42 µm
Zmin	-20 µm	Zmax	20 µm

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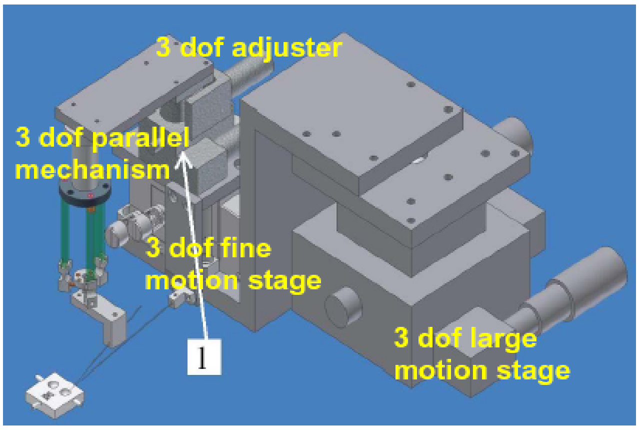
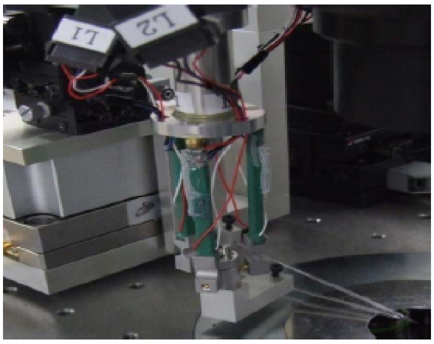
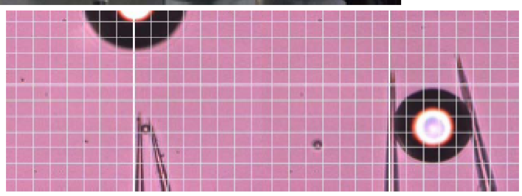
2009 Model

Combination of large, fine motion stages, adjuster and parallel mechanism yields multi-scalability and simple set up procedure, and is capable of manipulating 100um & 20um in the same scene.







10um and 100um objects can be manipulated in the same scene.

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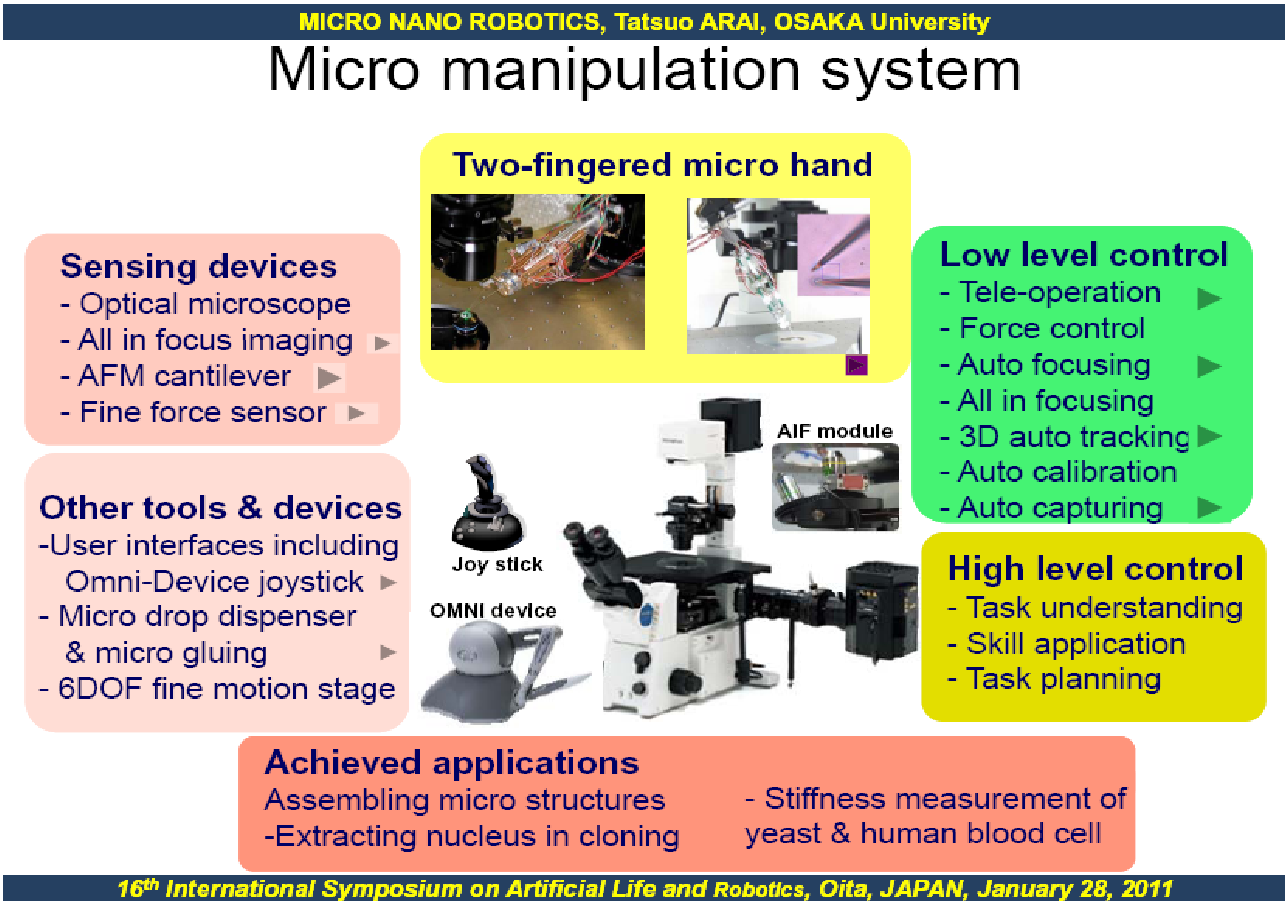
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Micro manipulation system
Two-fingered micro hand
Sensing devices
- Optical microscope
- All in focus imaging
- AFM cantilever
- Fine force sensor
Low level control
- Tele-operation
- Force control
- Auto focusing
- All in focusing
- 3D auto tracking
- Auto calibration
- Auto capturing
AIF module
Joy stick
OMNI device
Other tools & devices
-User interfaces including
Omni-Device joystick
- Micro drop dispenser
& micro gluing
- 6DOF fine motion stage
High level control
- Task understanding
- Skill application
- Task planning
Achieved applications
Assembling micro structures
-Extracting nucleus in cloning
- Stiffness measurement of
yeast & human blood cell
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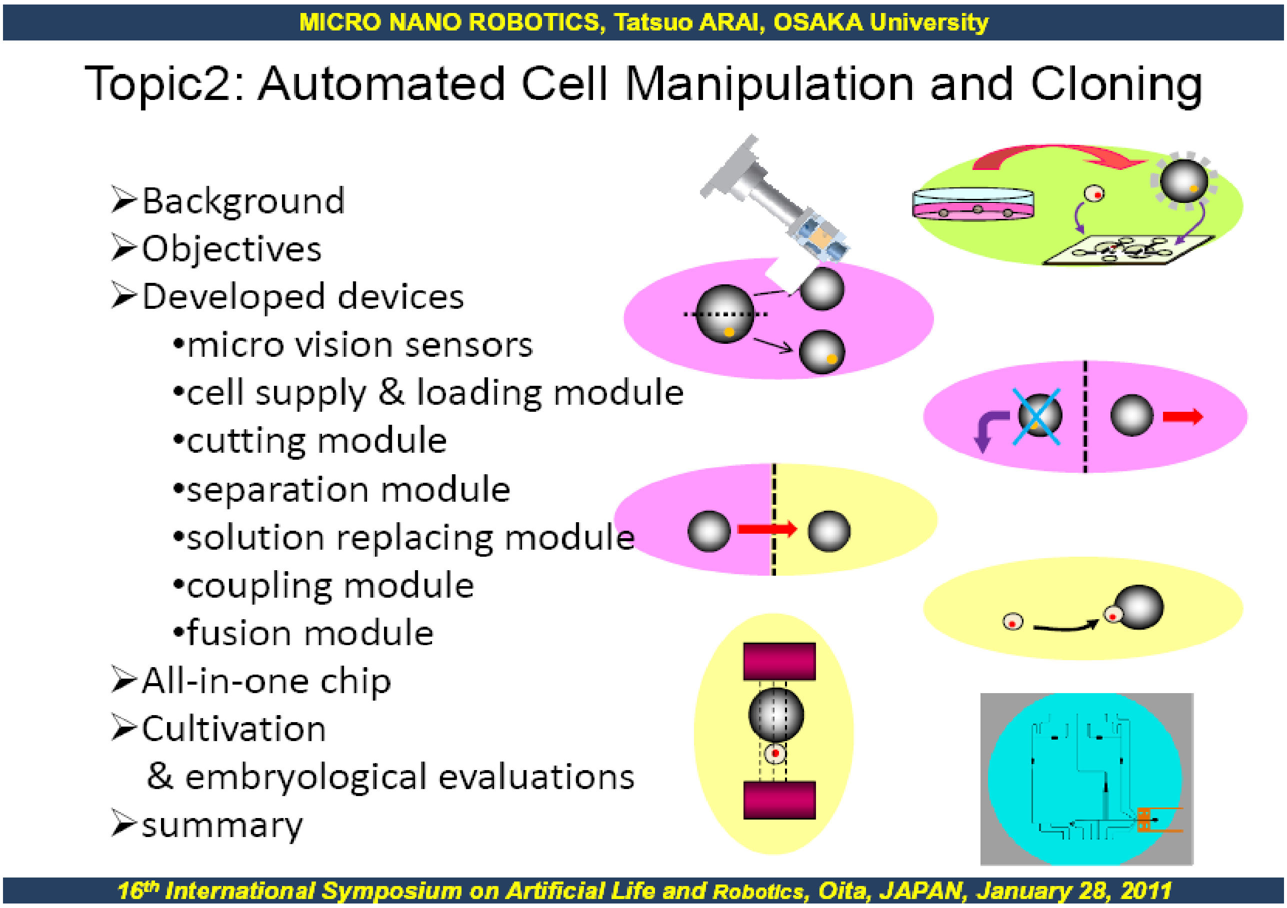
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Topic2: Automated Cell Manipulation and Cloning
➢Background
➢Objectives
➢Developed devices
•micro vision sensors
•cell supply & loading module
•cutting module
•separation module
•solution replacing module
•coupling module
•fusion module
➢All-in-one chip
➢Cultivation
& embryological evaluations
➢summary
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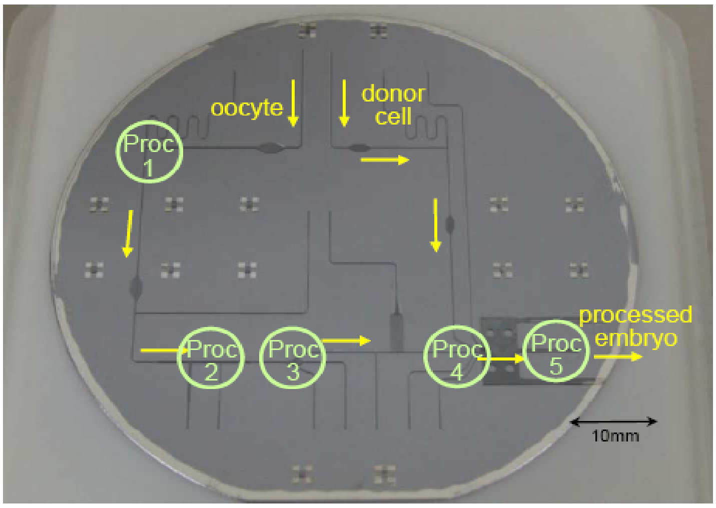
Learning from factory

- Cells may be conveyed in micro channels.
- Every process is achieved in channels.
- Automation may be achieved similarly to factory assembly line system.



Micro channels and process devices are fabricated on PDMS chip.

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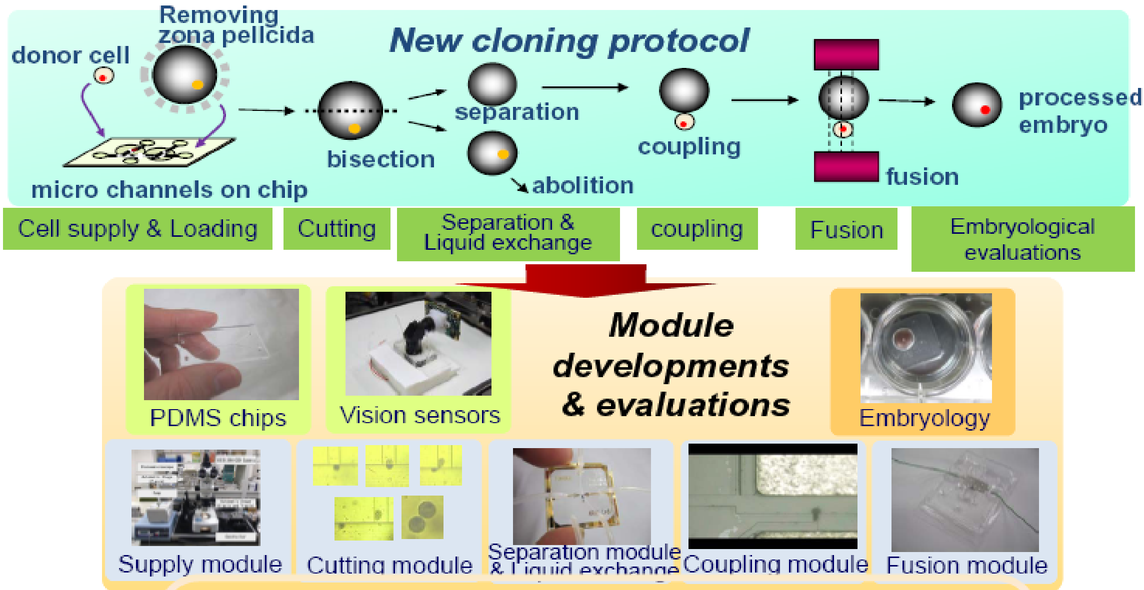
Objectives



Target specification:

-total processing time of 100 cells/3h(tentative).

-total success rate of 30% more.

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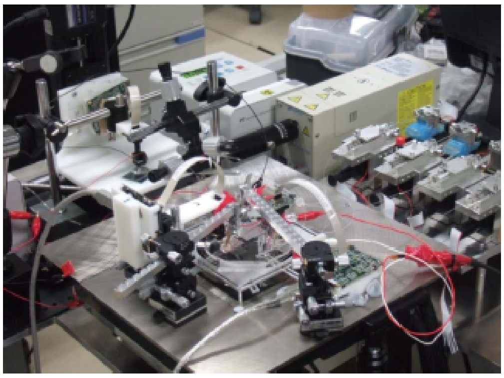
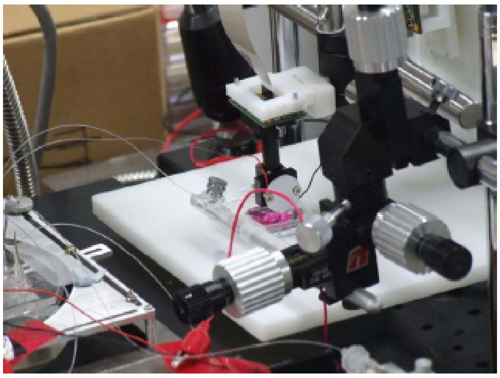
Desktop bio-plant system for cloning





The system includes fabricated one-chip device, various sensors, pumps. The experiments verifies cloning capability using bovine oocyte and fibroblast.

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