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Manipulation of submillimeter-sized electronic parts using force control and vision-based position control

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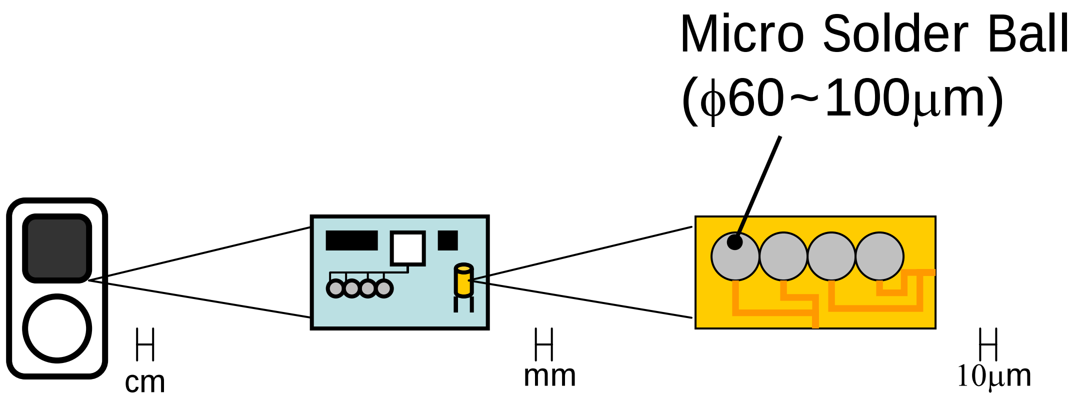
1. Introduction
2. Equipment
3. Force control mechanism with mechanical springs
4. Experimental result of force control
5. Manipulation of small electronic parts
6. Conclusions and future works

1. Introduction

1-1. Background



- Assembly of electronic parts

Downsizing and density increase of electronic devices

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Electronic parts: Submillimeter or smaller

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Assembly technologies are important

(e.g. Joining with small solder balls [Yoshida 2003])

- Accurate positioning (micrometer order)
- Reducing load and damage to the parts

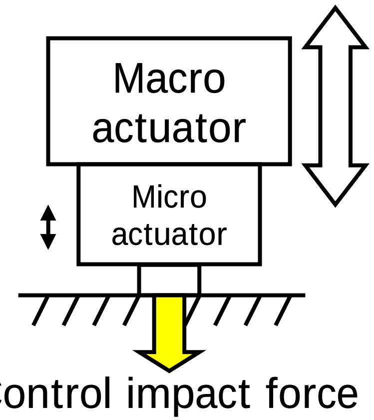
1-2. Previous works

Passive force control

- Micro gripper and RCC unit [Bang 2005]
  - Task: Peg in hole
  - 100μm shaft and hole
- Assembly using RCC Unit [Choi 2006]
  - Task: Assembling camera modules for a mobile phone

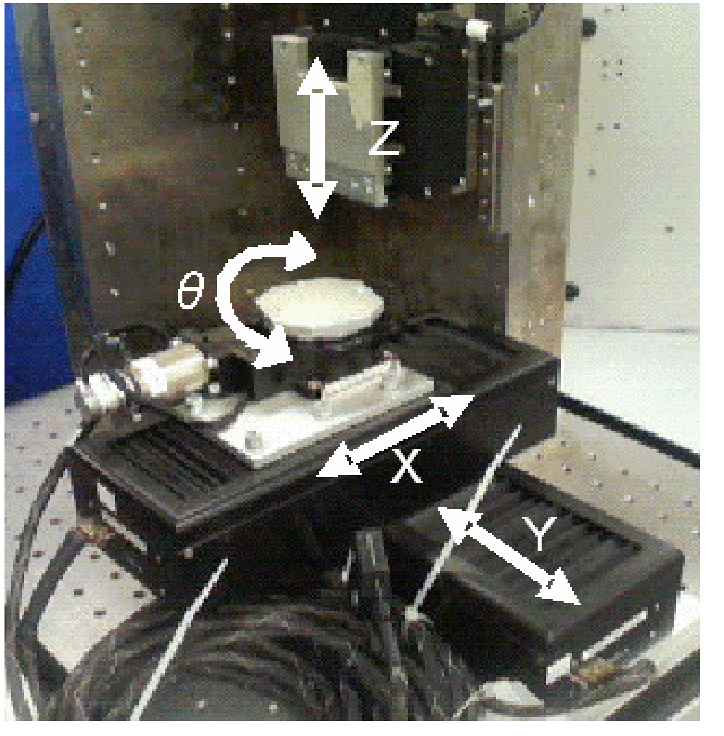
Active force control

- Macro/micro positioning system [Lee 2002]
  - Precise force control in chip mounting
  - Micro actuator and force sensor
  - Usually expensive



Assembly robot [Yoshida 2003][Matsumoto 2003]

- 4 d.o.f.
  - (XYθ: Horizontal positioning stage / Z: For pick-and-place)
- Camera above the stage
- Vision-based position control
- Passive force control
  - With air damper



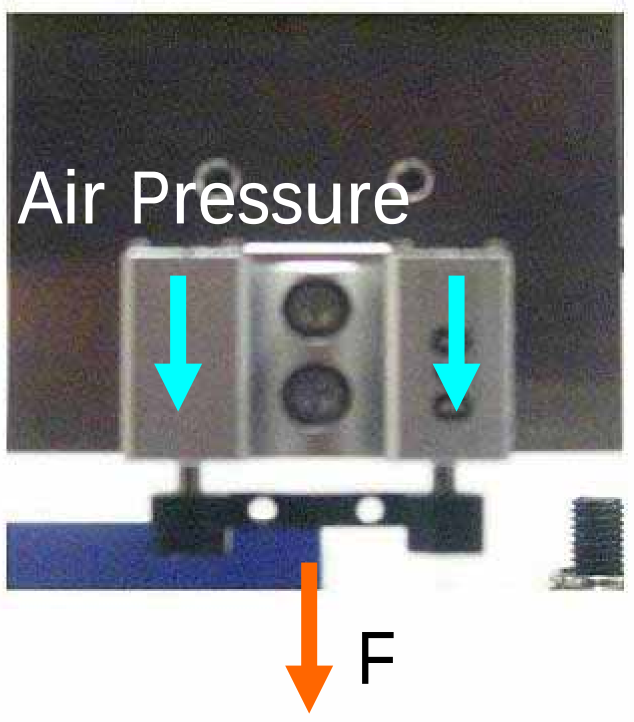
Assembly Robot (AJI Co., Ltd.)

Passive force control using air damper

- Force Control Unit (FCU)
  - Attached to the tip of the Z-axis
  - Control pressing load to a constant value
  - Change the load by air pressure

<u>Problem</u>

  - Impossible to change the load speedily
  - The load under 0.2 [N] is not available
    (Because of the weight of floating unit)



Force Control Unit

1-3. Objective

Manipulation of small parts using active force control and vision-based position control

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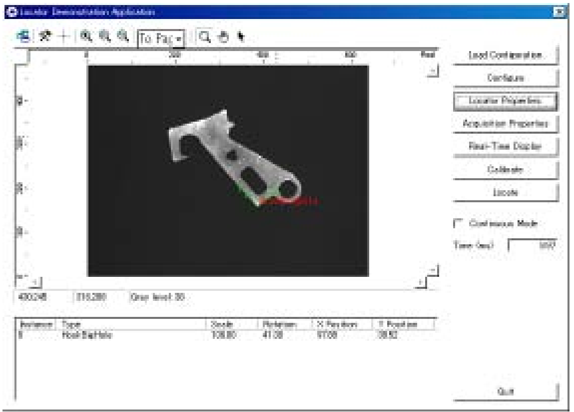
Active force control of 4 d.o.f. assembly robot

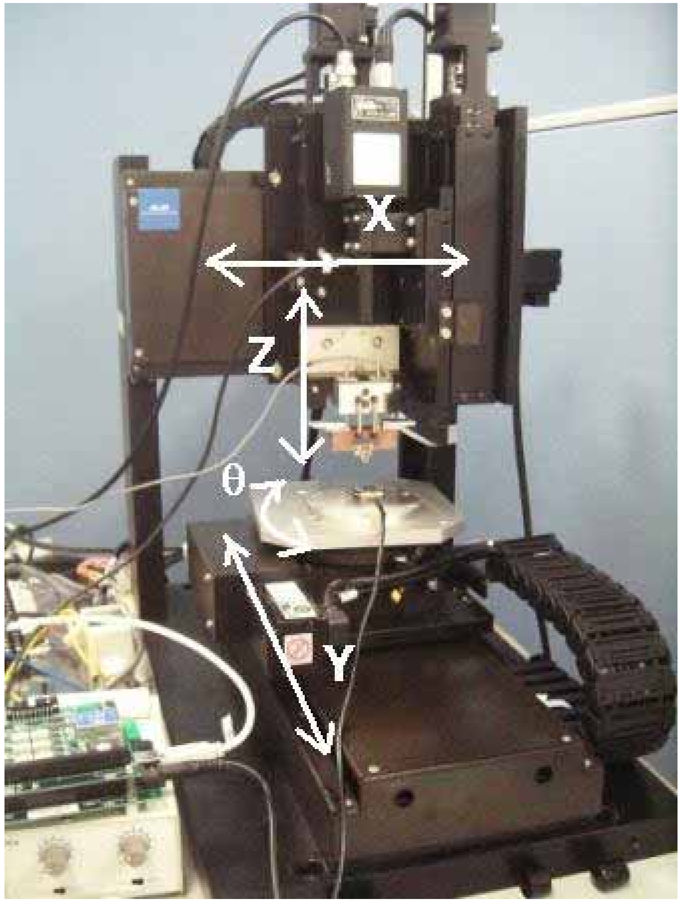
Method of force control

- By changing resilience force of springs
- Measure the displacement of spring and feed back to the position control of Z-axis

2. Equipment

- 4 d.o.f. assembly robot
  (AJI Co., Ltd.)
  - Z-axis: rate control with displacement sensor
  - XYθ-axis: vision-based position control
  - Image processing software: HexSight
    (Adept Technology, inc.)





4 d.o.f. Assembly Robot
(AJI Co., Ltd.)

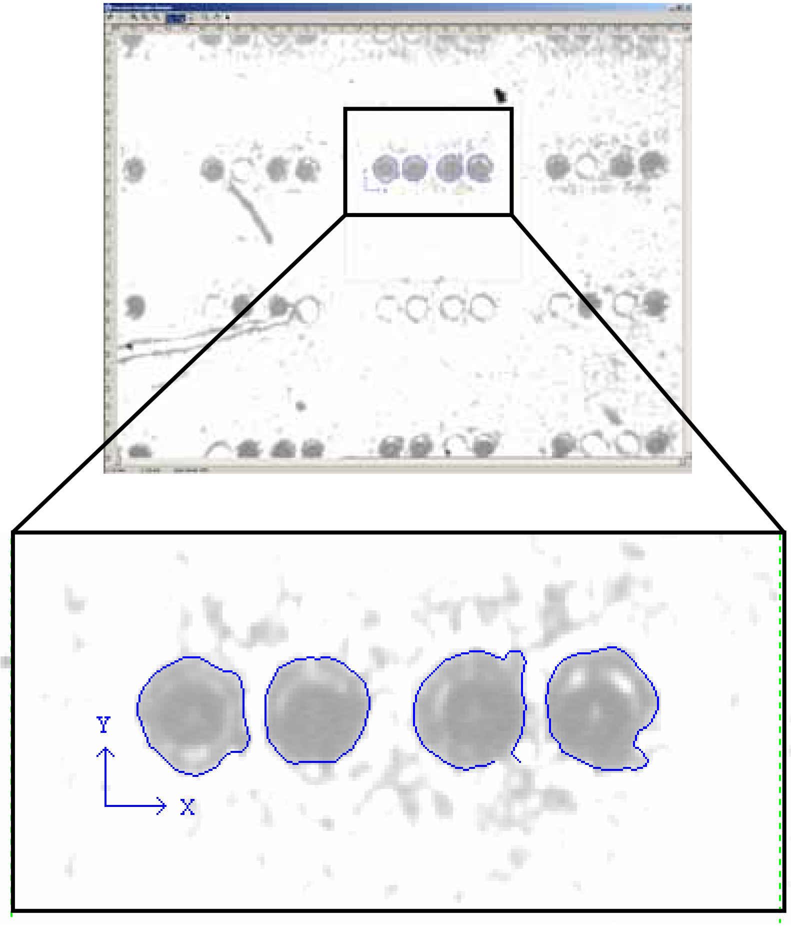
Vision-based position control with HexSight

Register the target model (contours)

Set target position and orientation

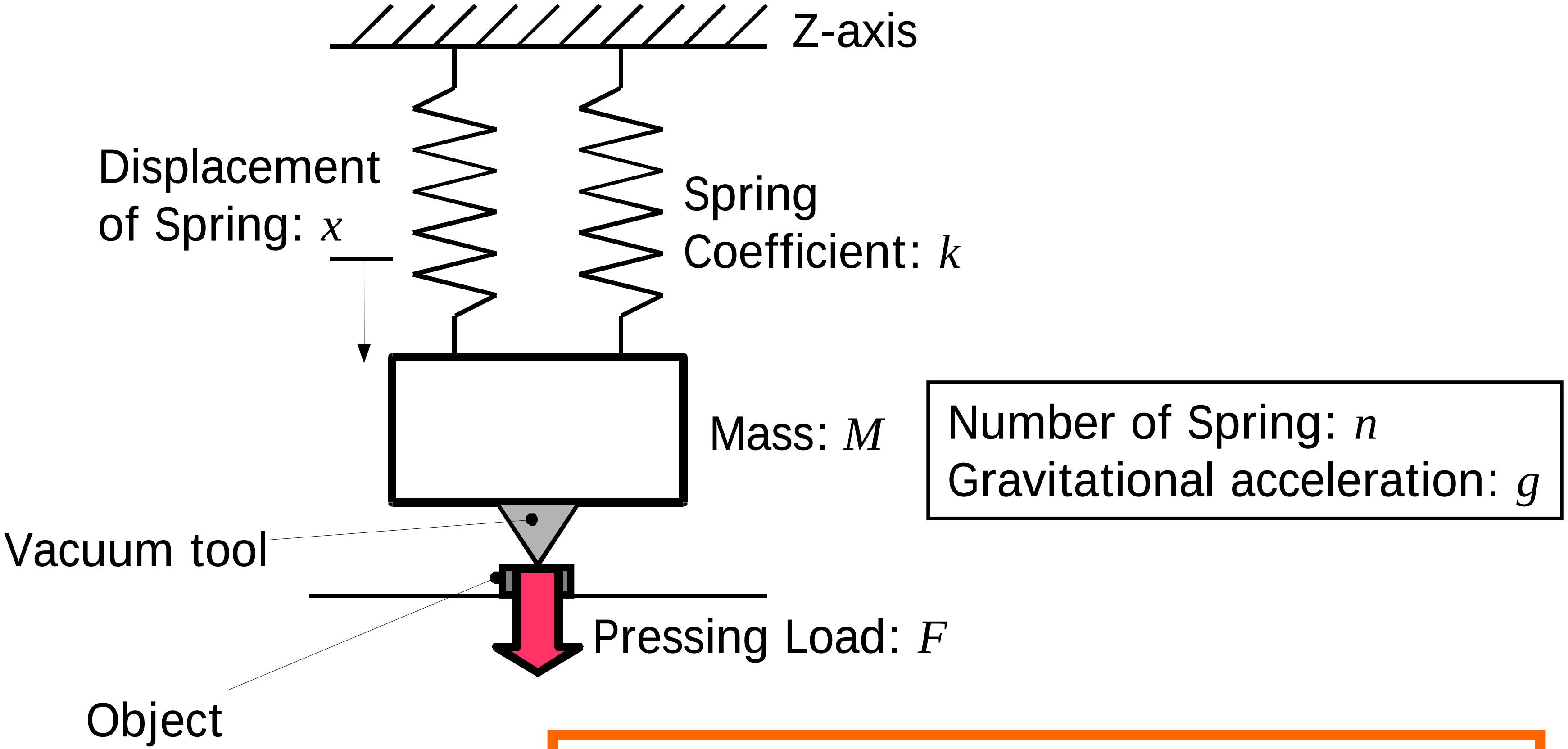
Detect contours in captured image and calculate the position and orientation

Move each axis with the feedback



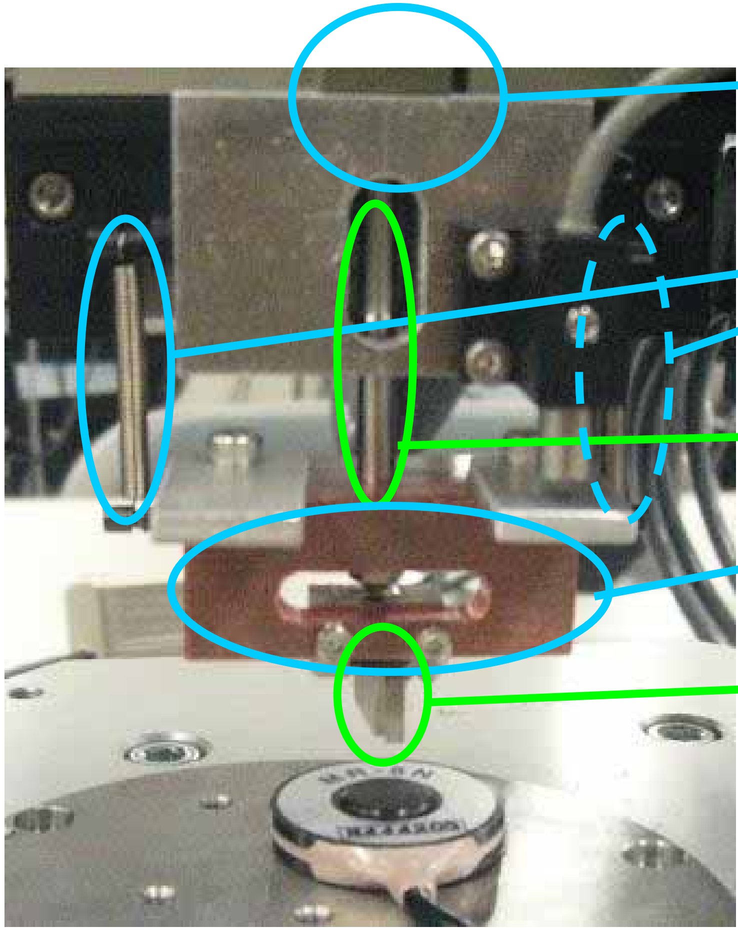
3. Force control with mechanical springs

3-1. method



$$F = Mg - n(kx + T_0)$$

3-2. Mechanical design

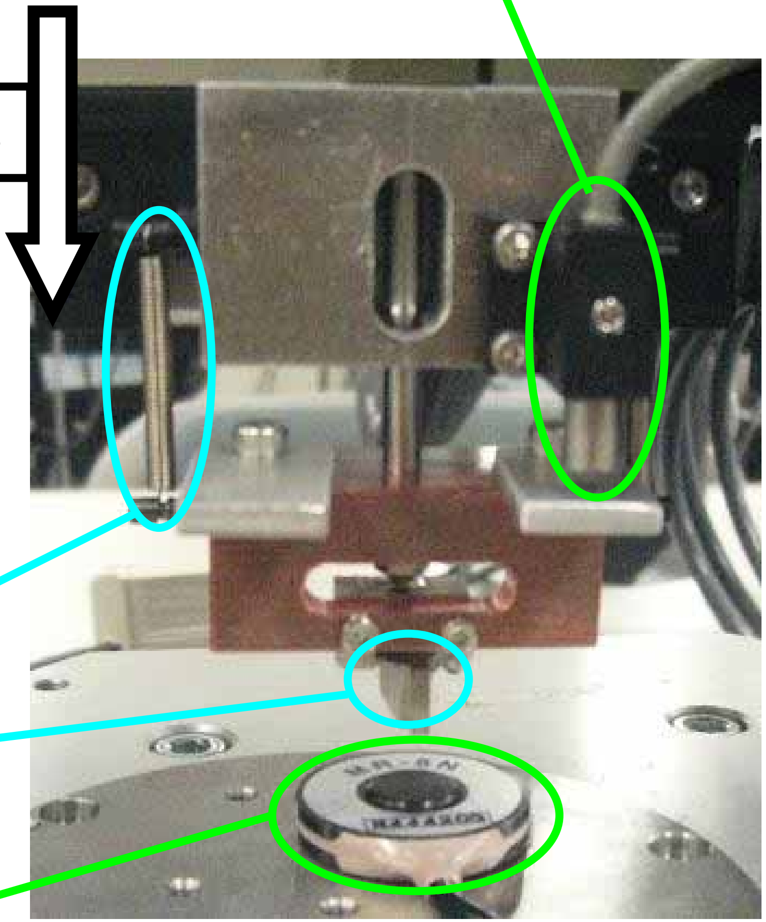


(One shaft and two springs)

Designed Parameter			
M [kg]	k [N/mm]	n	T_0 [N]
0.086	0.0525	2	0.21

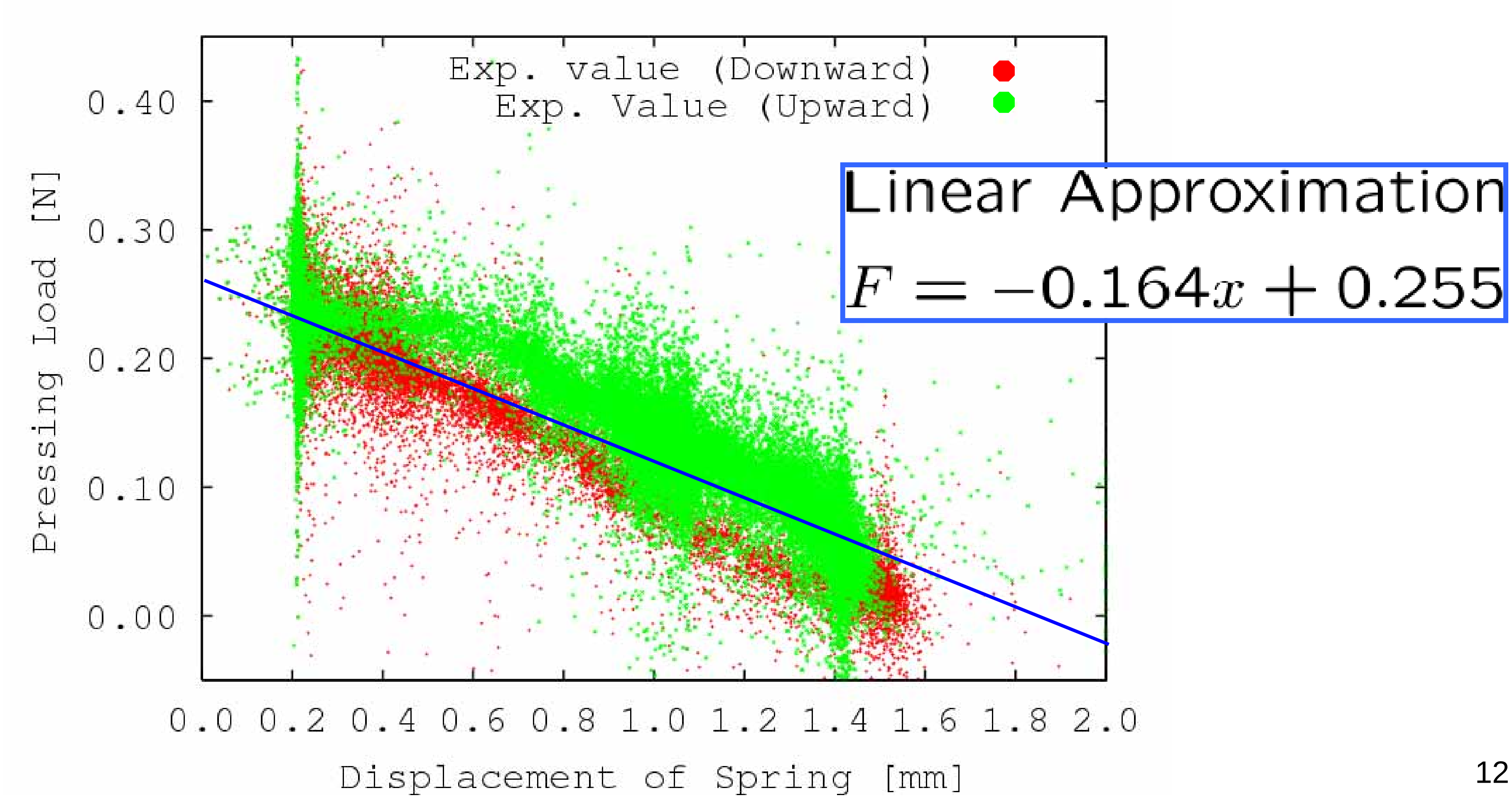
4. Force control experiment
4-1. method

- Measure the displacement of spring by a displacement sensor
- Control the motor of Z-axis with the feedback
- Measure the pressing load by a load cell (**used only for calibration and verification**)

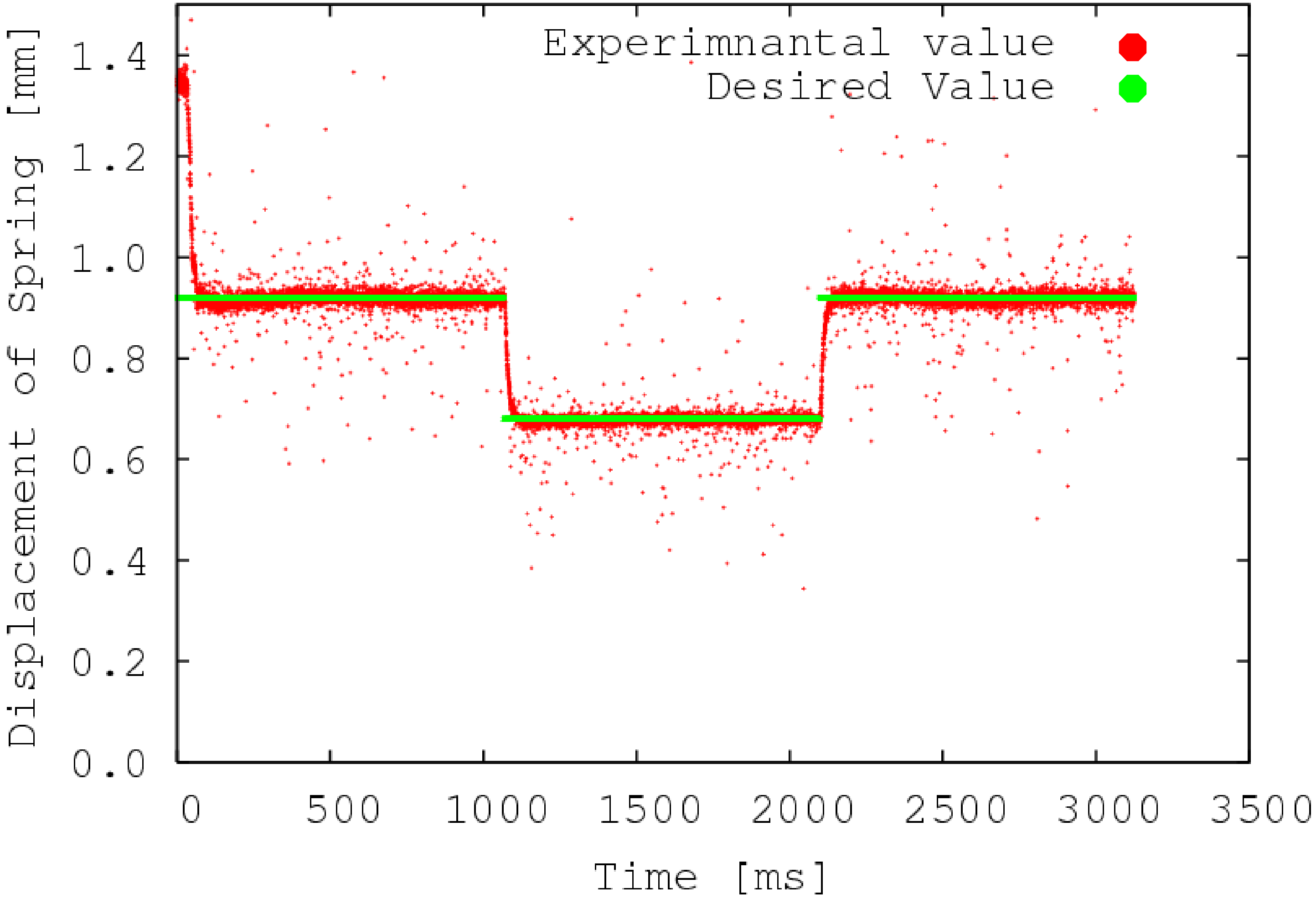


4-2. Result

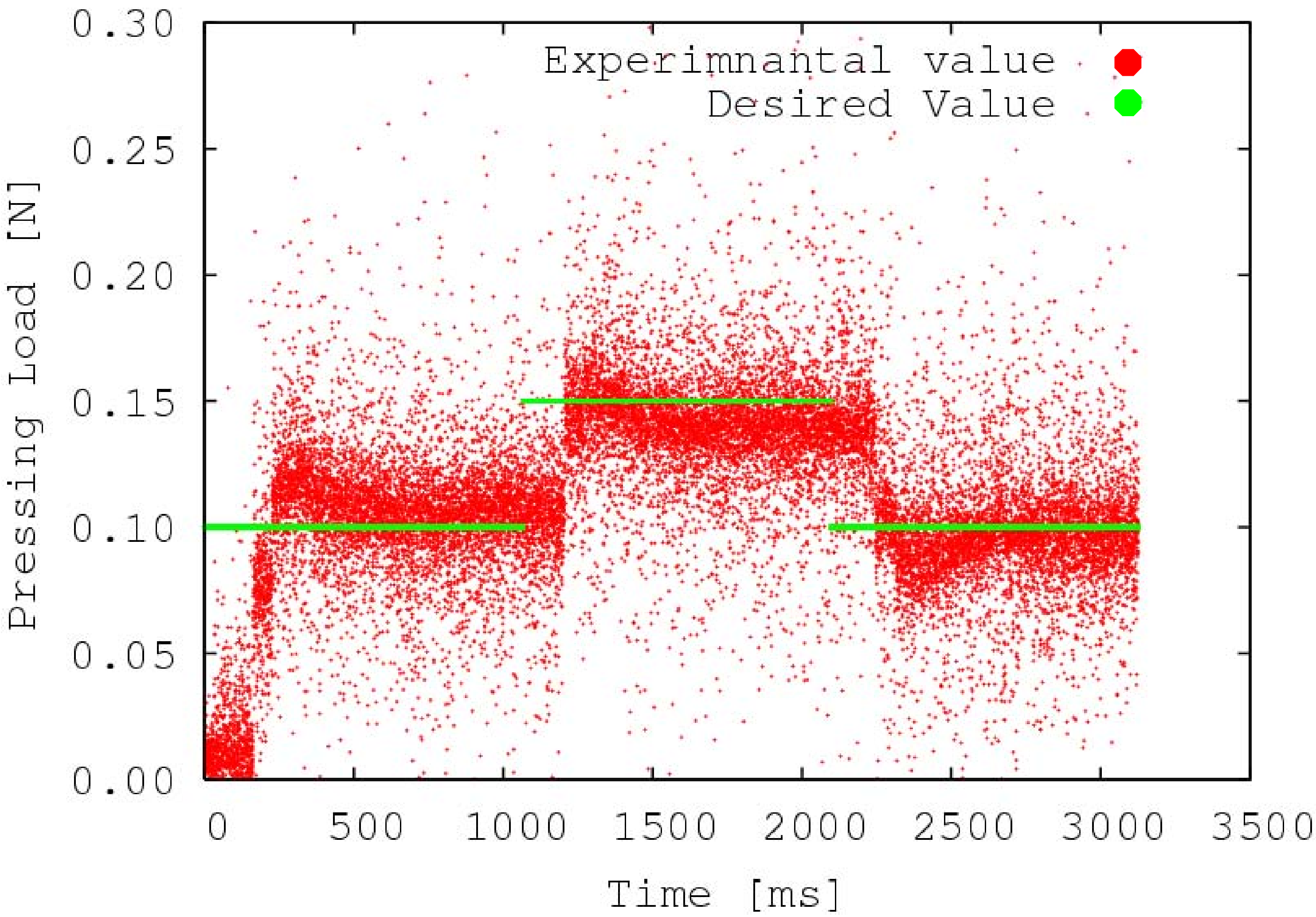
- Calibration
  - (Relationship between pressing load and displacement of spring)



- Displacement of spring (for changing desired load)



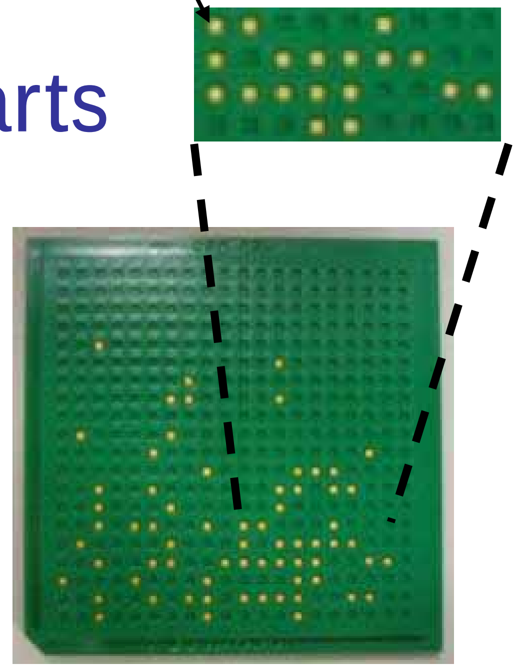
- Pressing load (for changing desired load)



5. Manipulation of small parts

5-1. Pick and place of chip-shaped parts

Chip (yellow)

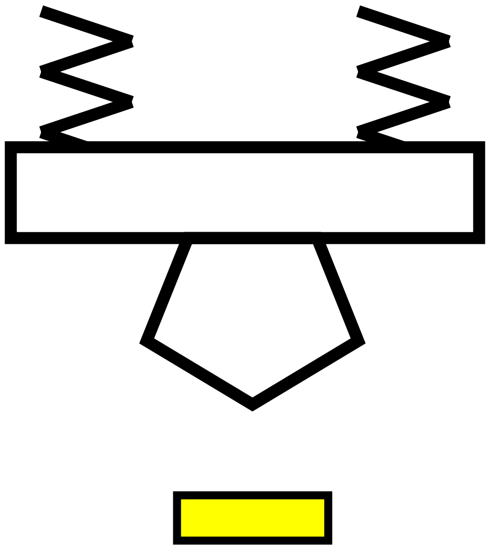


- 0.55mm square×0.3mm thick

Mounting

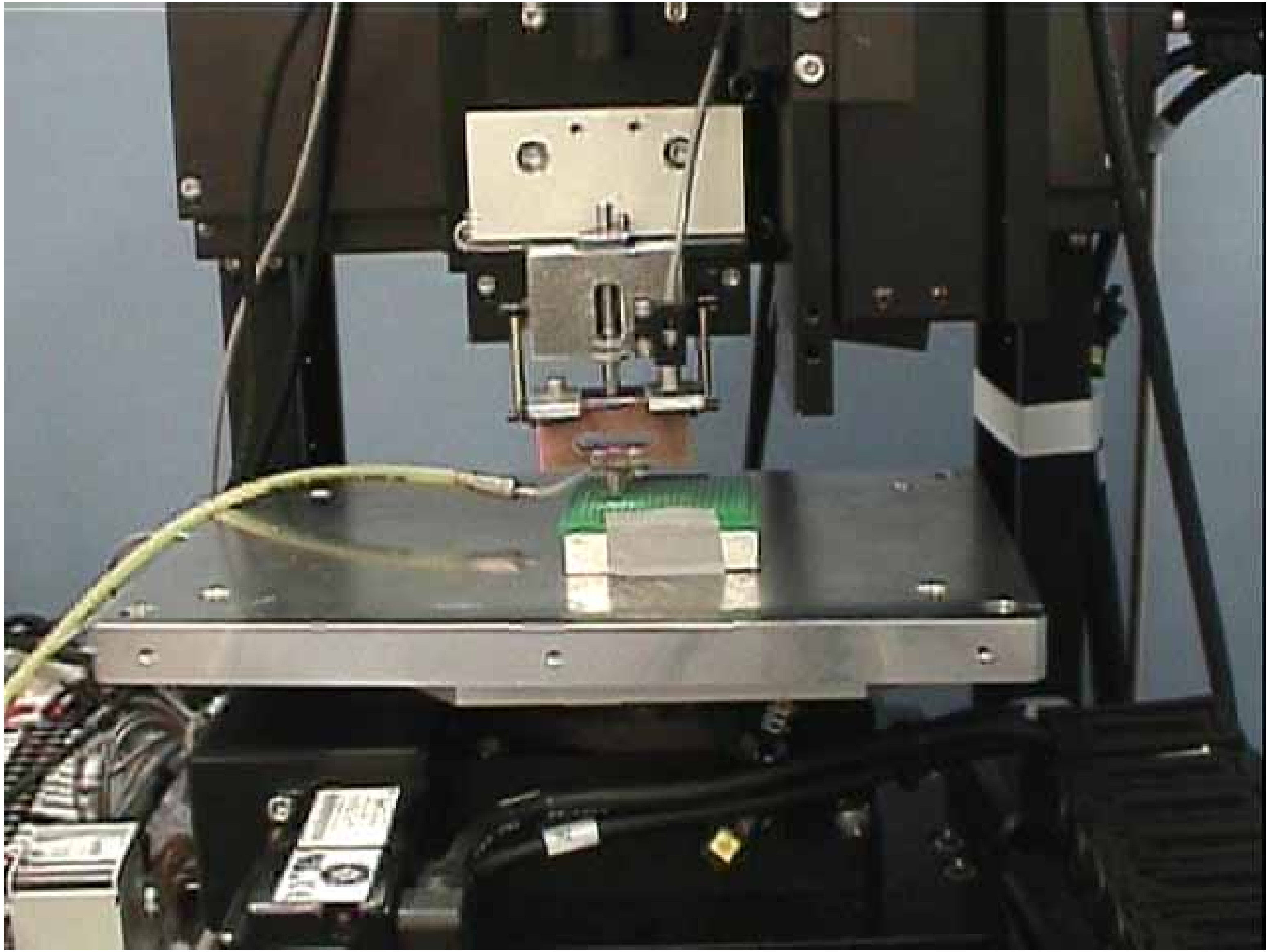
Force control

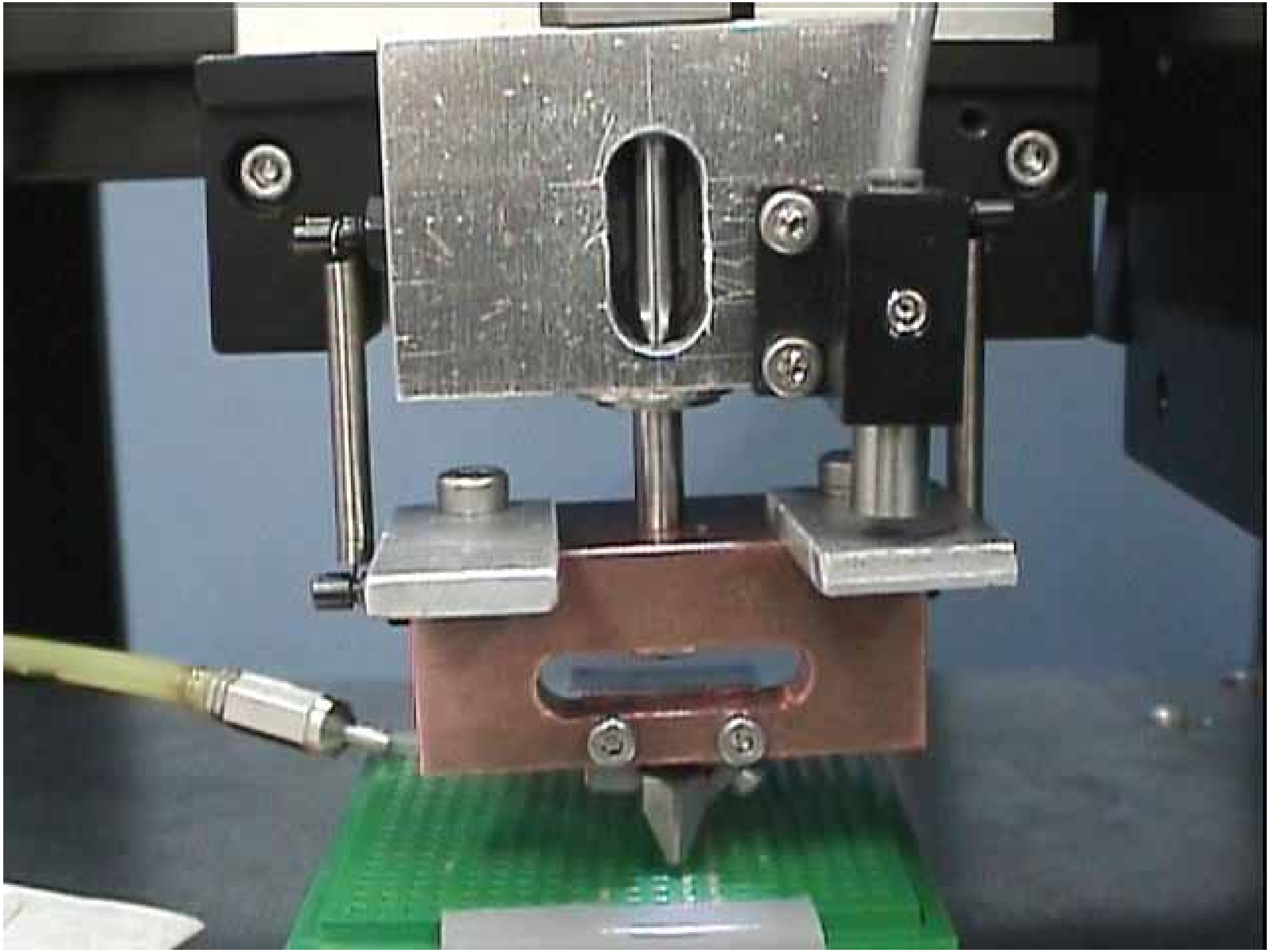
osition control



Chip-shaped Electronic Parts

- Robot motion in chip mounting





Success rate of chip mounting for various pressing load (25 trials for each)

		Pressing load in mounting [N]		
		0.05	0.10	0.15
Pressing load in pickup [N]	0.05	80%	88%	100%
	0.10	72%	92%	88%
	0.15	64%	84%	92%

Appropriate force control in each process
-> Increase success rate of chip mounting

6. Conclusion

- Active force control with simple spring mechanism
- Vision-based position control

⇩ Integration

- Manipulation of submillimeter-sized electronic parts

Future works

- – Improve the accuracy of force control mechanism
- – Improve the condition of image capturing
- – Reduce assembly cycle time
- – Increase variation of the object