

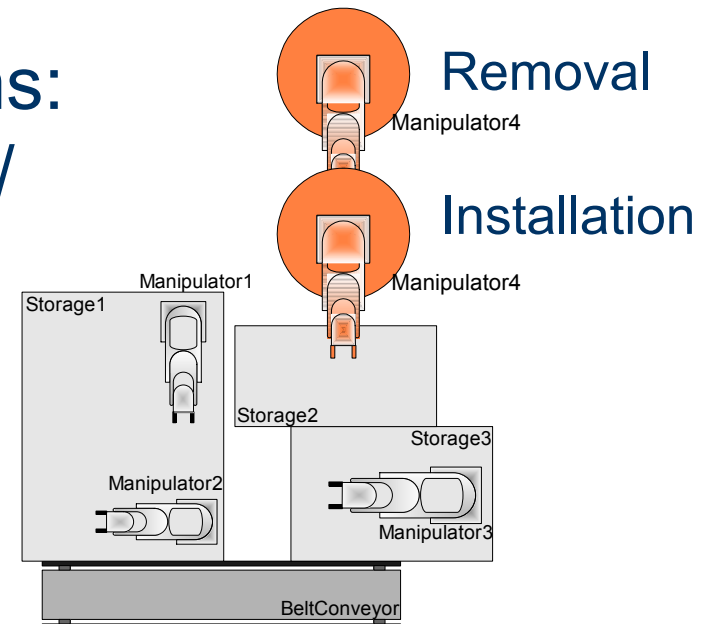
# An Easily Reconfigurable Robotic Assembly System

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# Reconfigurability of Assembly Systems

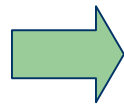
- Reconfigurability is needed for manufacturing systems to cope with market uncertainty [Koren 99]
- In robotic assembly systems: Quick and easy installation/removal of robots



# Related Works

## Actual robotic assembly systems with reconfigurability

- Restructurable Assembly Center [Tamaki 93]
- Cellular Assembly System [Kondoh 98]
- APS (Adaptive Production System) [Hanai 99]

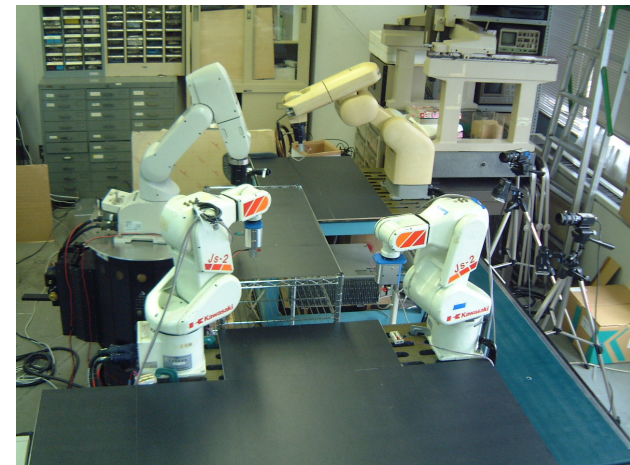


Specially designed hardware for reconfigurability

# Objective

- Easily reconfigurable assembly system consisting of conventional devices

➔ Implement “Plug & Produce” function on our robotic assembly system

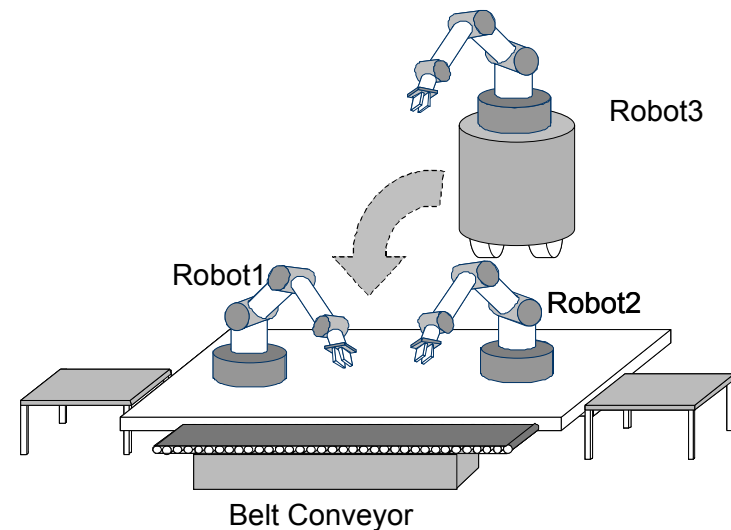


# Plug & Produce

Plug & Produce: System's function that supports physical reconfiguration [Arai 97] [Sugi 03]

→ Easy addition/removal of manufacturing devices

- Easy calibration of position/orientation of newly installed robots
- Management mechanism of positional information of robots

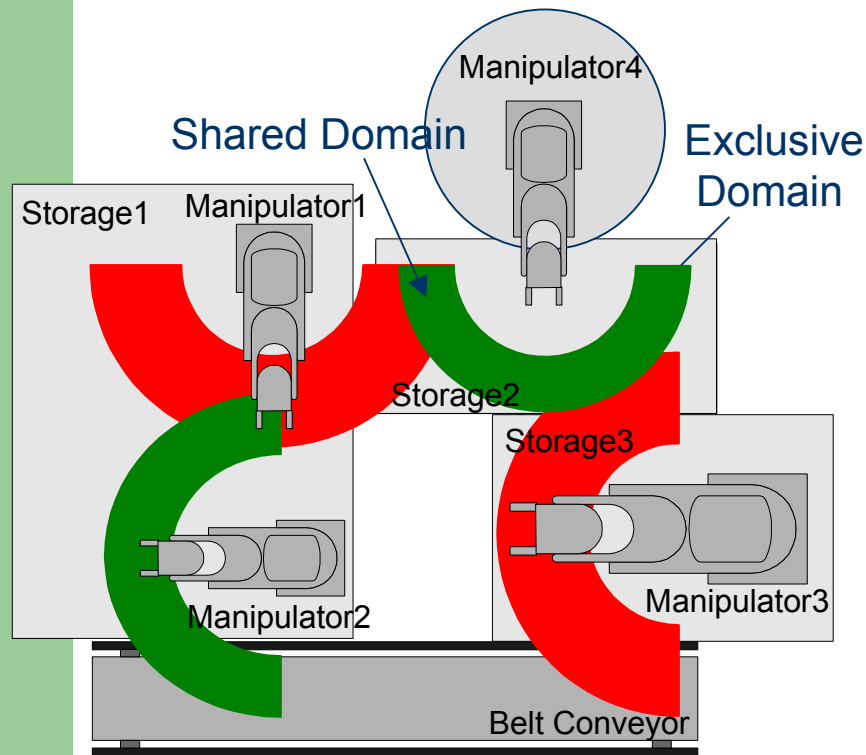


# Agenda

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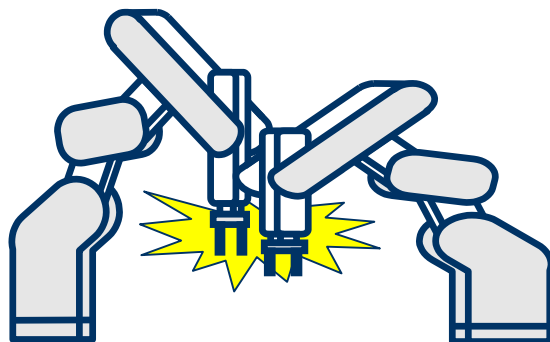
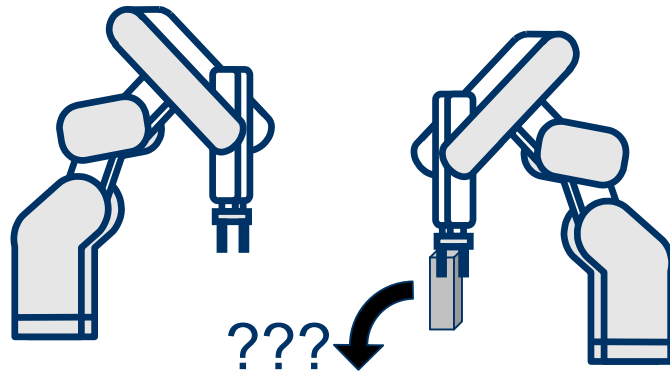
- Introduction
- Calibration for Plug & Produce
- Management of Positional Information for Plug & Produce
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# Targeted Assembly Cell



- Robot, belt conveyor, and storage
- Hand-over parts at shared domains and assemble them at exclusive domains

# Calibration for Plug & Produce

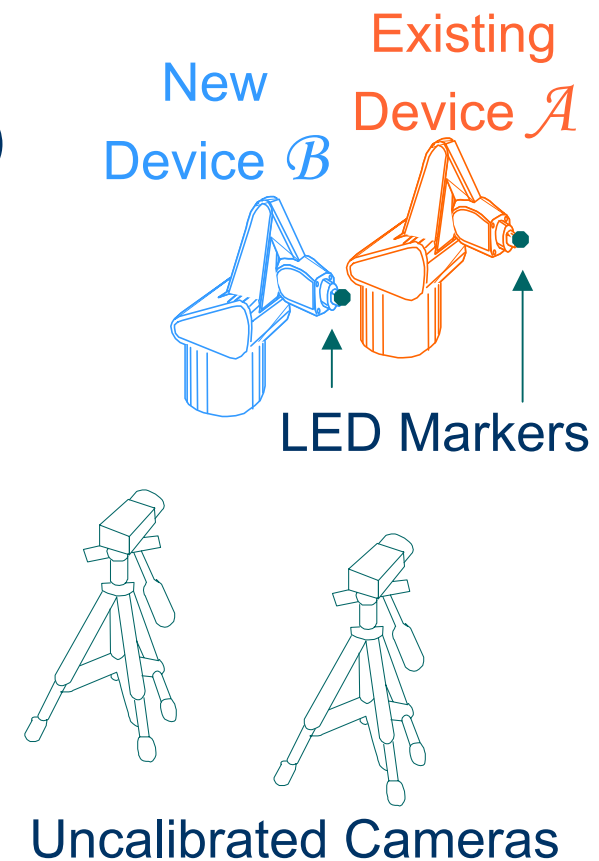


Calibration of mutual positional relationship is necessary for coordination

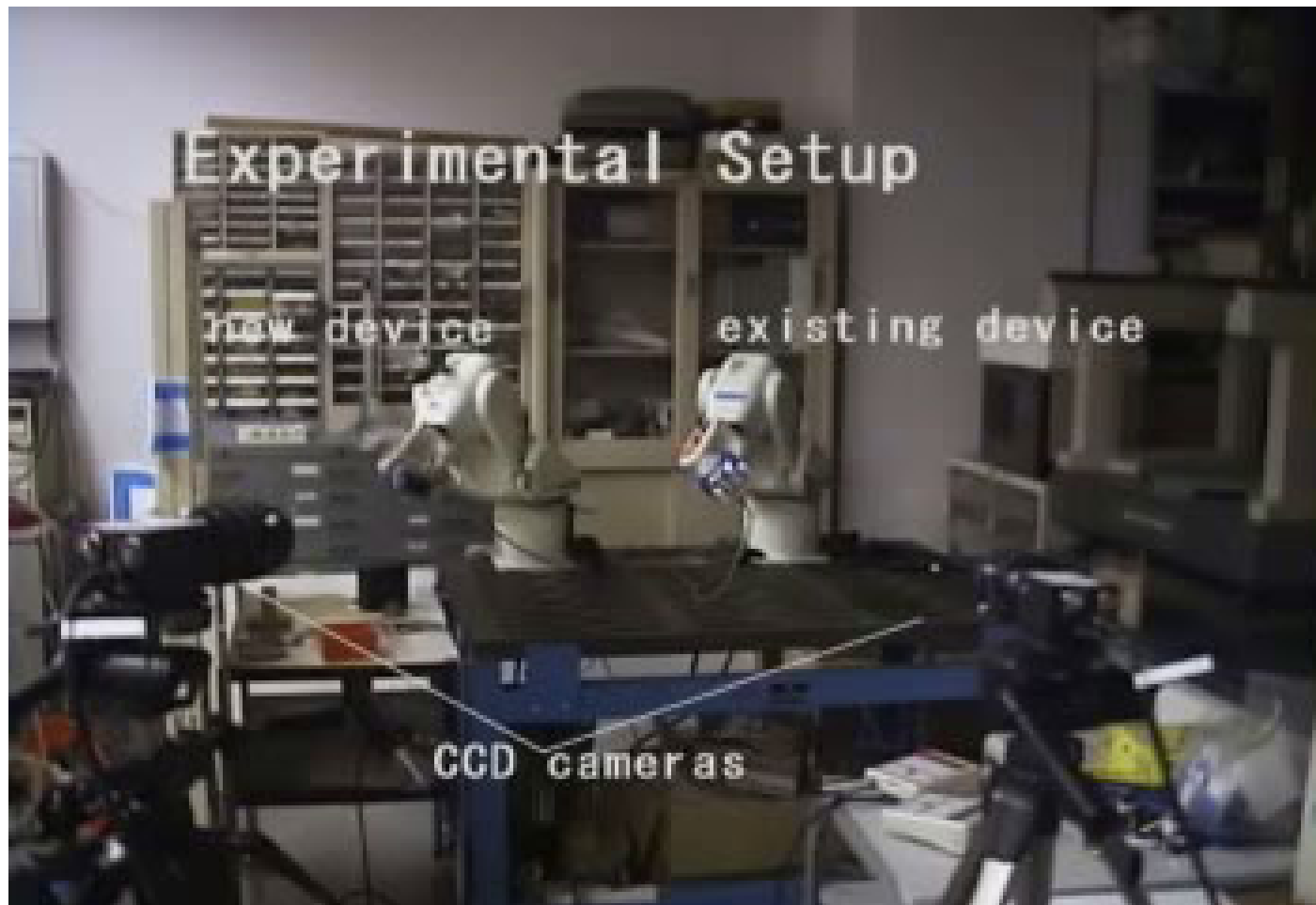


# Our Calibration Method [Arai 02]

- Stereo vision based (DLT: Direct Linear Transformation)
- Mostly automated
- Minimum modification to robots (LED markers attached)
- No need for calibrated cameras



# Calibration Procedure



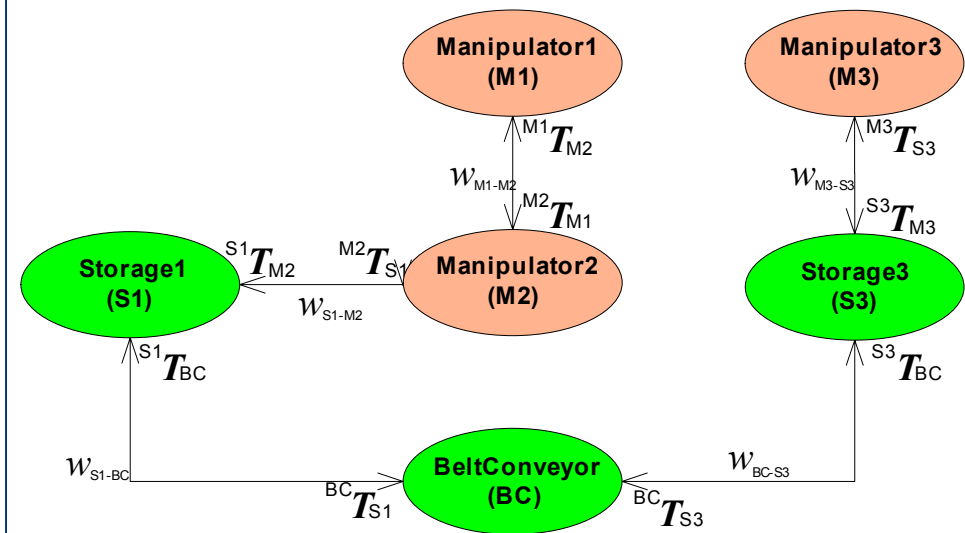
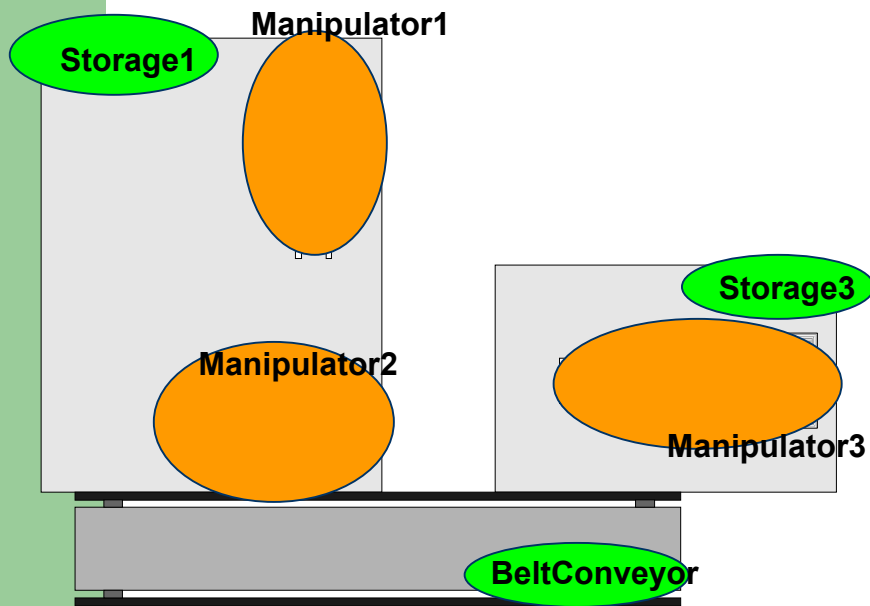
Accuracy:  
~0.5 [mm]

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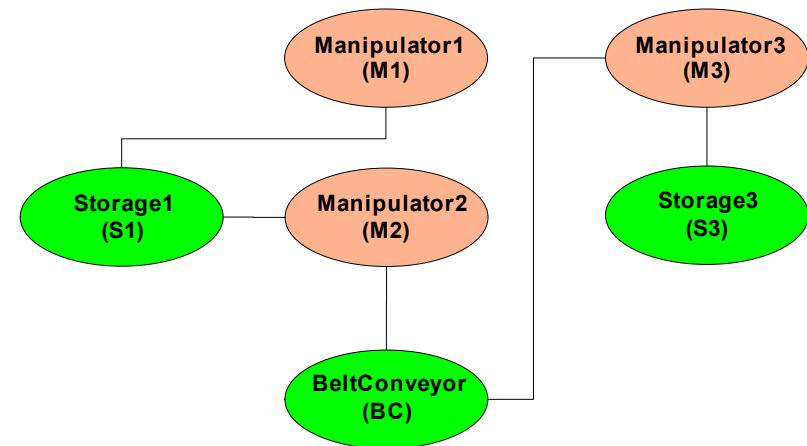
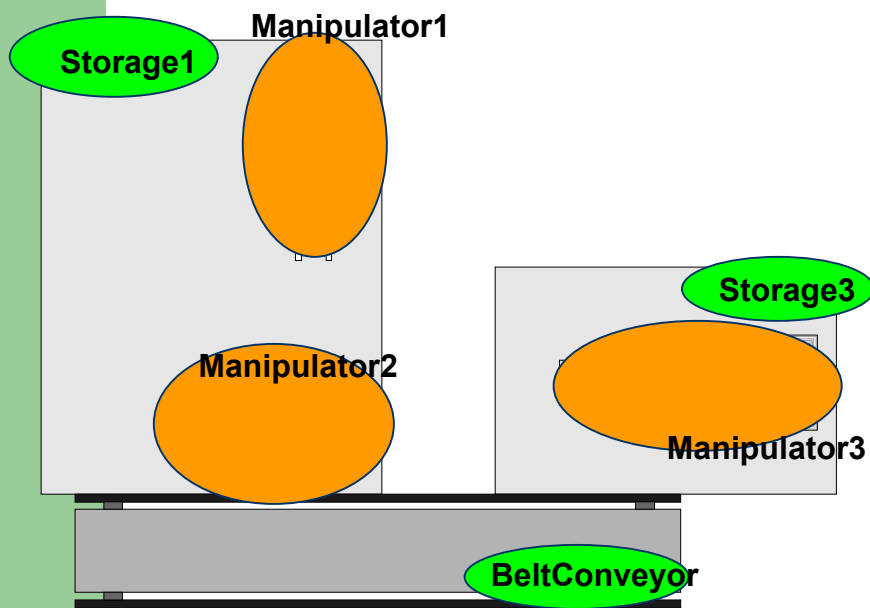
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# Graph Representation of Positional Relationships



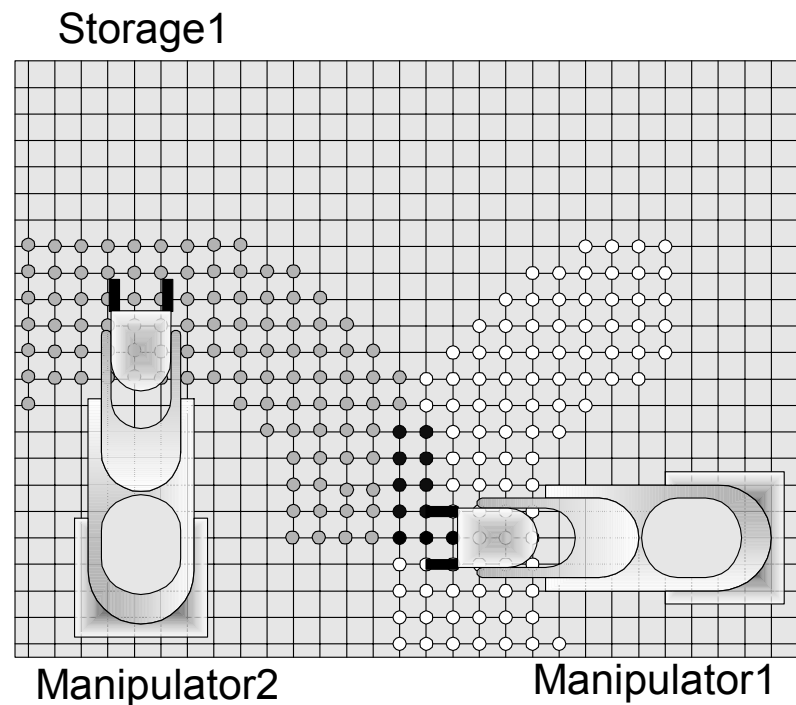
“calibration graph”

# Graph Representation of Adjacency Information



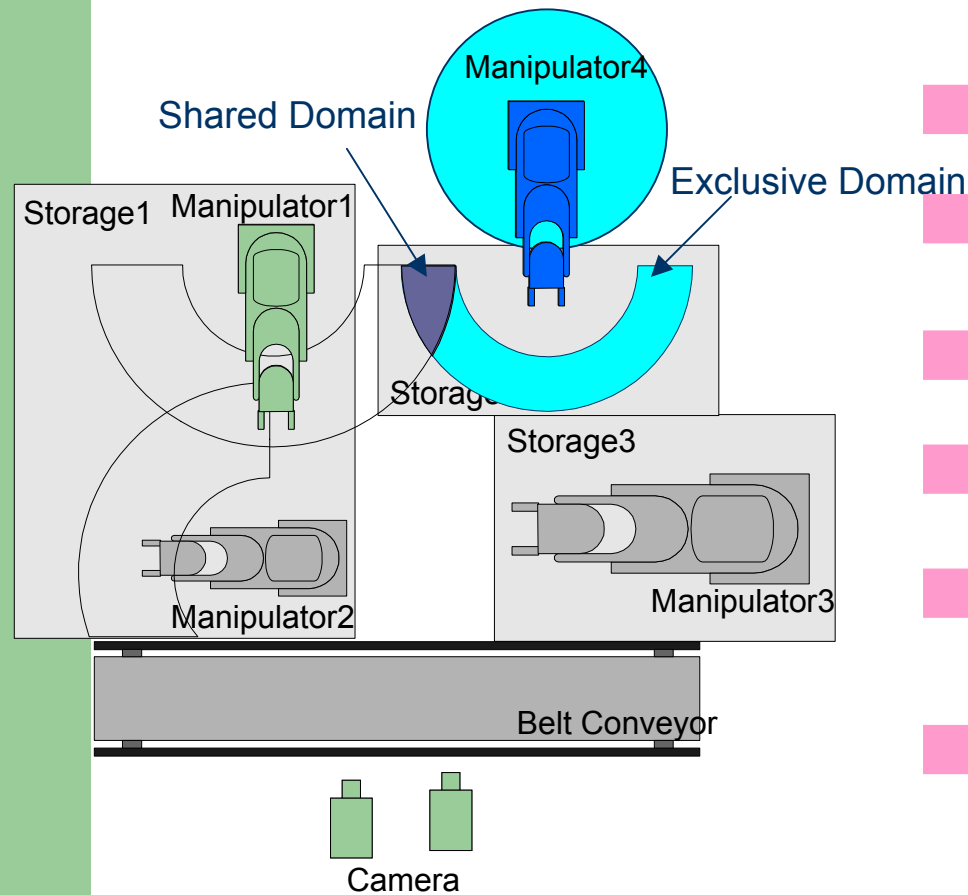
“adjacency graph”

# Workspace Allocation according to Calibration Result



- Exclusive (Manipulator1)
- Exclusive (Manipulator2)
- Shared (Manipulator1 & Manipulator2)

# Plug-in Procedure



- ➔ 1. Install New Manipulator
- ➔ 2. Place cameras
- ➔ 3. Automated calibration
- ➔ 4. Update calibration graph
- ➔ 5. Assign shared/exclusive domains
- ➔ 6. Update adjacency graph

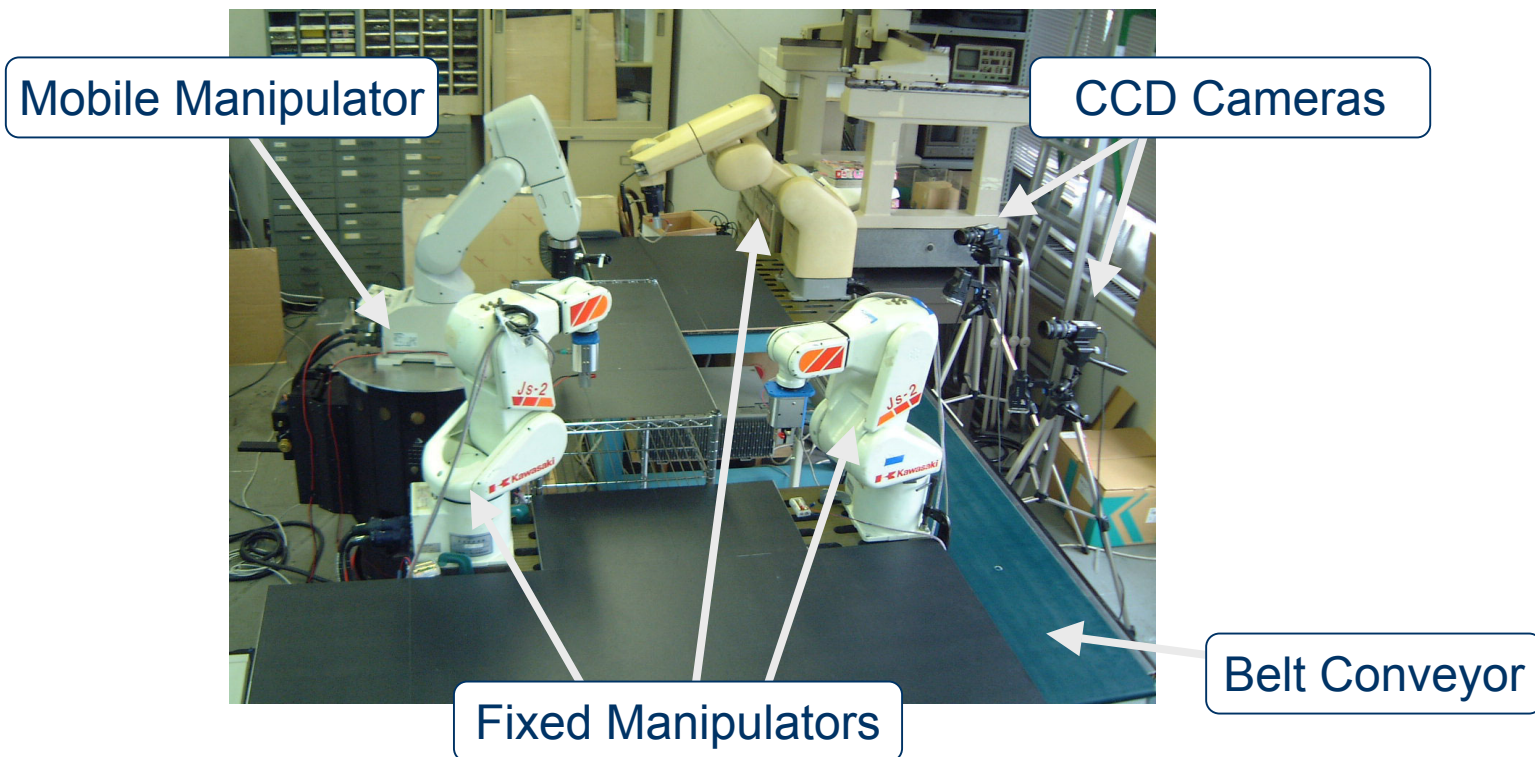
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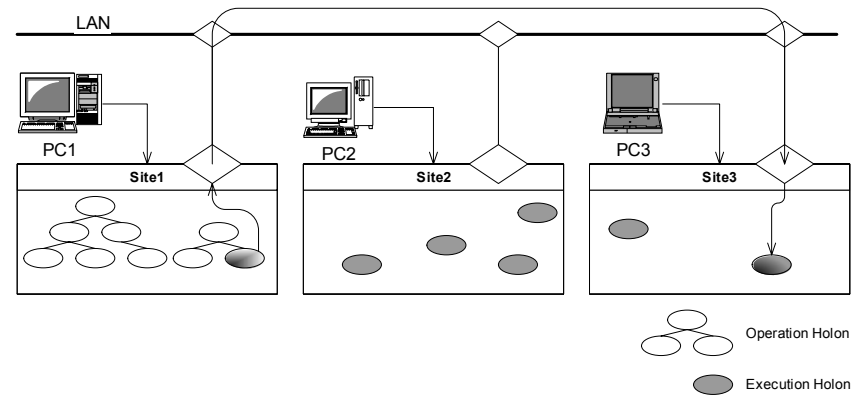
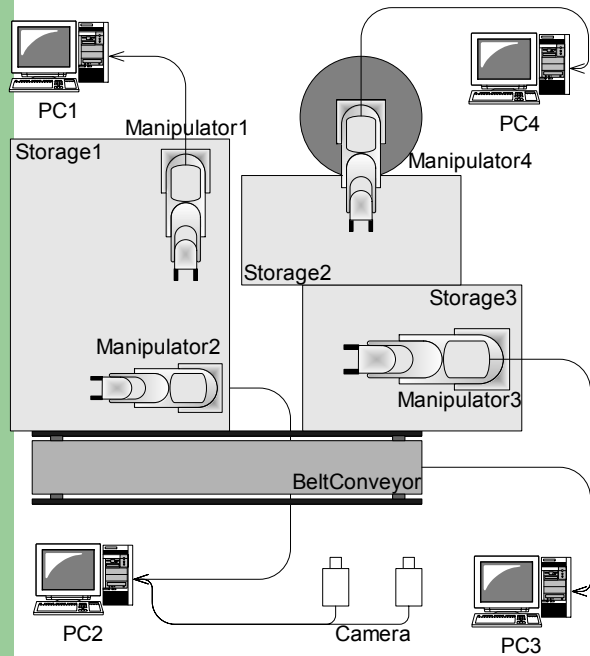
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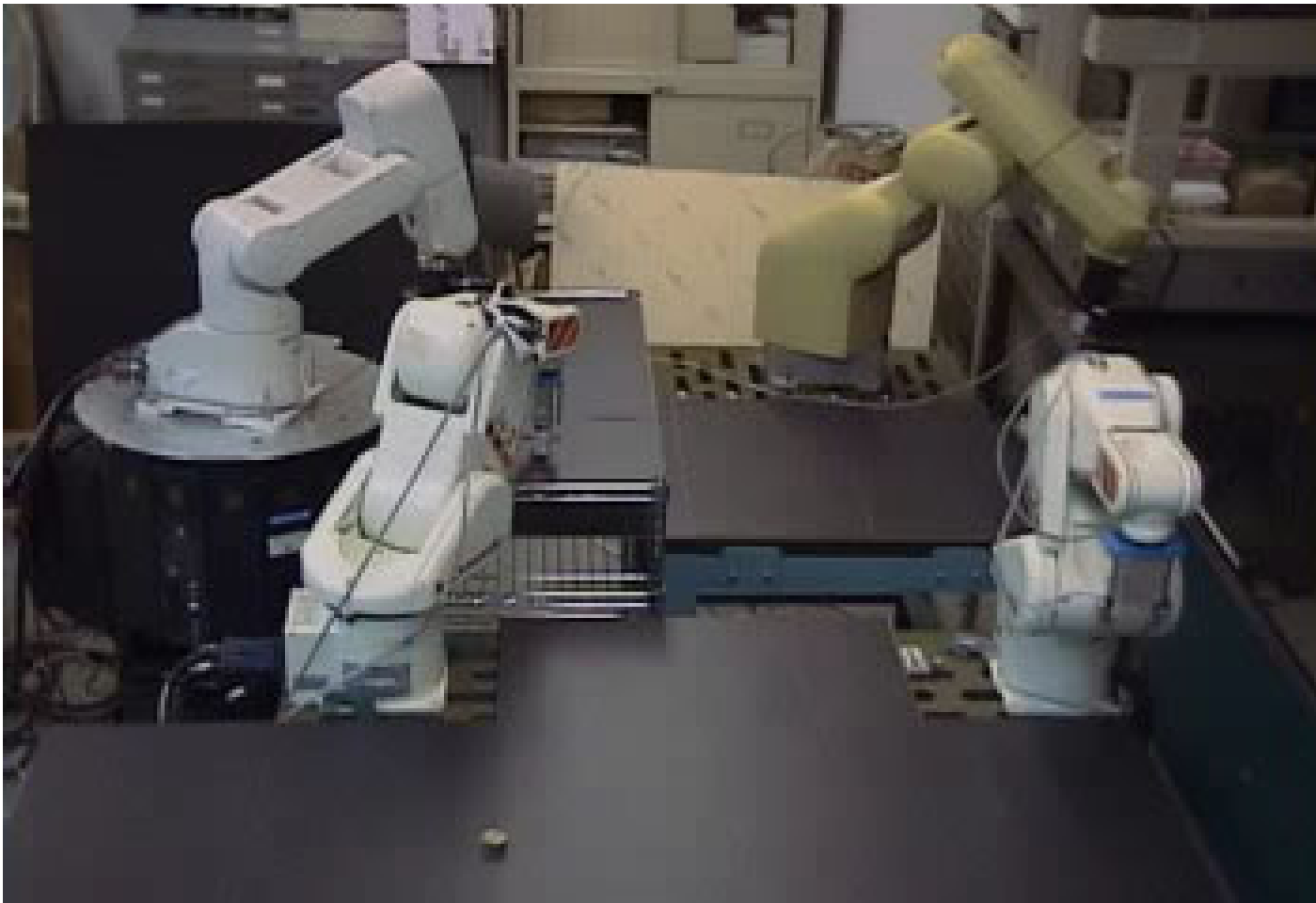
# Our Reconfigurable Assembly System



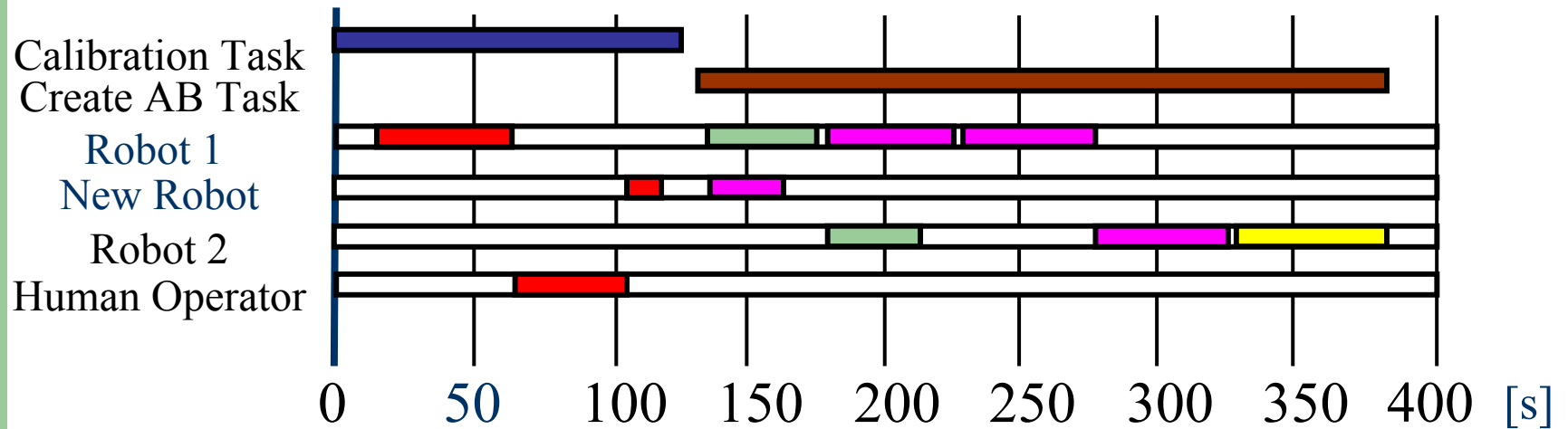
# Implementation of System



# Plug-in & Assembly (Movie)



# Plug-in & Assembly (Gantt Chart)



- Move Part B Operation
- Move Part A Operation
- Insert A into B Operation
- Calibration Operation

# Summary

- Semi-automated calibration method of robot coordinates for Plug & Produce
- Management of positional information of robots for Plug & Produce
- Experiment of robot installation and assembly

\*See also [Arai 03] at ISATP'03  
for other system details

