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

• Introduction
• Calibration for Plug & Produce
• Management of Positional Information for Plug & Produce
• Experiment of New Robot Installation
• Conclusion
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

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

[Arai 02]
Calibration Procedure

Accuracy: \(~0.5\ [\text{mm}]\)
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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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Our Reconfigurable Assembly System

- Mobile Manipulator
- Fixed Manipulators
- CCD Cameras
- Belt Conveyor
Implementation of System

Java-based Implementation
Plug-in & Assembly (Movie)
Plug-in & Assembly (Gantt Chart)

- Calibration Task
- Create AB Task
- Robot 1
- New Robot
- Robot 2
- Human Operator

Operational Activities:
- Move Part B Operation
- Move Part A Operation
- Insert A into B Operation
- Calibration Operation

Timelines:
- 0 50 100 150 200 250 300 350 400 [s]
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