Teaching of Grasp/Graspless Manipulation for Industrial Robots by Human Demonstration

Yusuke MAEDA
Nanako ISHIDO
Haruka KIKUCHI
Tamio ARAI

The University of Tokyo

Introduction

- Problems in robot programming
    - Difficult for novice operators
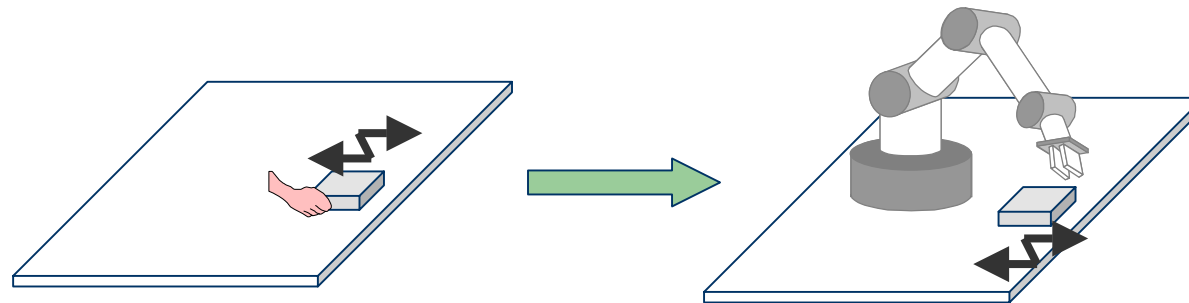   - Time-consuming

Easy robot programming is highly demanded

Teaching by Showing

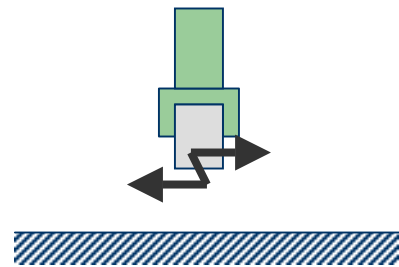- Intuitive robot programming by human demonstration
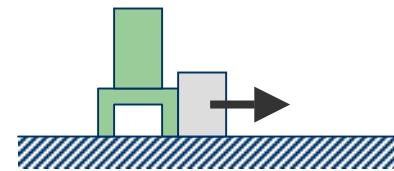
[Ikeuchi 94] [Kuniyoshi 94] …

- <u>Not ready for industrial application</u>
  - Complexity of implementation
  - Necessity of bothersome robot calibration
  - Expensive hardware (e.g. special sensors)

Objective

- Simple and easy robot programming
  - Easy implementation
  - Quick and easy calibration
  - For grasp/graspless manipulation by conventional industrial robots
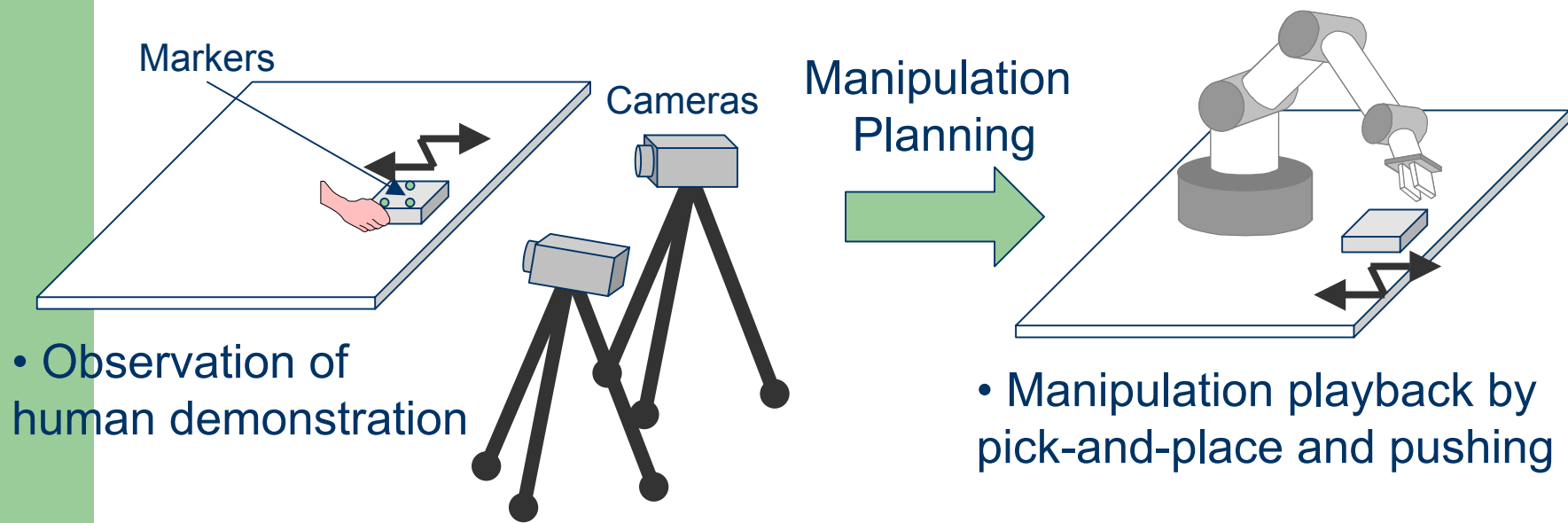
pick-and-place   pushing
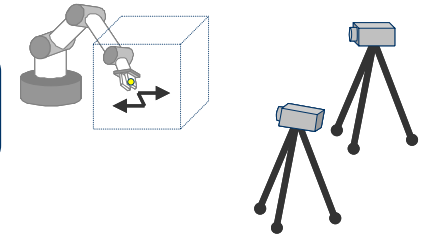
Outline of Our Robot Programming

Quick and easy method of robot programming

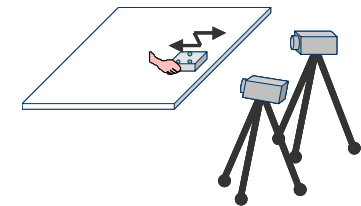➡ Integration of human demonstration and motion planning

Markers

Cameras

Manipulation Planning

• Observation of human demonstration

• Manipulation playback by pick-and-place and pushing

Procedure of Robot Programming

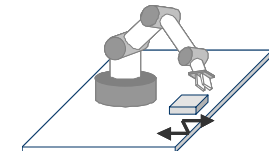Camera Calibration for Human Demonstration

⬇

Human Demonstration of Manipulation
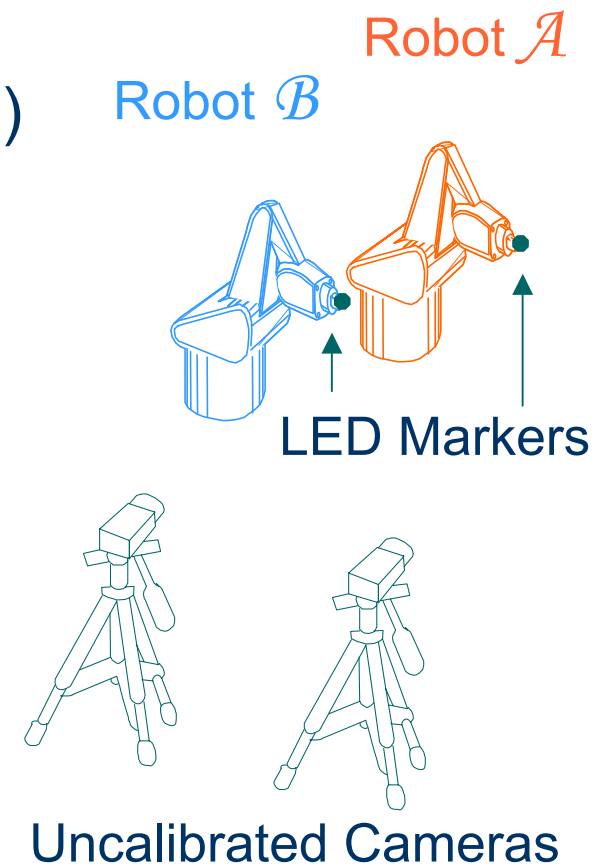
⬇

Motion Planning for Demonstrated Path

⬇
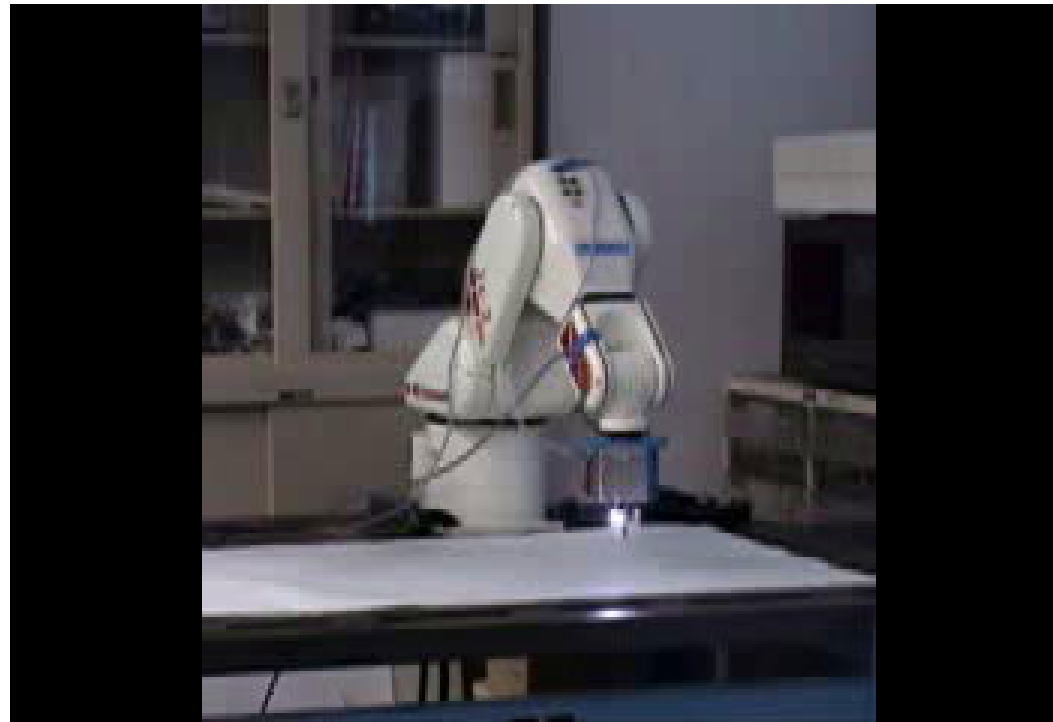
Manipulation Playback by Robot(s)
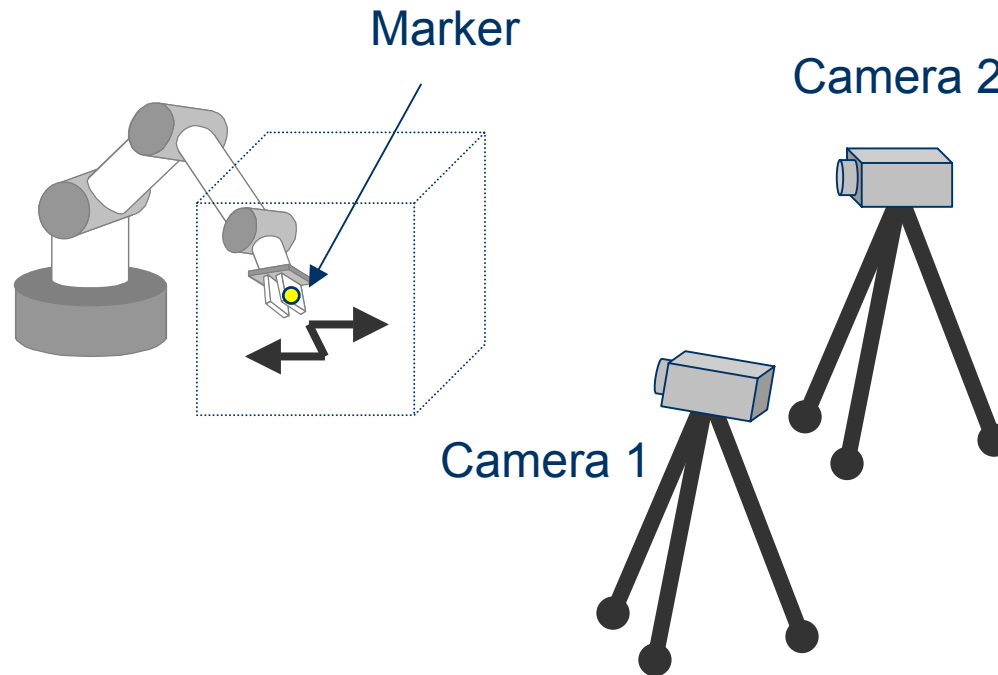
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Calibration for Human Demonstration

- Stereo vision based
  (DLT: Direct Linear Transformation)

- Mostly automated

- Minimum modification to robots
  (LED markers attached)

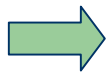- No need for calibrated cameras

- Freely placed cameras

Robot $\mathcal{A}$

Robot $\mathcal{B}$

LED Markers

Uncalibrated Cameras

Calibration Procedure
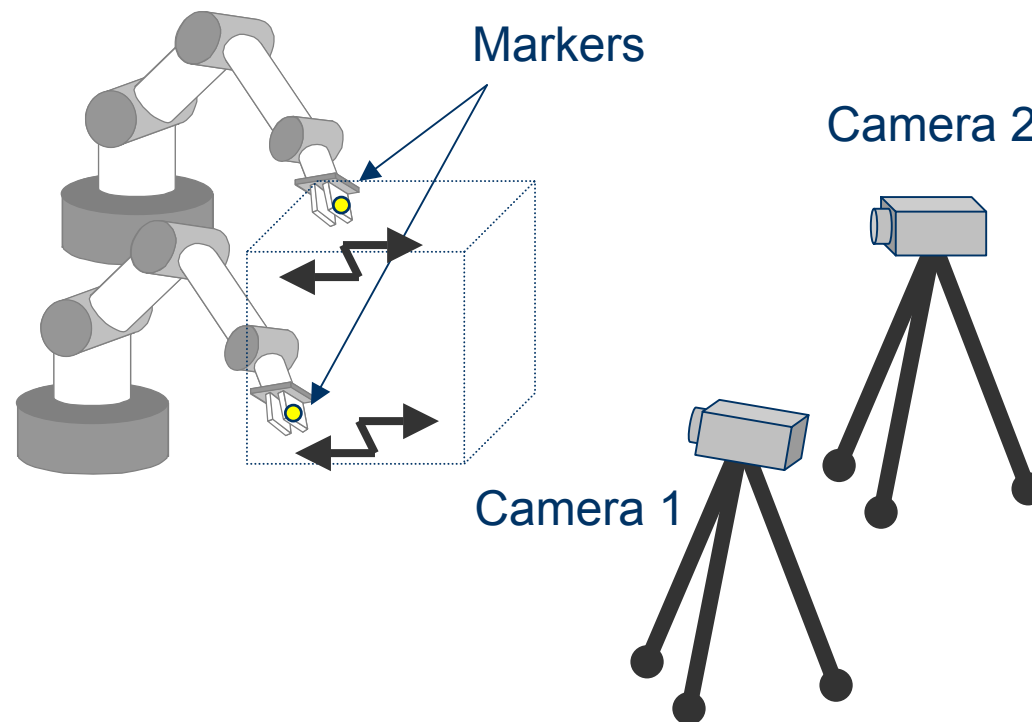
Calibration for Single Robot

Marker

Camera 2

Camera 1

Camera Calibration using <u>Robot Coordinates</u>

Absolute positional error of robots can be canceled!

Calibration for Multiple Robots

Markers
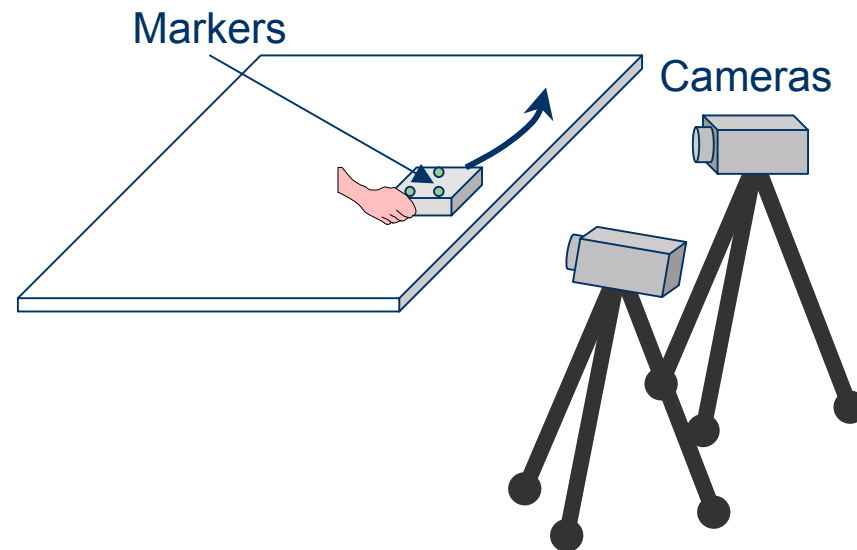
Camera 2

Camera 1

Mutual positional relationship
between the robots is also obtained [Arai 02]
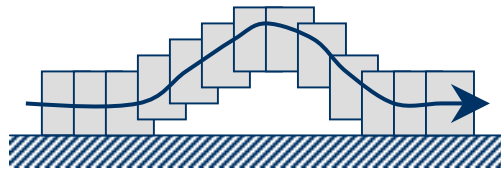
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Human Demonstration of Manipulation

- Object path is obtained by observing markers attached on the object

Markers

Cameras

- Positions of the markers on the object are known

- Markers are removed after human demonstration

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Path Segmentation for Manipulation Planning

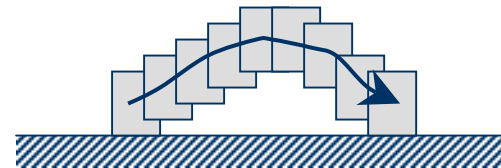Object path obtained in human demonstration

3D Hough Transformation
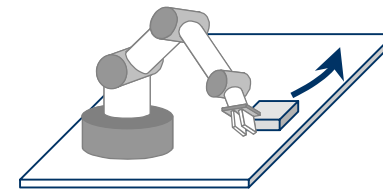
Segments on a plane
(Constrained motion)

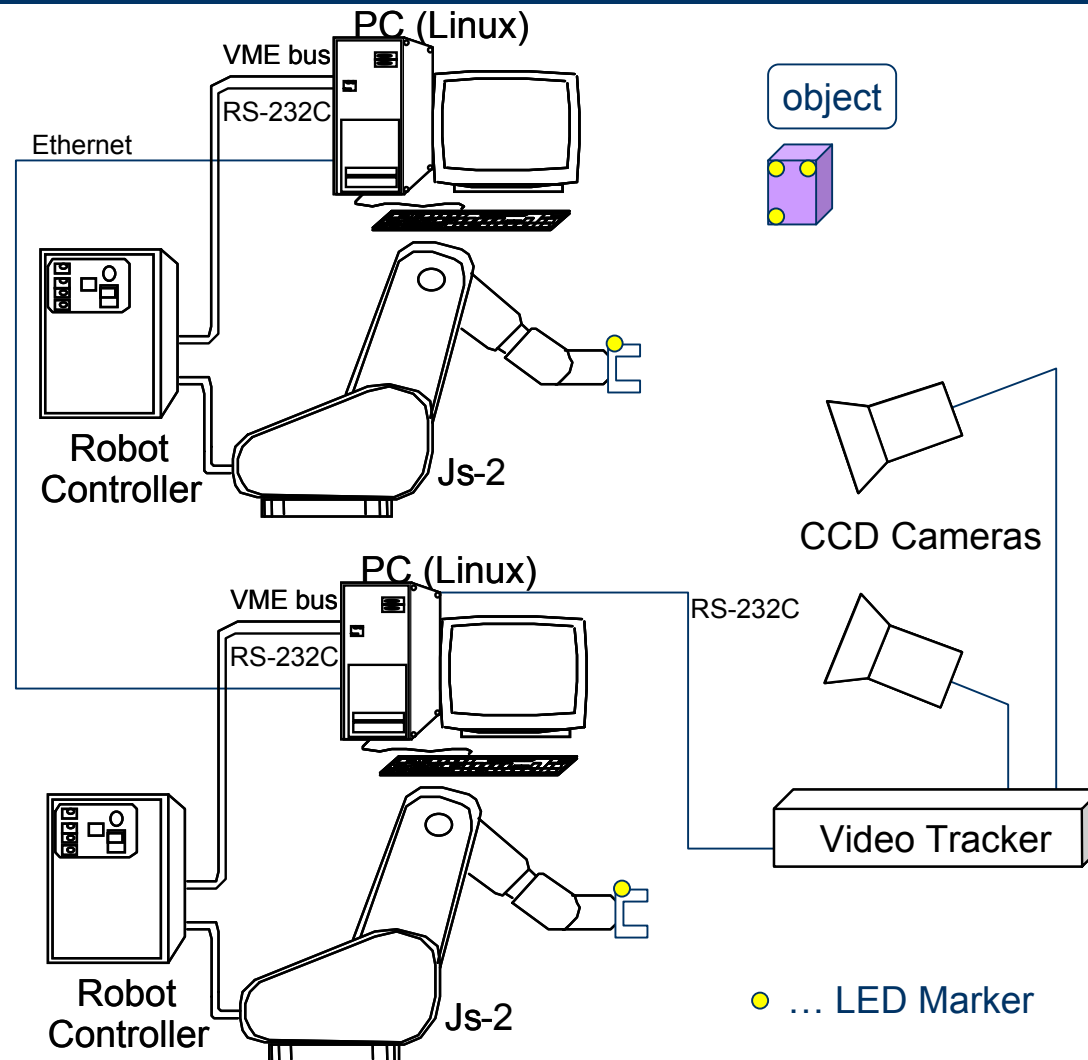Segments not on a plane
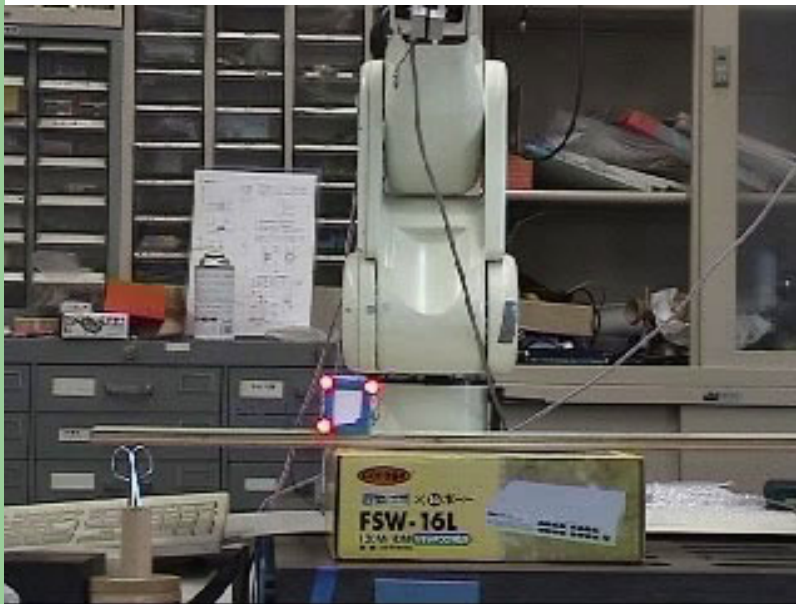(Unconstrained motion)

Manipulation Planning for Path Reproduction

- Pick-and-Place (for unconstrained motion)
- Pushing (for constrained motion)
- Operation Transition
  - Pick-and-Place ⇨ Pushing
  - Pushing ⇨ Pick-and-Place
- Regrasping (for collision avoidance)
  - Pick-and-Place ⇨ (Regrasping) ⇨ Pick-and-Place
  - Pushing ⇨ (Regrasping) ⇨ Pushing
- Operation Assignment to Multiple Robots

Experimental Setup

PC (Linux)

VME bus

RS-232C

Ethernet

object

Robot Controller

Js-2

CCD Cameras

PC (Linux)

VME bus

RS-232C

RS-232C

Robot Controller

Js-2

Video Tracker

○ … LED Marker

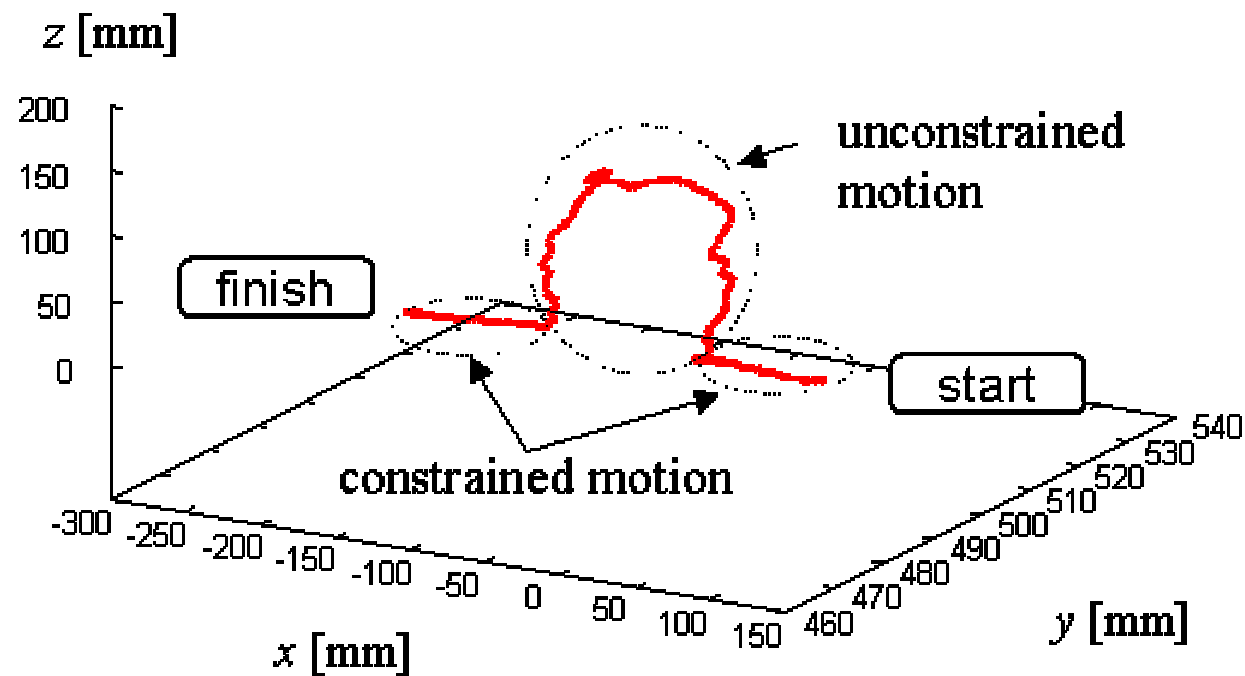# Experiment: Manipulation Playback by Pick-and-Place and Pushing
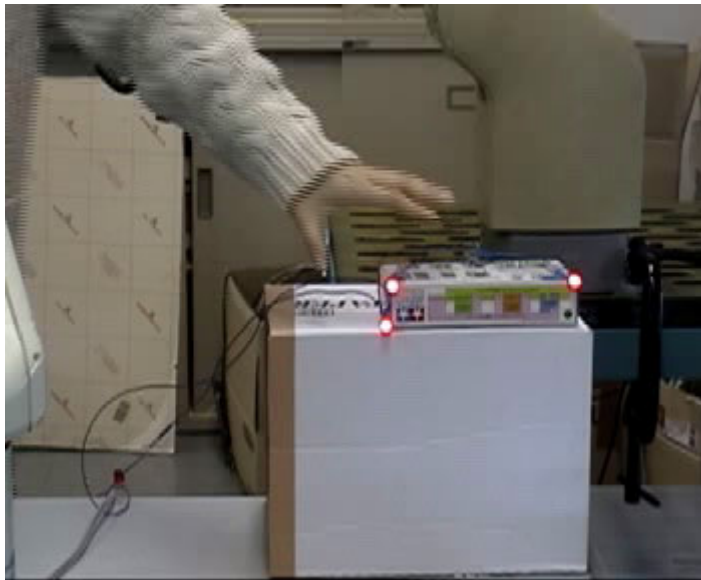

Human Demonstration

Playback

The Demonstrated Path

Experiment: Manipulation Playback by Two Robots

Human Demonstration

Playback

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Summary

- Instant robot programming by human demonstration
  - Using markers for human demonstration
    - For easy implementation
  - Automated camera calibration using robot coordinates
    - Absolute positional error of robots can be canceled
  - Manipulation planner for path reproduction
    - Pick-and-place and pushing

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Future Work

- Coping with occlusion
- More sophisticated manipulation planner
- Application to "Plug & Produce" in manufacturing systems