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

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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] …

- Not ready for industrial application
  - 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

• Observation of human demonstration
• Manipulation playback by pick-and-place and pushing
Procedure of Robot Programming

1. Camera Calibration for Human Demonstration
2. Human Demonstration of Manipulation
3. Motion Planning for Demonstrated Path
4. Manipulation Playback by Robot(s)
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
Calibration Procedure
Calibration for Single Robot

Camera Calibration using Robot Coordinates

Absolute positional error of robots can be canceled!
Calibration for Multiple Robots

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

- Object path is obtained by observing markers attached on the object
  - Positions of the markers on the object are known
  - Markers are removed after human demonstration
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 $\Rightarrow$ Pushing
  - Pushing $\Rightarrow$ Pick-and-Place
- Regrasping (for collision avoidance)
  - Pick-and-Place $\Rightarrow$ (Regrasping) $\Rightarrow$ Pick-and-Place
  - Pushing $\Rightarrow$ (Regrasping) $\Rightarrow$ Pushing
- Operation Assignment to Multiple Robots
Experimental Setup

- CCD Cameras
- Video Tracker
- RS-232C
- PC (Linux)
- VME bus
- Robot Controller
- Ethernet
- Robot
- Js-2
- CCD Cameras
- Video Tracker
- … LED Marker
Experiment: Manipulation Playback by Pick-and-Place and Pushing

Human Demonstration

Playback
The Demonstrated Path

[Diagram showing a 3D coordinate system with labeled start and finish points. The diagram illustrates unconstrained and constrained motion paths.]
Experiment: Manipulation Playback by Two Robots

Human Demonstration

Playback
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
Future Work

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