View-Based Teaching/Playback for Industrial Manipulators

Yusuke MAEDA and Yuki MORIYAMA
Yokohama National University
Background

- Conventional Teaching/Playback
  - still widely used
  - versatile
  - for constant task conditions
    - e.g.) initial pose of object does not change
When the initial object pose is not constant...

- Object localization with cameras
  - Model-based image processing
    - Feature extraction: edge, vertex, ...
    - Pattern matching
  - Object-specific: versatility is limited
Motivation

- To develop a **versatile** robot programming method that can cope with change of task conditions

“View-based teaching/playback”: robot programming with **view-based** image processing
Model-based vs. View-based

- Model-based approach
  - with object-specific models
  - accurate

- View-based (Appearance-based) approach
  - without object-specific models
  - versatile
Overview of view-based teaching/playback

1. Human (operator) commands a robot to perform a manipulation task
2. Obtain the mapping from image to motion
3. Playback: Robot motion generation according to the mapping

Diagram:
- Image
- Mapping
- Hand motion
- Camera
- Robot

Images and diagrams are used to illustrate the process.
Mapping from image to motion (1)

- Neural network

Raw pixel data?

Input Layer

Hidden Layer

Output Layer

Robot Motion

Movement(t)
Mapping from image to motion (2)

- PCA (Principal Component Analysis)

\[ \text{Movement}(t - \Delta t) \]

\[ \text{Factor scores of current image} \]

\[ \text{FS}(t) \]

\[ \text{Robot Motion Movement}(t) \]

\[ \text{Output Layer} \]

\[ \text{Hidden Layer} \]

\[ \text{Input Layer} \]
View-based teaching/playback

- View-based image processing using PCA
  - not object-specific
  - no need for camera calibration
- Adaptability to change of initial object pose using the generalization ability of neural networks
  - generalization from multiple demonstrations
Virtual manipulation environment for proof of concept [Maeda 2010 ICAM]

PC + Data glove + Dynamics Simulator
Application to actual robot system

- Pushing a block to a goal by an industrial robot

- Robot motion (output of NN): planar displacement of robot hand
  \[ (\Delta \hat{x}(t), \Delta \hat{y}(t)) \]
Experimental setup

Manipulator

CCD Camera (for evaluation)

Object

CCD Camera (for teaching/playback)

6DOF

640x480, grayscale, 30FPS

gamepad (for demonstration)
Experiment: human demonstrations

- From different initial positions to the same goal

Teaching: Demonstration 1

Teaching: Demonstration 2
Experiment: playback

- From different initial positions to the same goal
Adaptability to initial position fluctuations

Position errors of the object at the goal

- Demonstration
- Error < 1.5 mm
- Error < 3mm
- Error >= 3 mm
- Not terminated
Change of lighting conditions

Experimental Setup

Fluorescent Lamps

(original)

(darker)
Coping with change of lighting conditions

1. Gray-level normalization
2. Gray-level diversification
Gray-level normalization

Normalization of camera images by gamma correction

\[ I_{\text{norm}} = \left( \frac{I - I_{\text{min}}}{I_{\text{max}} - I_{\text{min}}} \right)^\gamma \]

- \( I_{\text{norm}} \): normalized gray level
- \( I \): original gray level
- \( I_{\text{max}} \): maximum gray level
- \( I_{\text{min}} \): minimum gray level

\( \gamma \) is determined so that \( I_{\text{norm}} = 0.5 \) when \( I \) is the median

\( I_{\text{norm}} \) before normalization (original) vs. \( I_{\text{norm}} \) after normalization (darker)
Gray-level diversification

- Fabrication of artificial teaching images with different gray levels

\[ I_{\text{div}} = I^\gamma \]

- \( I_{\text{div}} \): diversified gray level
- \( I \): original gray level

\[ \gamma = 0.8, 0.9, (1.0), 1.1, 1.2 \]

- Neural network is trained with all of these images
Coping with change of lighting conditions: result

- Demonstration
- Playback (w/o any measures)
- Playback (w/ gray-level normalization)
- Playback (w/ gray-level diversification)

Initial position

In darker condition

W/ normalization

W/ diversification

W/o any measures
Conclusion

- View-based teaching/playback was proposed and implemented on an industrial manipulator
- It worked well for pushing tasks
  - Initial position fluctuations were allowed
  - Change of lighting conditions was allowed
Future Work

- Application to various robotic tasks that require higher DOF
- Integration of various sensors
  - Two or more cameras, range sensors, etc.
- Reinforcement learning to reduce human demonstrations
  [Maeda 2011 ISAM (to appear)]