View-Based Teaching/Playback for Industrial Manipulators

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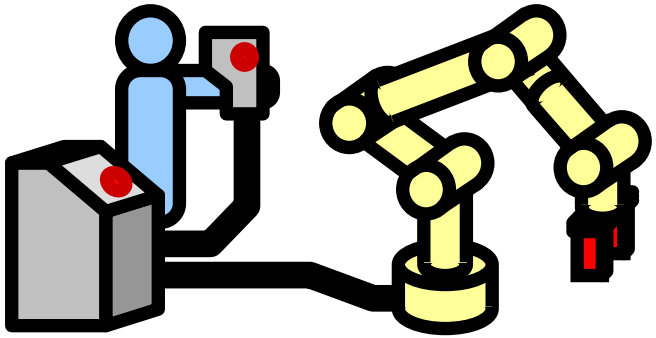
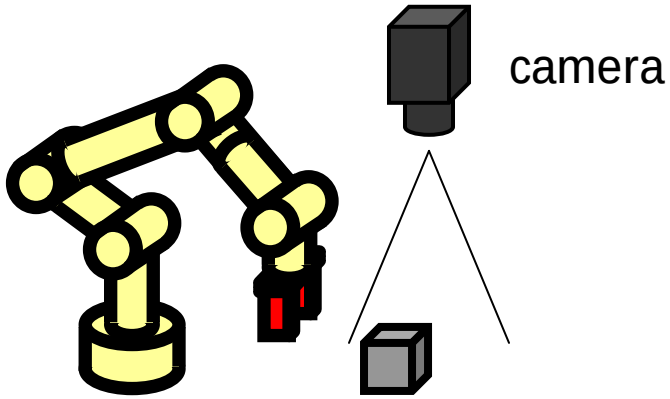
Background

- 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

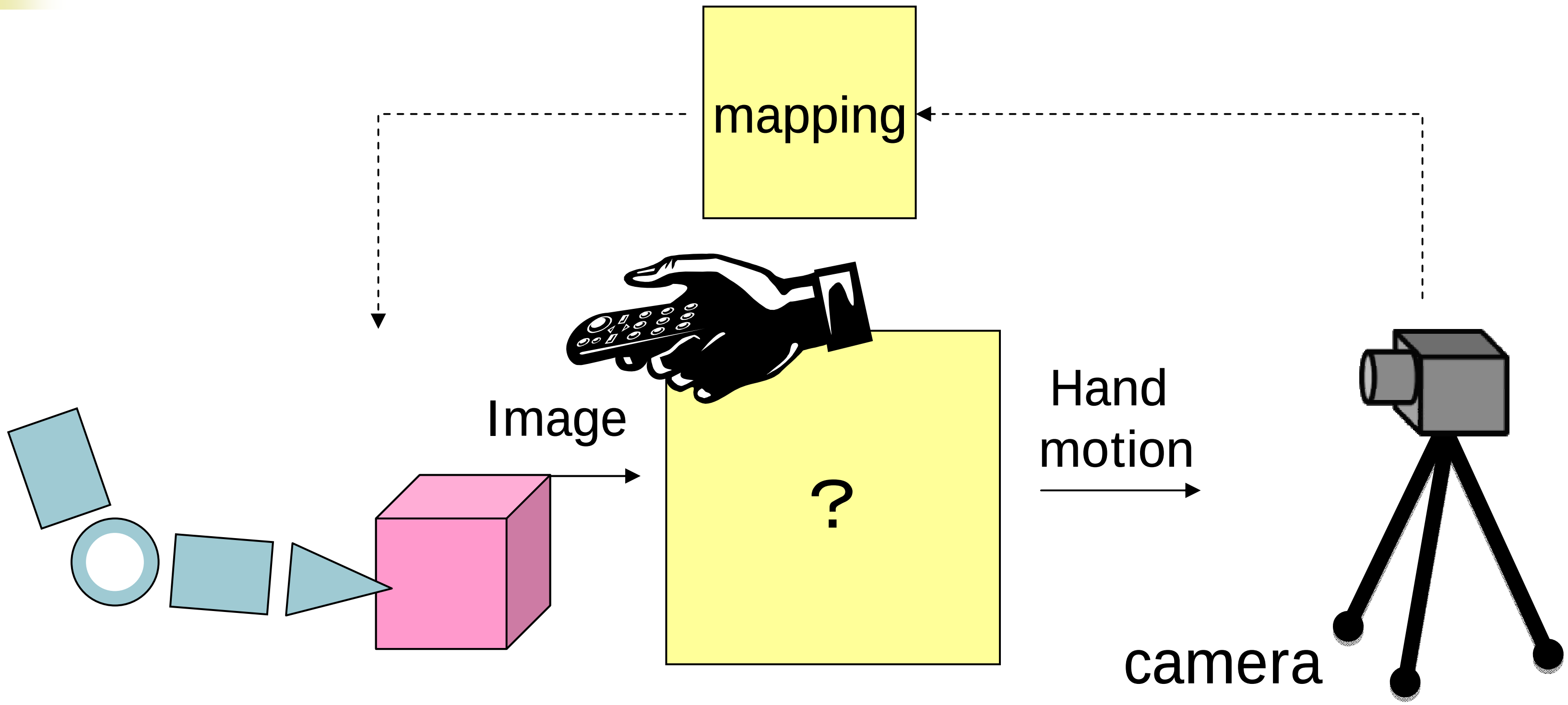
- To develop a **versatile** robot programming method that can cope with change of task conditions

"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

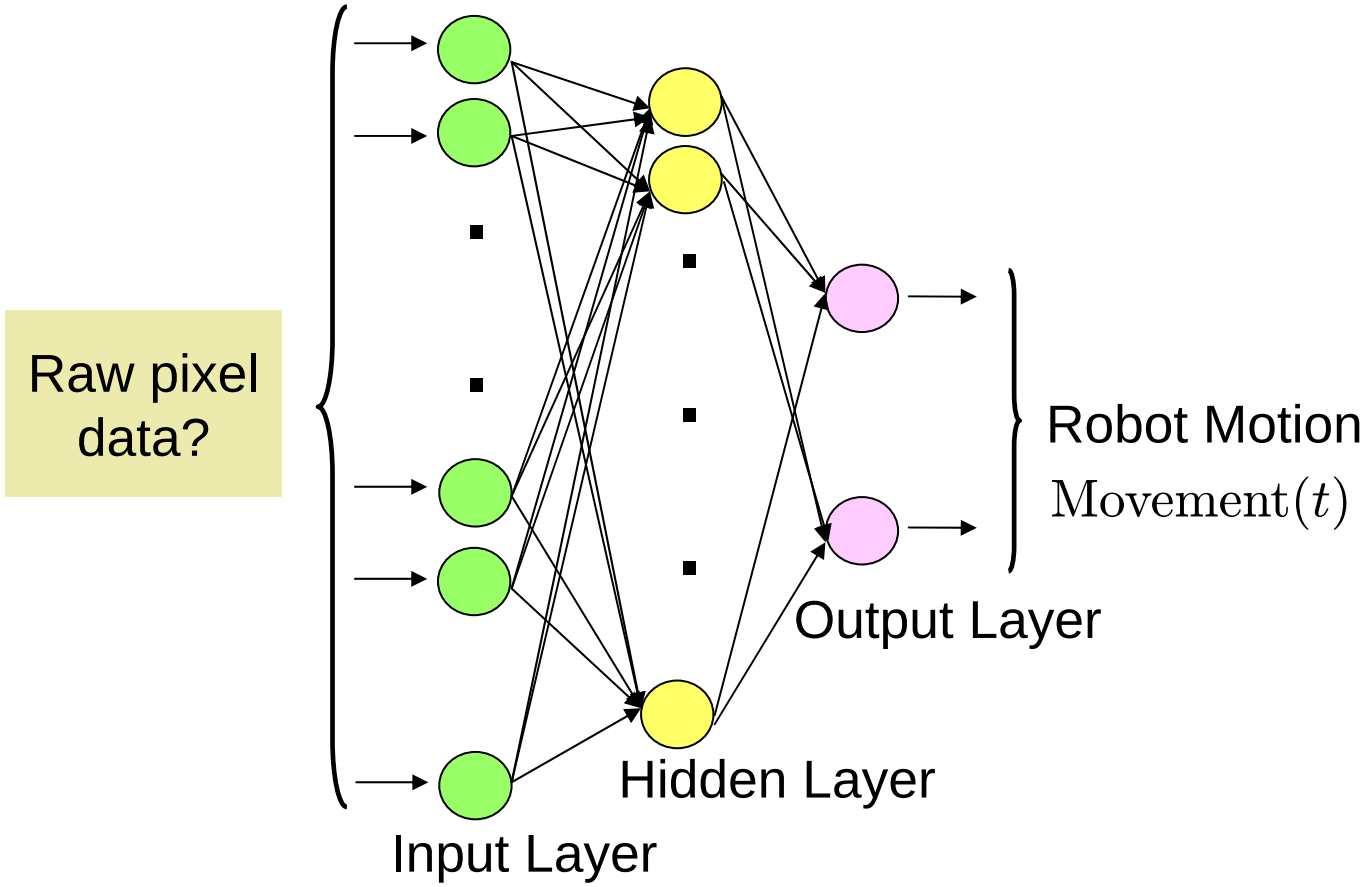
Overview of view-based teaching/playback



1. Human demonstrates a robot to perform a manipulation task
2. Obtain the mapping from image to motion
3. Playback: Robot generates motion according to the mapping

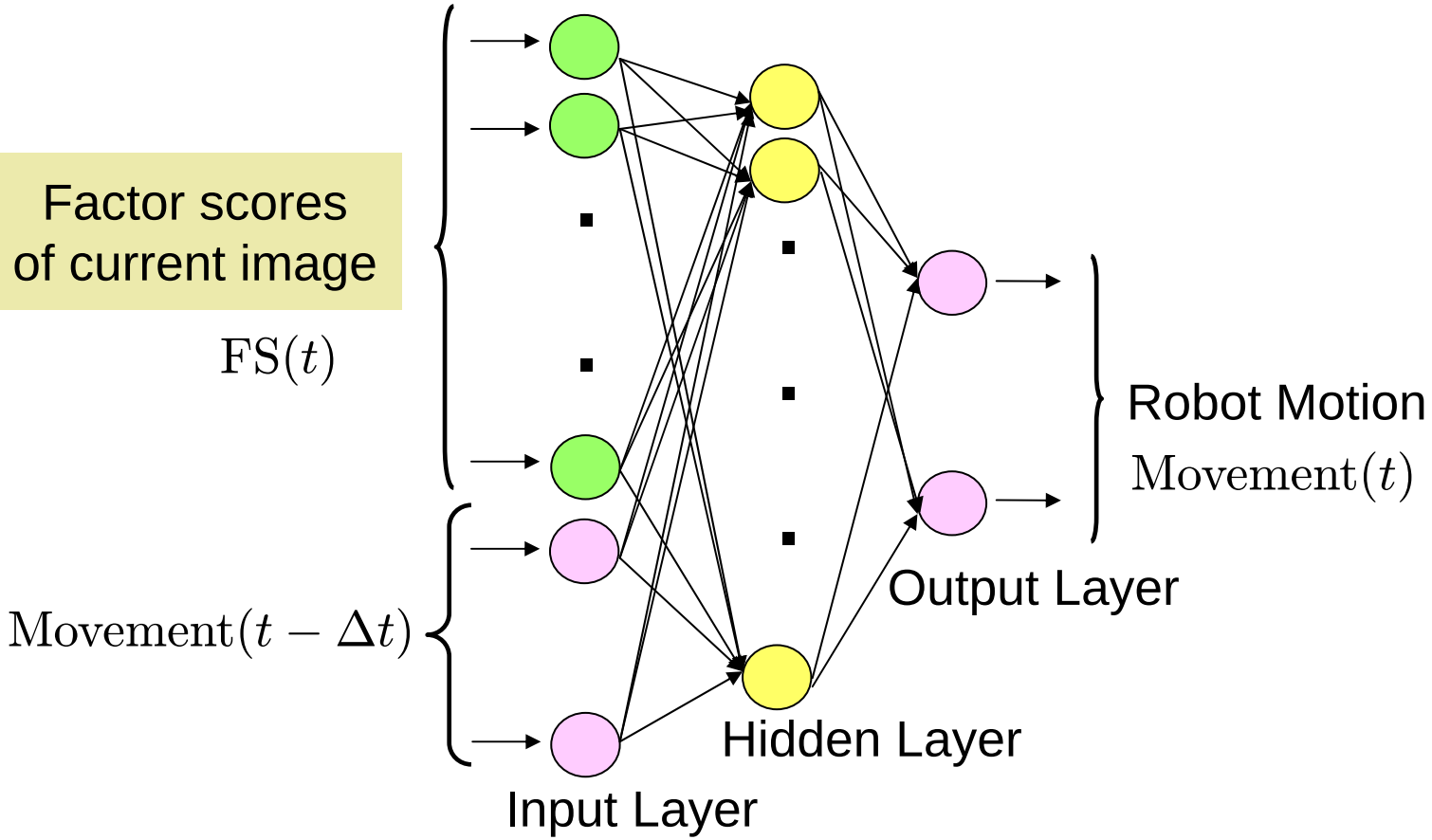
Mapping from image to motion (1)

- Neural network



Mapping from image to motion (2)

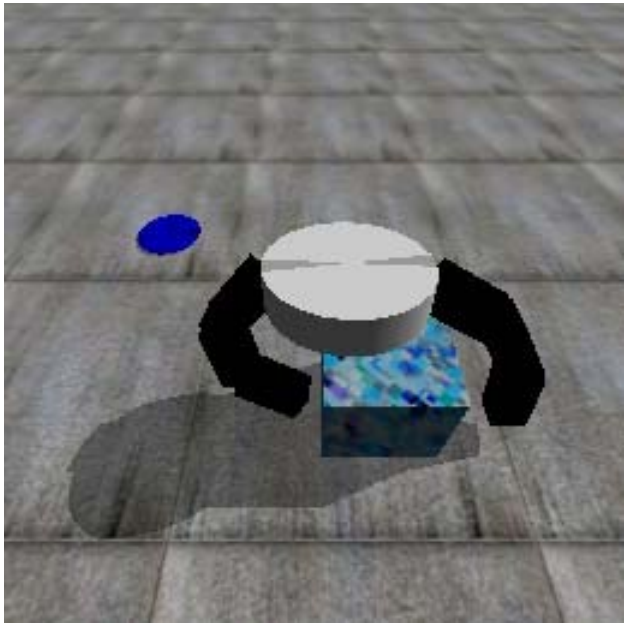
- PCA (Principal Component Analysis)



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

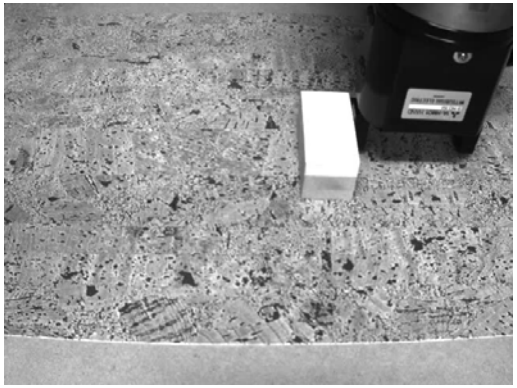
Virtual manipulation environment for proof of concept [Maeda 2010 ICAM]



PC + Data glove + Dynamics Simulator

Application to actual robot system

- Pushing a block to a goal by an industrial robot

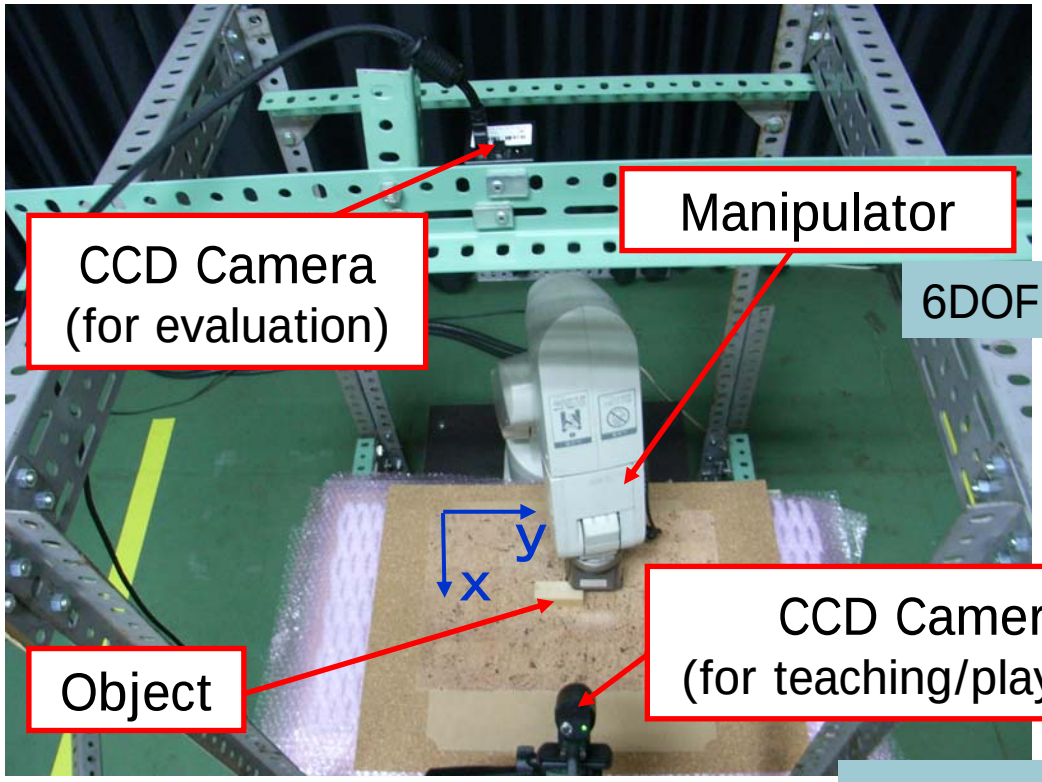


- Robot motion (output of NN): planar displacement of robot hand

$$\left(\Delta\hat{x}(t), \Delta\hat{y}(t)\right)$$

Experimental setup

gamepad
(for demonstration)



640x480, grayscale, 30FPS

Experiment: human demonstrations

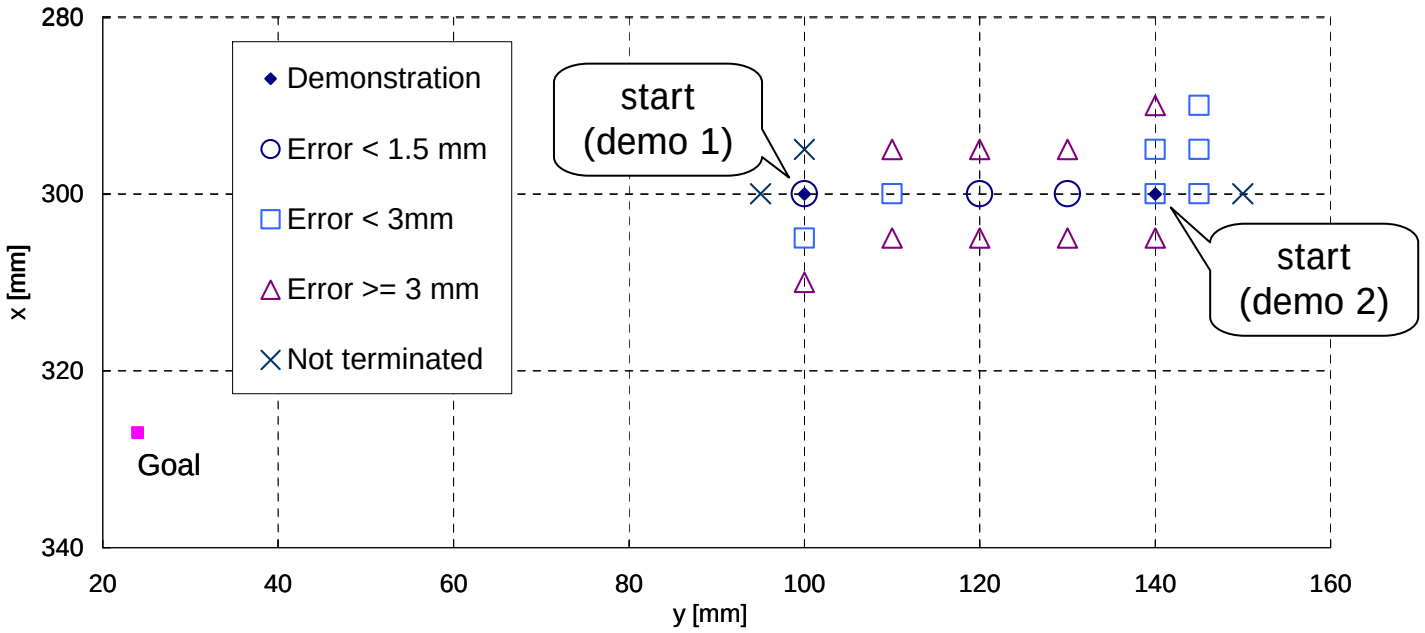
- From different initial positions to the same goal

Experiment: playback

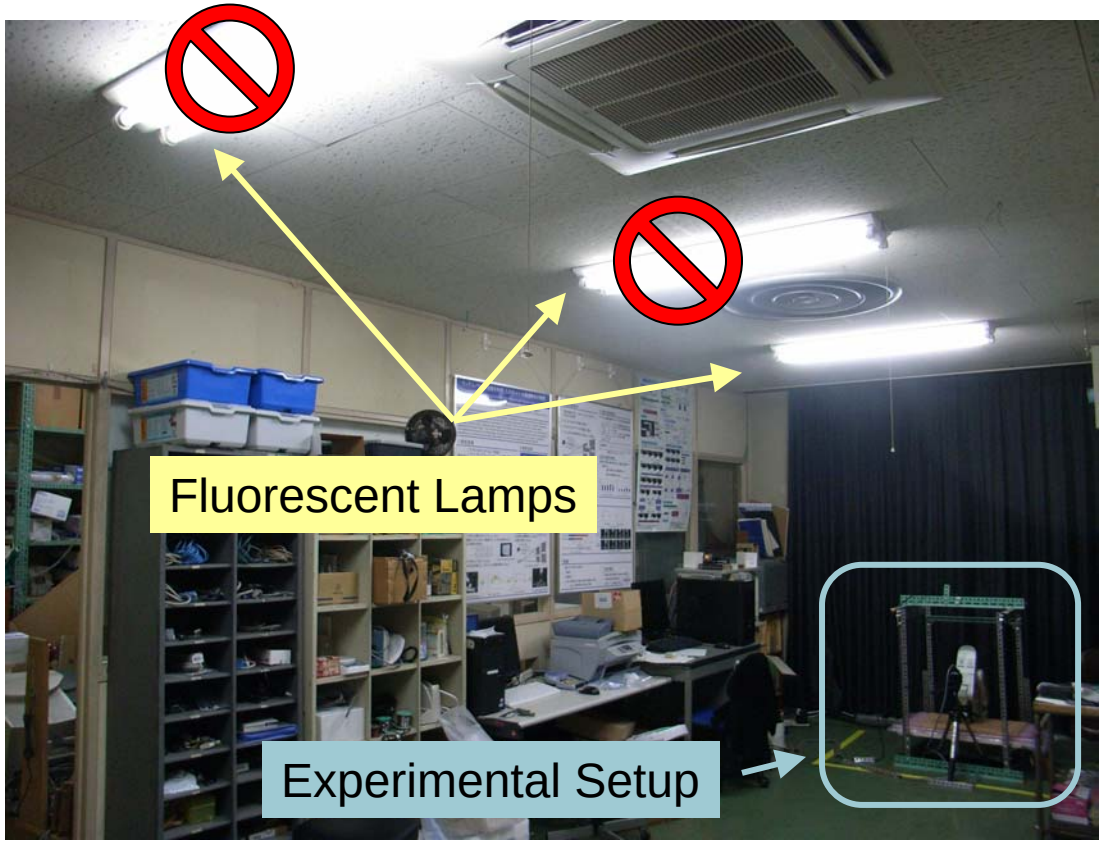
- From different initial positions to the same goal

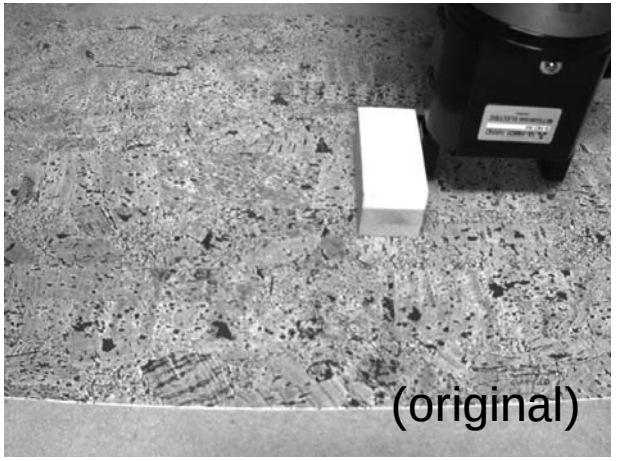
Adaptability to initial position fluctuations

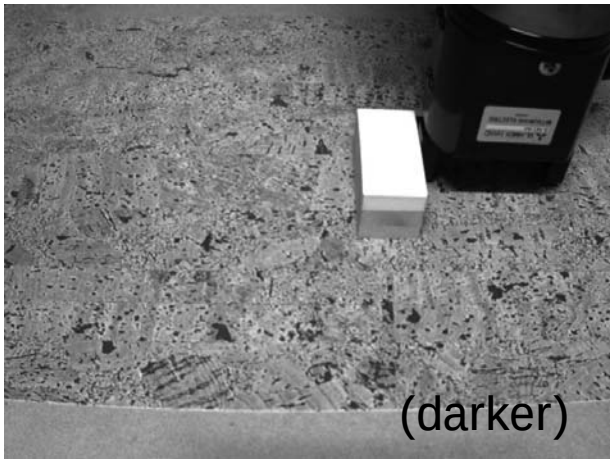
- Position errors of the object at the goal



Change of lighting conditions







Coping with change of lighting conditions

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

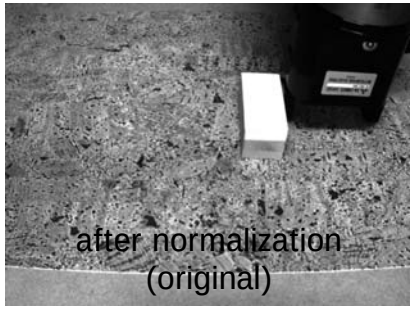
Gray-level normalization

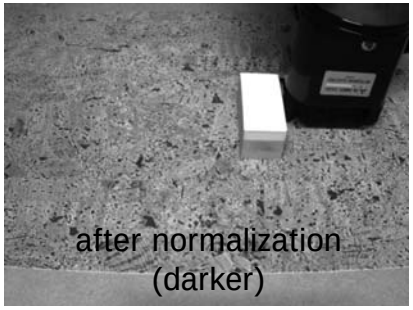
- Normalization of camera images by gamma correction

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

I_{norm} : normalized gray level
I : original gray level
$I_{\max}$: maximum gray level
$I_{\min}$: minimum gray level

γ is determined so that $I_{\text{norm}} = 0.5$ when I is the median





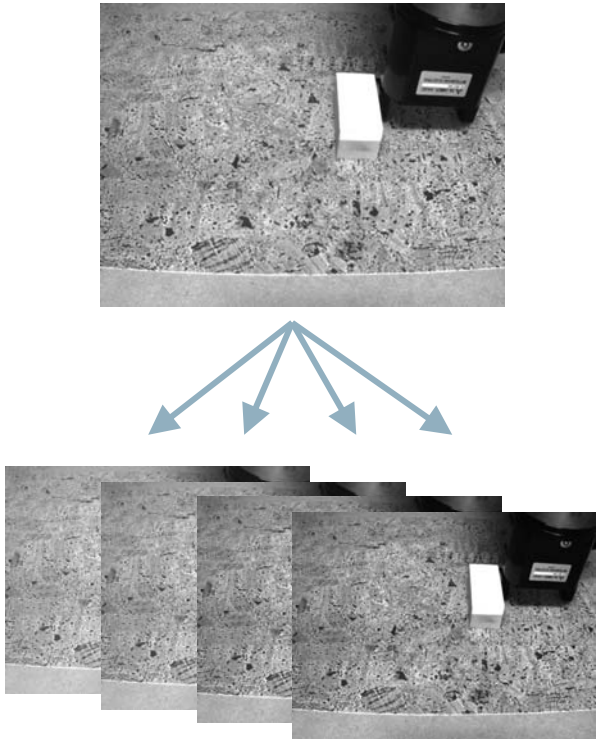
Gray-level diversification

- Fabrication of artificial teaching images with different gray levels

$$I_{\mathrm{div}} = I^{\gamma}$$

I_{div} : diversified gray level
I : original gray level

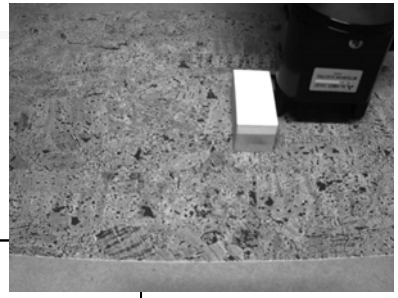
$$\gamma = 0.8, 0.9, (1.0), 1.1, 1.2$$

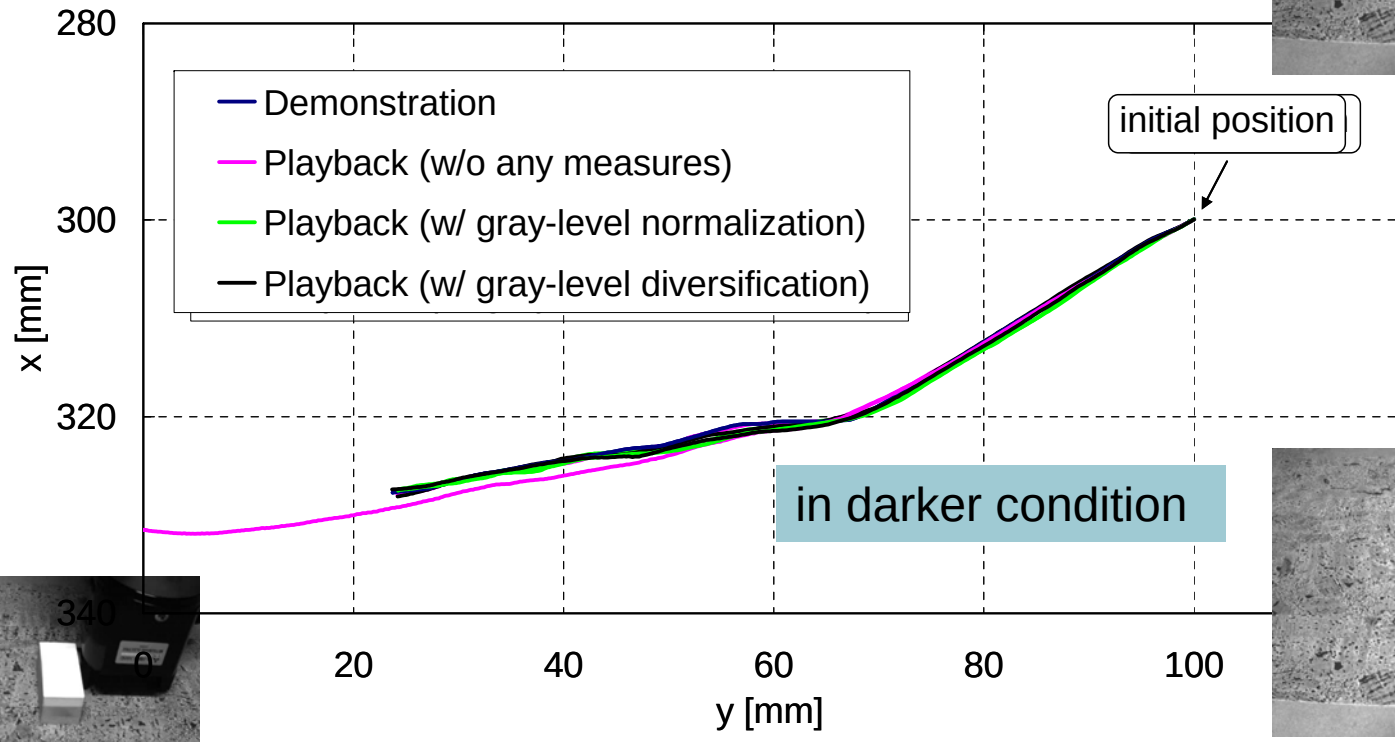


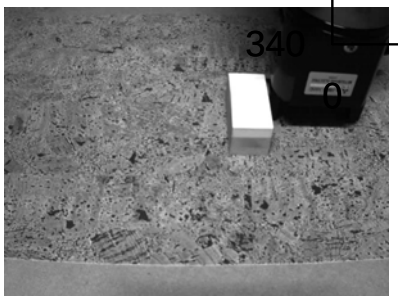
- Neural network is trained with all of these images

Coping with change of lighting conditions: result

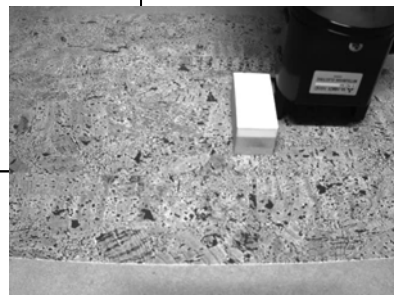
w/ normalization







w/o any measures



w/ diversification

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)]