



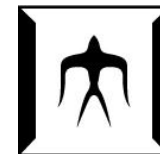
# Online Knowledge Acquisition and General Problem Solving in a Real World by Humanoid Robots

---

Naoya Makibuchi<sup>1</sup>, Furao Shen<sup>2</sup>, Osamu Hasegawa<sup>1</sup>

<sup>1</sup> Tokyo Institute of Technology, Japan

<sup>2</sup> Nanjing University, China





# Agenda

---

- Objective
- Proposed Method
- Experimental Results
- Conclusion & Future Works





# Existing Studies

---

Studies about intelligent humanoid robots have been extensively conducted.

- Motion Control
  - Autonomous bipedal robot (e.g., ASIMO)
  - Object-handling learning, etc.
- Intelligent Information Processing ?

Few studies have reported that robots are, “Able to autonomously execute nonprogrammed operations for general-purpose tasks”.



# Autonomous Mental Development (AMD)

---

A developmental system:

Requirements for AMD [Weng et al., Science 2001]

1. The system is not task dependent (or specific).
2. The tasks are unknown to the system designers.
3. The system can generate approaches for unknown tasks.
4. The system has an online learning ability.
5. The system has an open-ended learning ability.

**In 2010, studies that possess perfectly all the properties for AMD have not been reported.**



# Objective

---

The purpose of this study is

**to build a general problem-solving system  
in a real world that meets all the properties**

## Features

- Forming concepts of objects by using various sensory information
- Acquiring operators through interactions with the environment
- **Solving general-purpose problems by managing the acquired operators**



# Agenda

---

- Objective
- **Proposed Method**
- Experimental Results
- Conclusion & Future Works



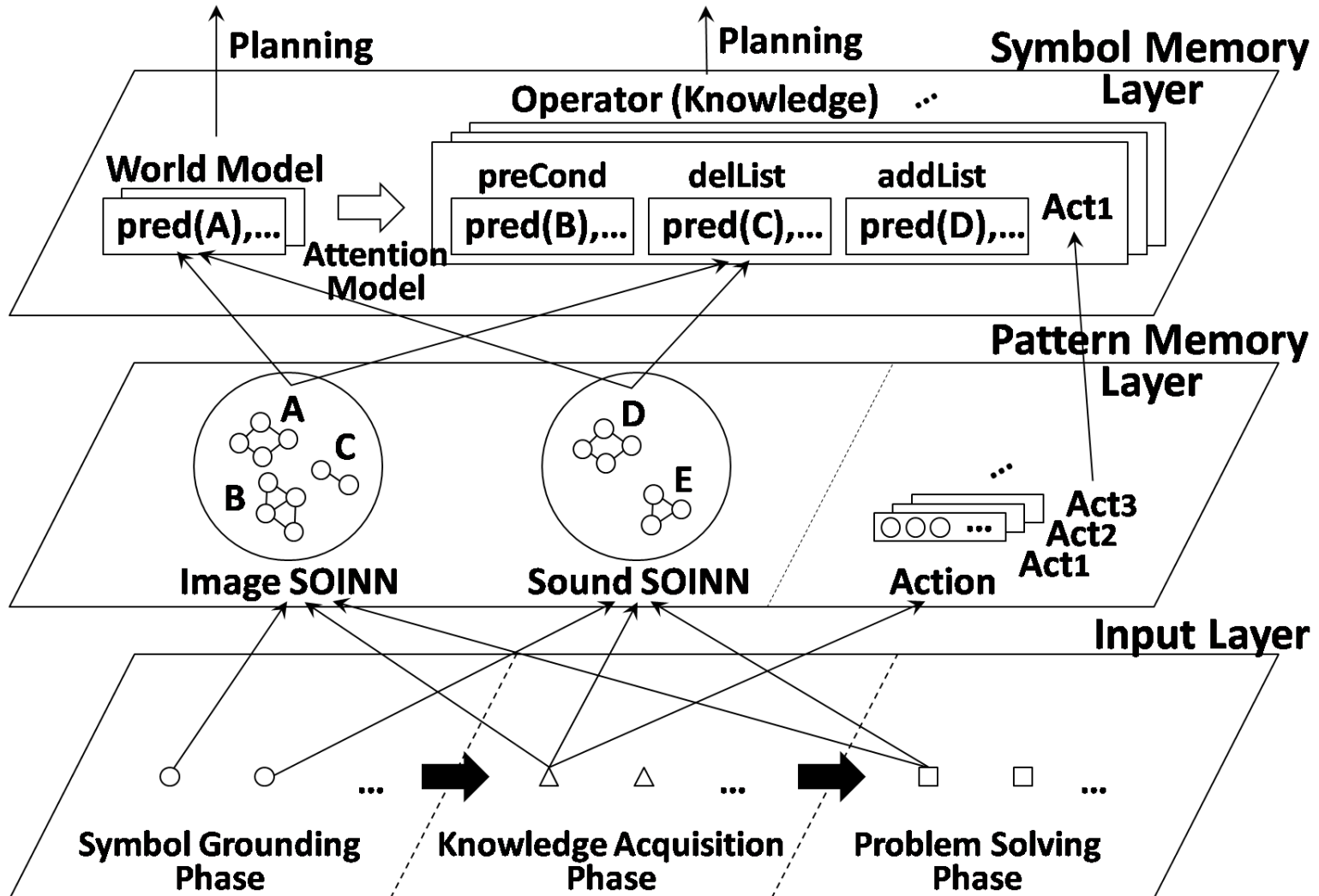


# Outline

---

- Self Organizing Incremental Neural Network (SOINN)  
*[Shen et al., NN 2005]*
  - Unsupervised, online learning mechanism
  - Incremental learning, Unnecessity to predefine its network structure, High robustness to noise
  - Proposed method use this mechanism to symbolize sensed data.
- Proposed Method
  - Three-layer architecture using an existing planner (General Problem Solver *[Ernst et al., 1969]*)
  - Multimodal information processing

# Proposed Architecture





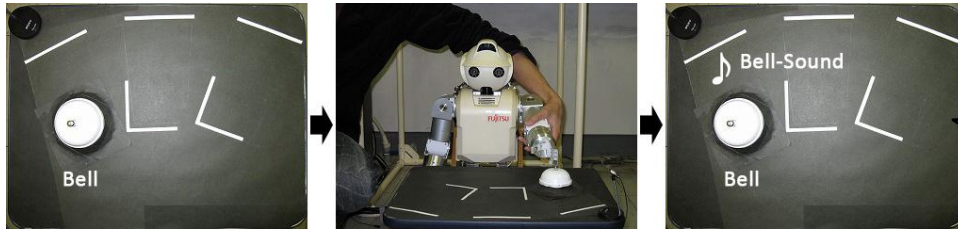
# Agenda

---

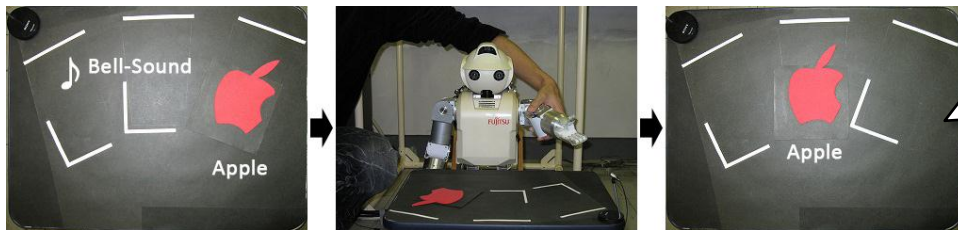
- Objective
- Proposed Method
- **Experimental Results**
- Conclusion & Future Works



# Experiment: Knowledge Acquisition Phase



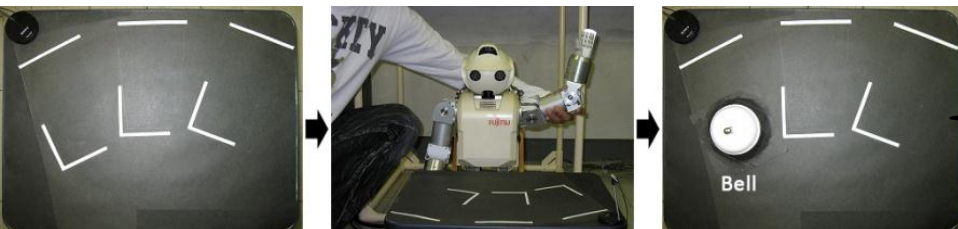
op1 : If the robot presses the bell, it will ring.



op3 : If the robot makes a "give me" gesture while the bell is ringing, the apple will move in front of it.

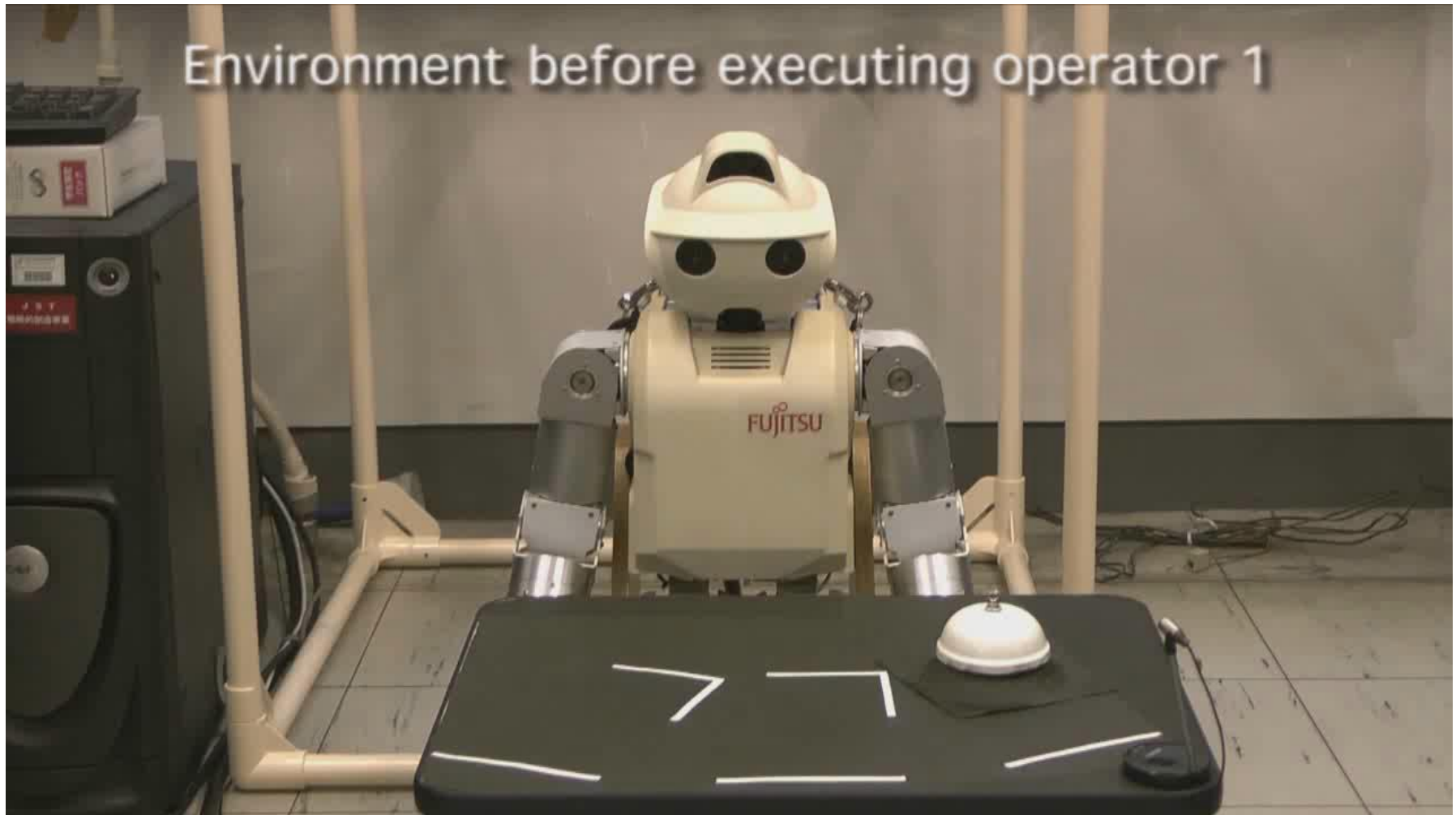


op5



op9

# Video: Operator Acquisition

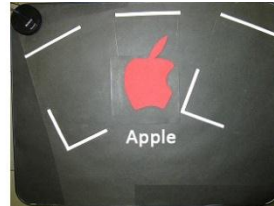


# Experiment: Problem Solving Phase

## Task



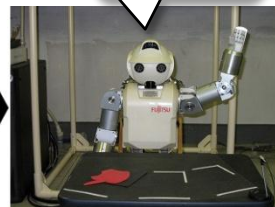
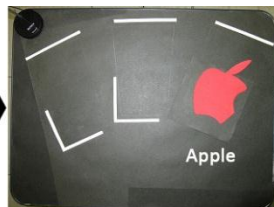
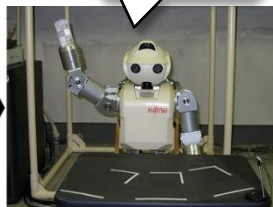
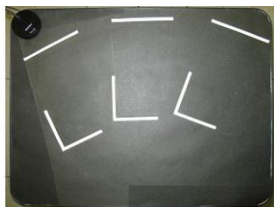
initial state



goal state

The robot has not directly experienced this task previously.

op5



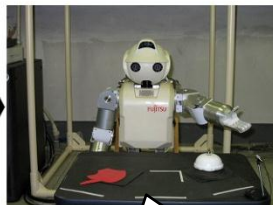
op9



op1

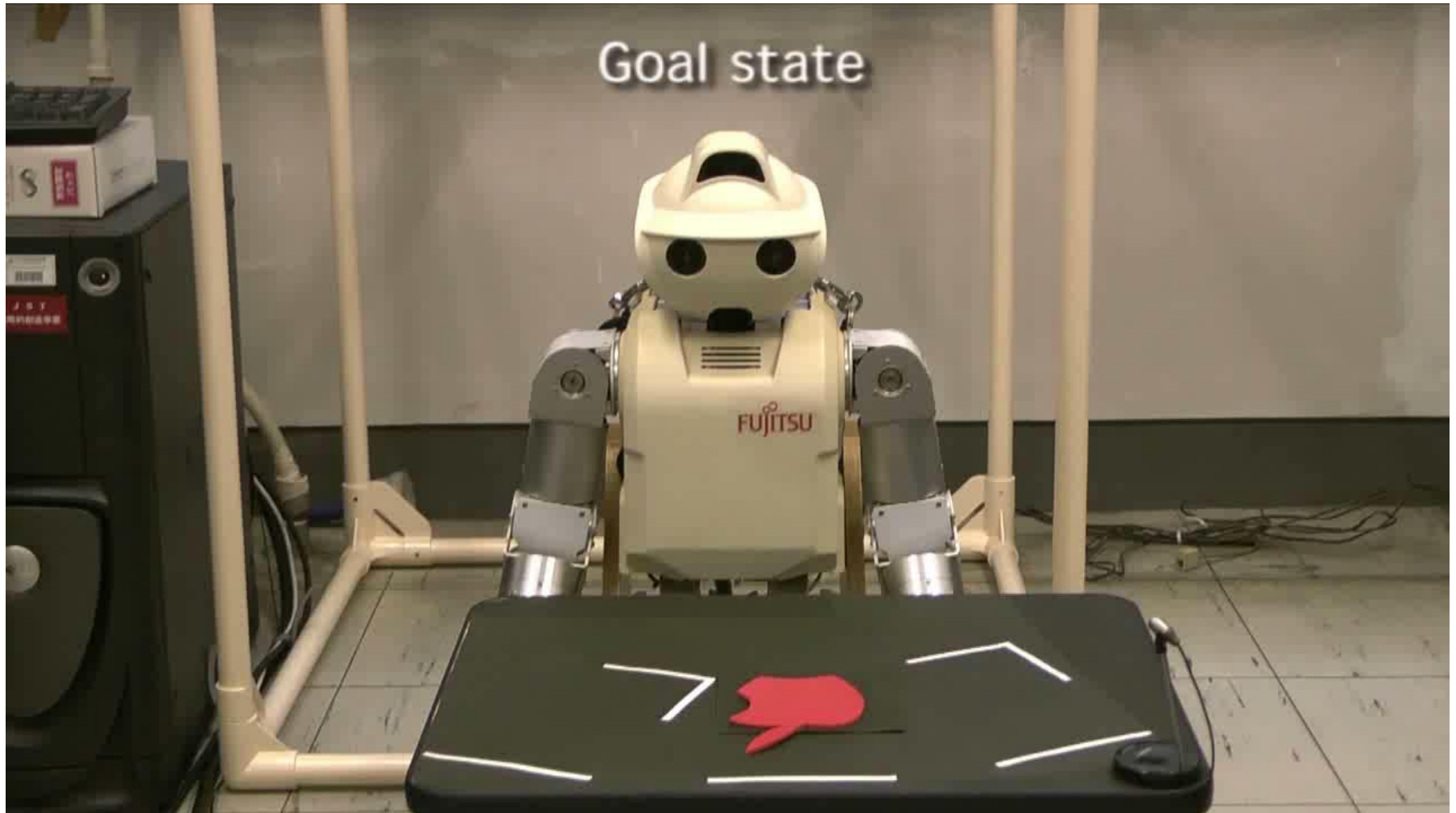


op3



Successful!

# Video: Task Execution





# Agenda

---

- Objective
- Proposed Method
- Experimental Results
- **Conclusion & Future Works**





# Conclusion & Future Works

---

## Three-layer architecture using an existing planner

- Possesses all the properties required for AMD
- Demonstrated through experiments using a humanoid robot that the method is effective for solving general-purpose problems in the real world.

## Future Works

- Automatic actions by getting accustomed to tasks
- Task instructions using languages