Easy Robot Programming for Industrial Manipulators by Manual Volume Sweeping

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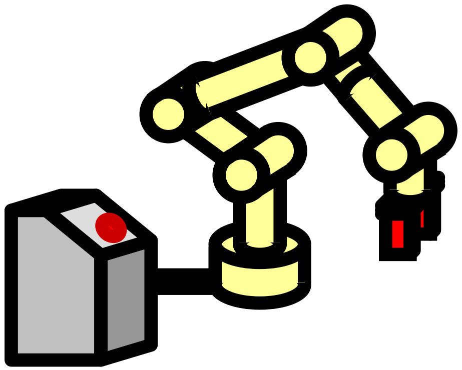
Intelligent & Industrial Robotics

Motivation

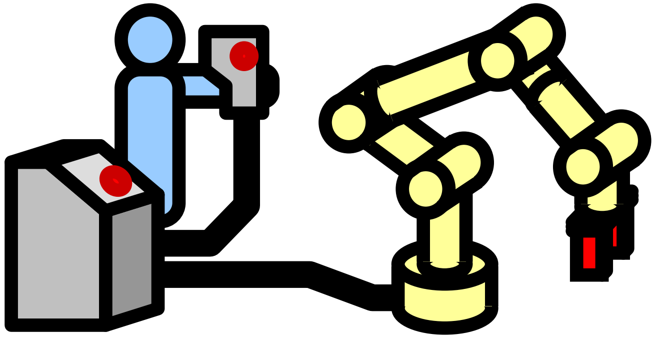
- Industrial manipulators are becoming cheaper
- Cost of robot programming: a barrier to robot dissemination among small-sized companies



Easy robot programming methods are highly demanded

Teaching Playback

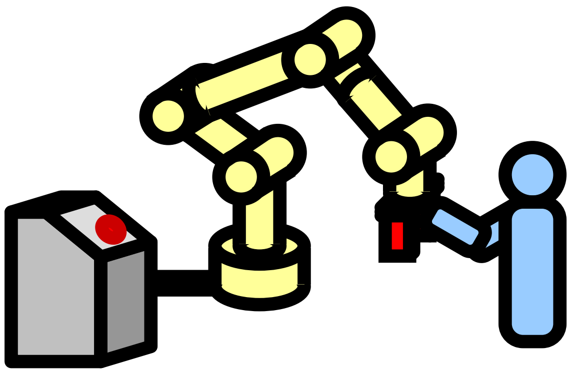
- Conventional teaching playback with teach pendant



  - Complicated and time-consuming for novice operators
  - Human operators must teach everything
    - Understanding robot kinematics and specifications is required for shorter cycle time

Previous Approach (1)

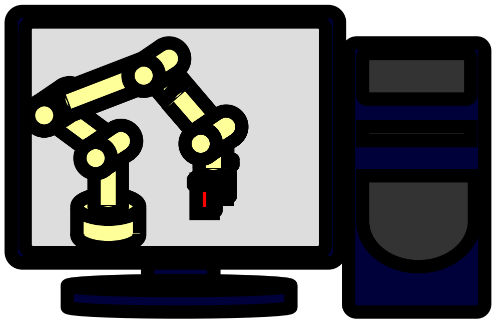
- Lead-through teaching (Direct teaching)
  - Operators move robots manually by grasping their end-effectors for teaching playback
  - Intuitive for novices



- Operators must teach “good” robot motions by themselves yet

Previous Approach (2)

- Offline programming with motion planning algorithms
  - Well-optimized robot motions can be obtained automatically



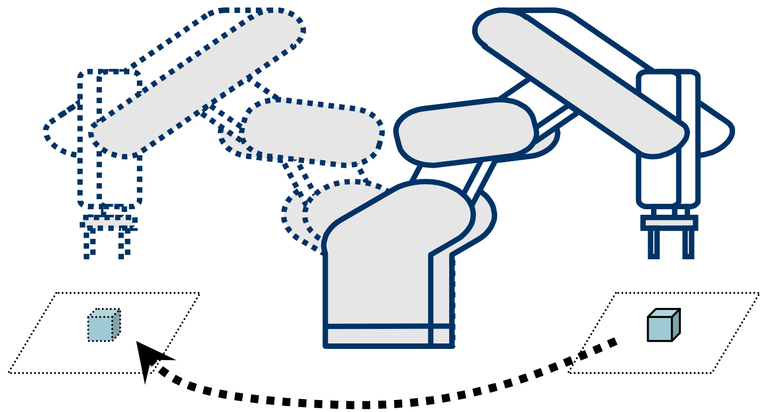
- Planned motions must be modified due to errors in robot motions and alignment
- Environmental information such as obstacles must be modeled and inputted to system

Demands on Robot Programming

- Easy for novice operators
- Executable in a short time
- Robot motion with short cycle time can be obtained

Objective

- To propose a robot programming method that enables novice operators to generate robot motions with short cycle time
  - We focus on robot programming for part handling

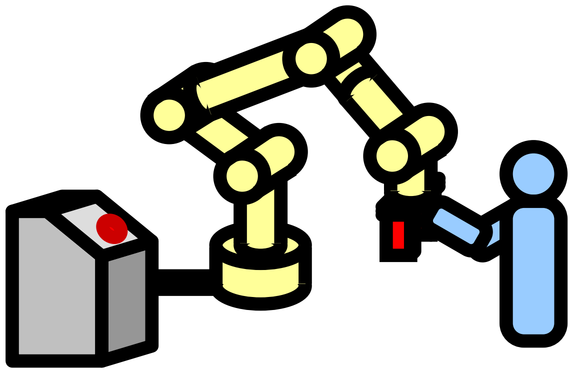


Outline

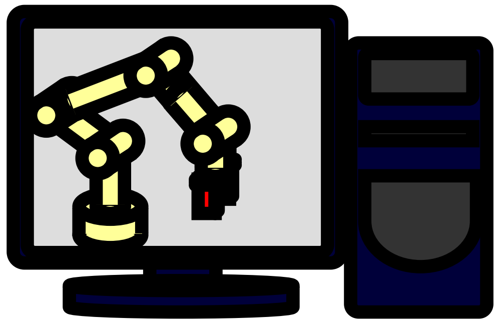
- Introduction
- Overview of Proposed Robot Programming
- Robot Programming Details
- Teaching Experiments
- Conclusion

Our Approach

- How to combine the advantages of both direct teaching and motion planning?



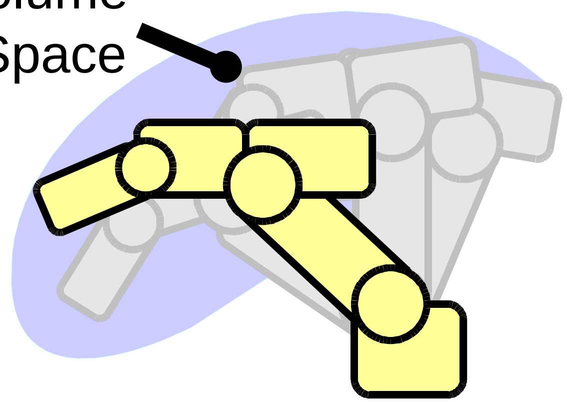
intuitive operation for novices



automatic generation of
well-optimized motion

Swept Volumes by Robot Bodies

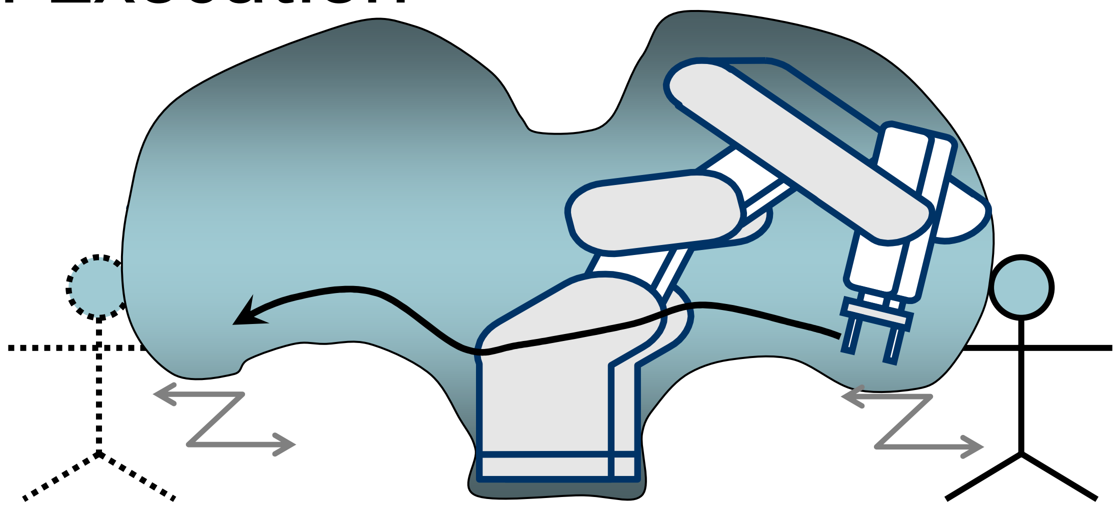
- Swept volume by robot bodies in Cartesian space stands for (a part of) free space [Hasegawa 04]
  - because the bodies have passed through the volume without collisions



Application of this idea to ordinary robot programming

Procedure of Our Proposed Robot Programming

1. Manual Volume Sweeping
2. Swept Volume Computation
3. Motion Planning
4. Motion Execution



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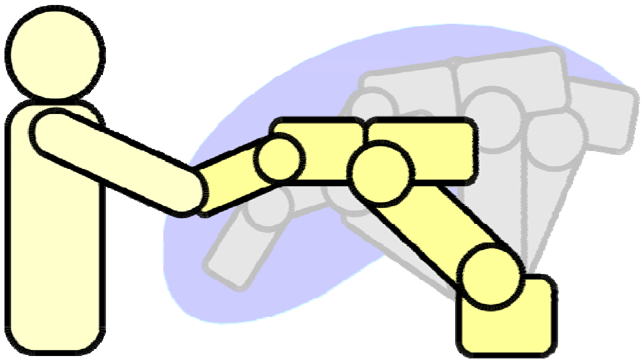
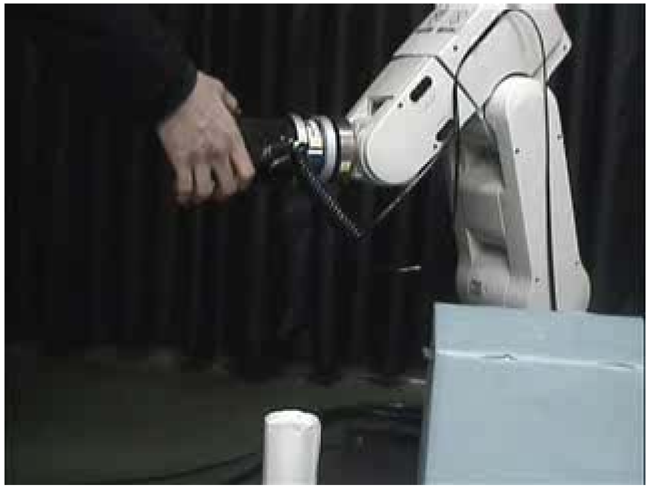
Manual Volume Sweeping

- Operator moves robot around so that its bodies sweep a volume without colliding obstacles
  - Robot is damping-controlled
  - All joint data are recorded



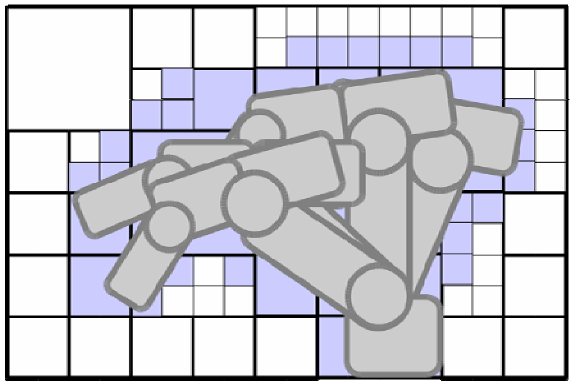


Teaching Initial/Goal Configurations

- Initial and goal configurations are taught additionally during manual volume sweeping

Swept Volume Computation

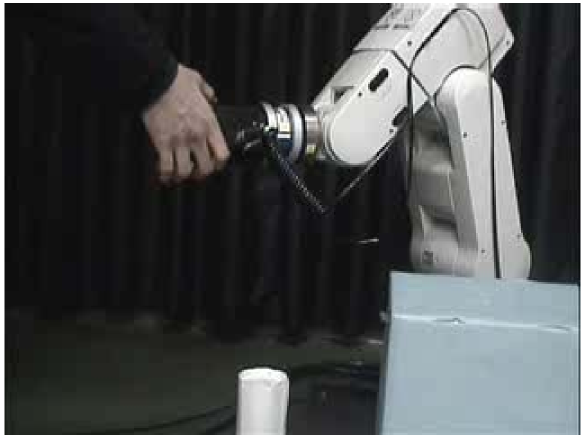
- Swept volume as a free space of robot is calculated from recorded joint data
  - Octree representation used

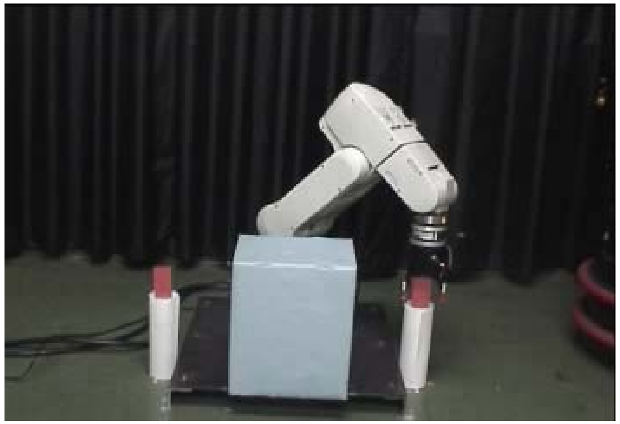


Motion Planning

- A well-optimized path from initial to goal configuration within swept volume is generated
  - MPK (by Stanford Univ.) is used in our implementation

Total Procedure





Features of Our Proposed Method

- Manual volume sweeping
  - Environmental information is available by easy operation
  - Note: Swept volume in Cartesian space contains robot configurations through which the robot has *not* passed in volume sweeping
- Online teaching of initial/goal configurations
  - High accuracy around these crucial points
- Motion planning
  - Automatic generation of well-optimized robot motions

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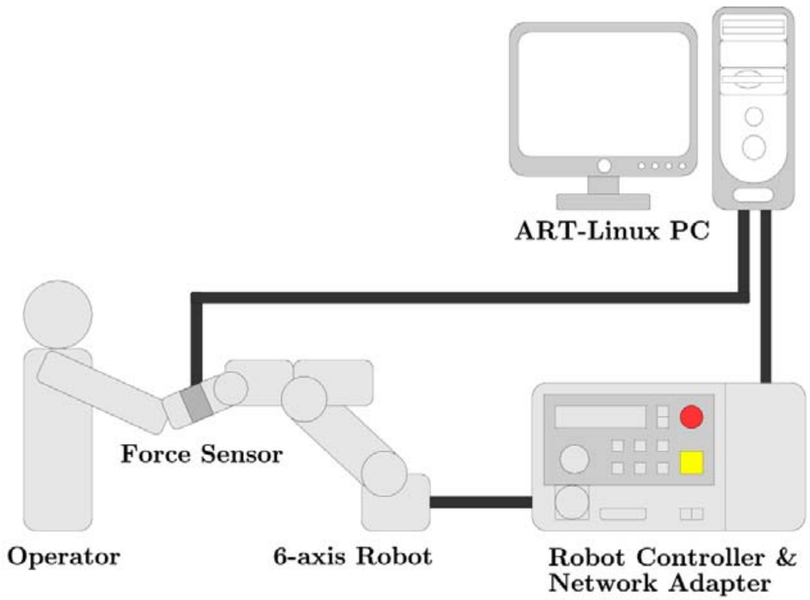
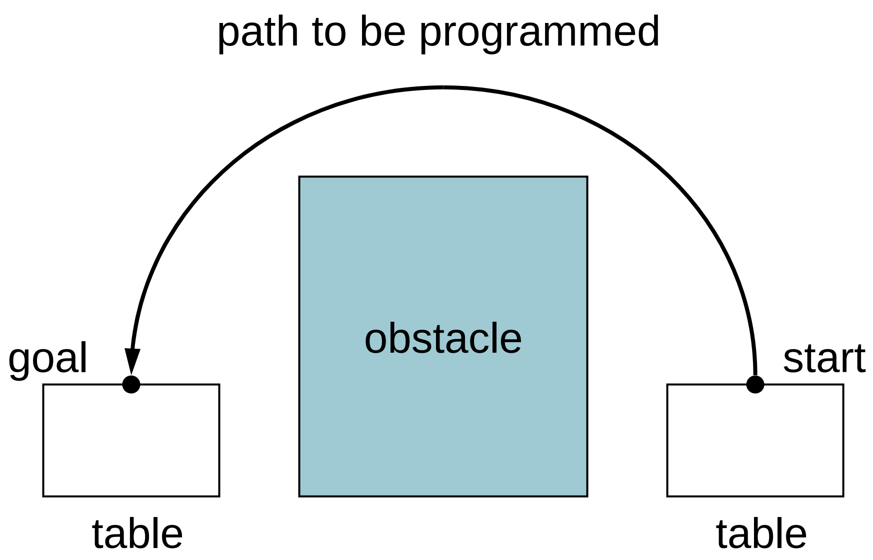
Experimental Setup

- Mitsubishi RV-1A (6 DOF manipulator) with Nitta force sensor
  - Controlled by a PC running on ART-Linux



Target Task

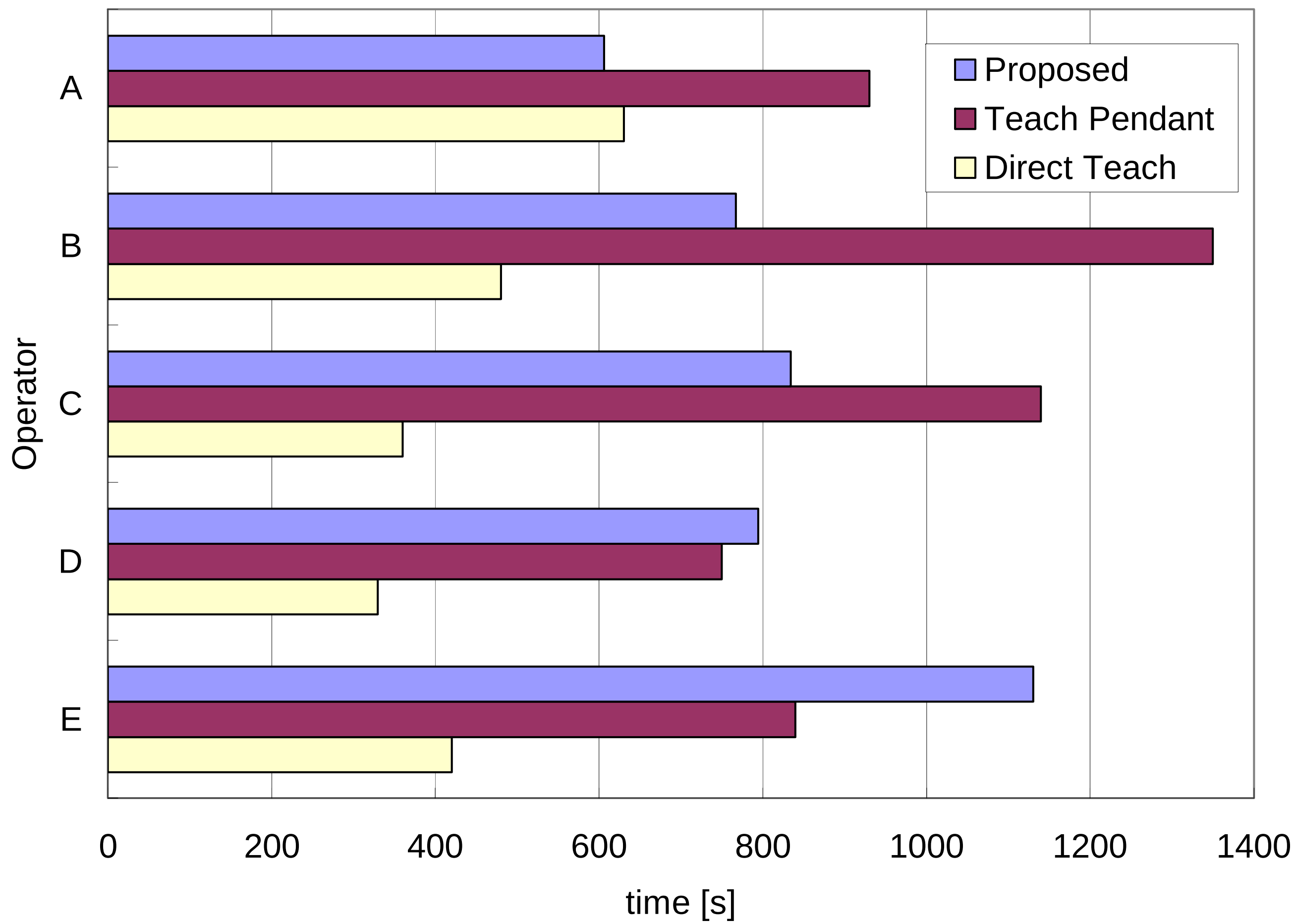
- Pick-and-place
  - Gripper open/close was skipped for simplicity



Tested Methods

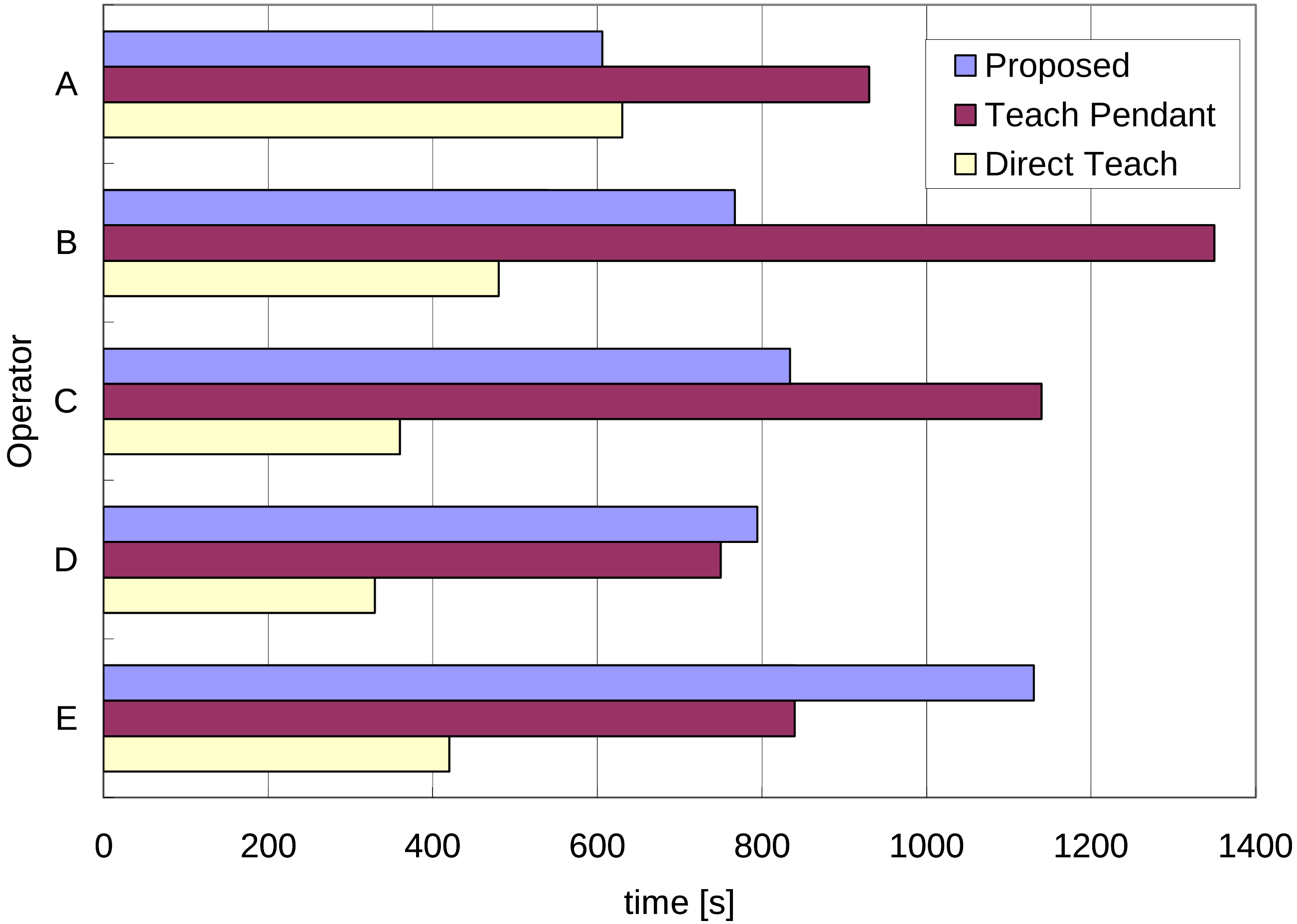
- Five novice operators tested the following methods:
  - **“Proposed”**: Robot programming by manual volume sweeping
  - **“Teach Pendant”**: Teaching playback using a teach pendant
  - **“Direct Teach”**: Teaching playback by direct teaching

Total Time for Programming



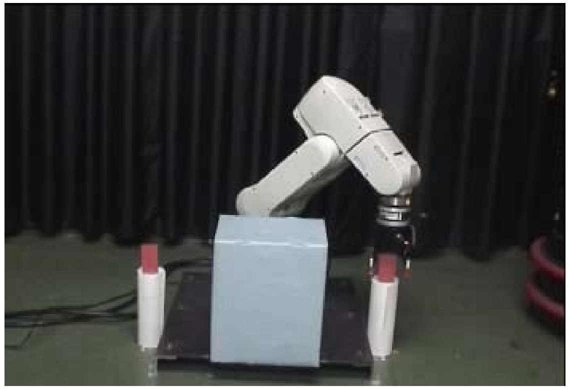
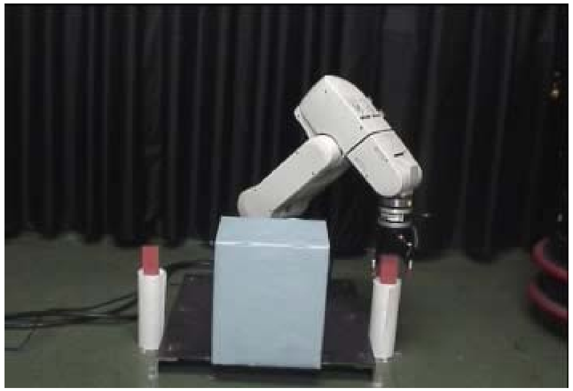
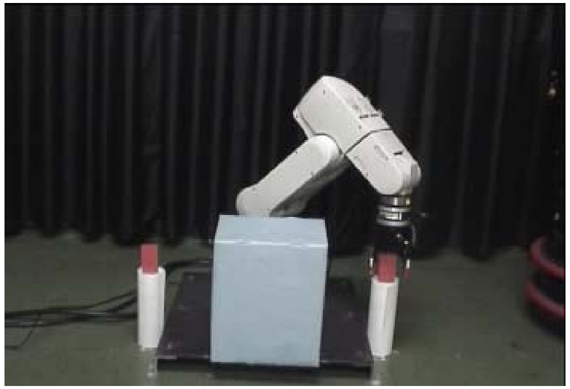
Time for Manual Operation

offline computation



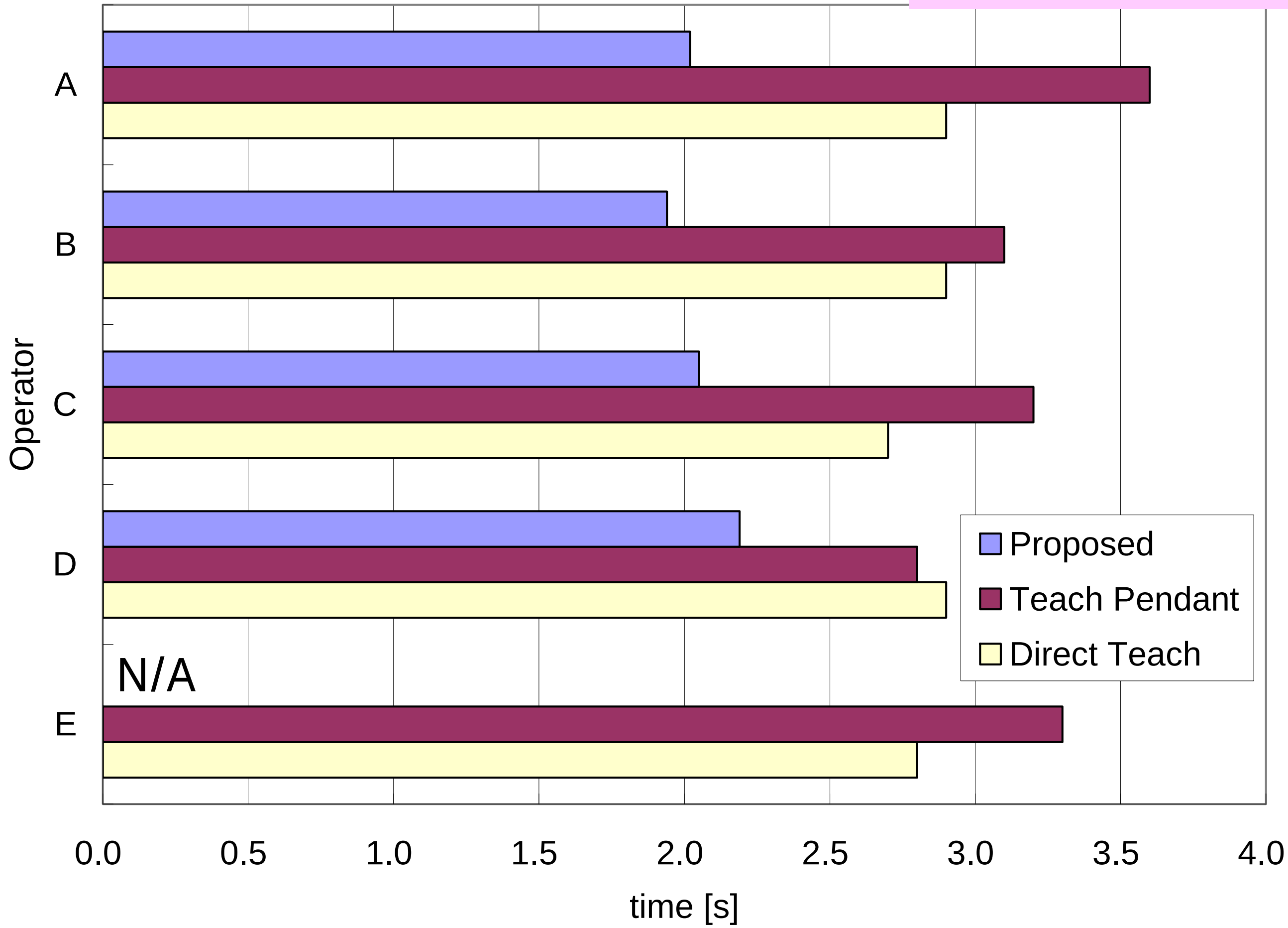
Example: Operator D's Case

Proposed	**Teach Pendant**	**Direct Teach**
Manual operation: 600 [s]	Manual operation: 750 [s]	Manual operation: 330 [s]
Offline computation: 190 [s]		
Cycle time: 2.2 [s]	Cycle time: 2.8 [s]	Cycle time: 2.9 [s]

Cycle Time

The proposed method can generate robot motions with short cycle time without heavy manual operations in most cases



Discussion

- Failure of motion planning
  - Narrow passage problem?
  - Using path in manual volume sweeping
  - Additional manual volume sweeping

Conclusion

- A robot programming method with manual volume sweeping was proposed
- It showed good performance in teaching experiments by novice operators in comparison with conventional approaches

Future Work

- More efficient computation of swept volumes
- User-friendly Interfaces
  - e.g. real-time display of swept volumes
- Measures against failure of motion planning
  - Using path in manual volume sweeping
  - Additional manual volume sweeping