Easy Robot Programming for Industrial Manipulators by Manual Volume Sweeping

Yusuke MAEDA, Tatsuya USHIODA and Satoshi MAKITA, Yokohama National University

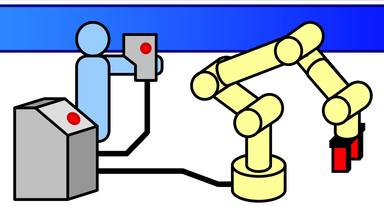
Abstract

In this paper, we propose a robot programming method for industrial manipulators. It enables novice human operators to teach "good" robot motions in a short period of time. First in this method, a human operator makes a robot manipulator sweep a volume by its bodies. The manipulator is equipped with a force sensor on its wrist and damping-controlled; the operator can move it freely by grasping its end-effector. The swept volume stands for a part of the manipulator's free space, because the manipulator has passed through the volume without collisions. Next, the obtained swept volume is used by a motion planner to generate a well-optimized path of the manipulator automatically. Finally, the planned motion is executed by the manipulator. Even non-skilled operators can generate robot motions with short cycle time by doing the above procedure. The effectiveness of our method is successfully demonstrated in teaching experiments for a comparison with other conventional methods.

Background

Programming of industrial robots: complicated and time-consuming for novice operators

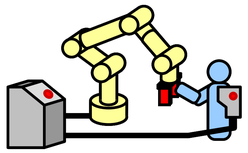
Conventional teaching playback:
- Operators must teach everything
- Operators must understand robot kinematics and specifications for shorter cycle time



Previous Approaches for Easy Robot Programming

Lead-through teaching (Direct teaching)

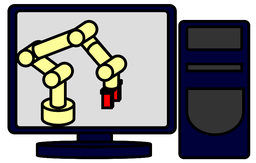
Teaching playback becomes intuitive, but…



- Human operators must teach "good" robot motions by themselves yet

Offline programming with motion planning algorithms

Optimized robot motion can be obtained, but…



- Planned robot motions must be modified due to errors in link parameters and alignment of actual robot
- Obstacles around robots must be modeled and inputted to the system

Objective

To propose a robot programming method that enables novice human operators to teach "good" robot motions for part handling in a short period of time

Overview of Proposed Robot Programming

Based on Hasegawa's Idea: A swept volume by robot bodies stands for a part of free space of robot [Hasegawa et al. 04]

Programming Procedure

1. Manual Volume Sweeping

A human operator moves the robot around so that it does not collide with obstacles and sweeps a volume by its bodies. All the joint variables are recorded.

2. Swept Volume Computation

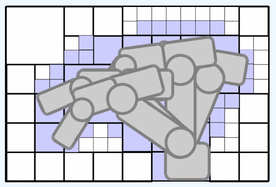
The swept volume is calculated from the recorded joint data.

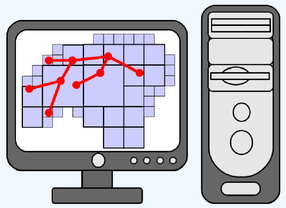
3. Motion Planning

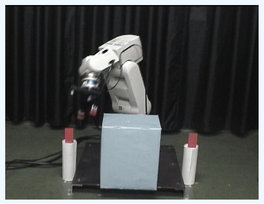
A motion planner generates a path from a start configuration to a goal in the swept volume.

4. Motion Execution

The robot follows the planned path.





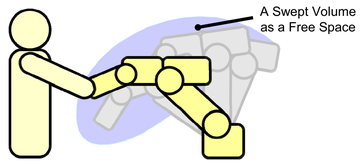


By manual volume sweeping, information on free space of robot can be obtained easily and intuitively → The above procedure enables even non-skilled operators to generate robot motions with short cycle time

Robot Programming Details

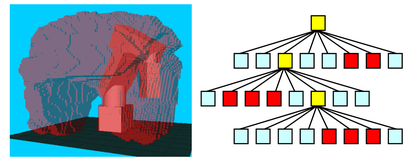
Manual Volume Sweeping

- Robot is damping-controlled for manual volume sweeping
- Start and goal configurations of robot are taught additionally to achieve high positional accuracy around them



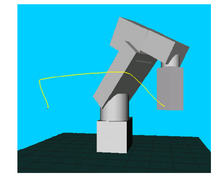
Swept Volume Computation

- Swept volume is computed from joint data with FreeSOLID
- Octree is used for effective representation



Motion Planning

- Computed swept volume is used as a free space
- An optimized path from initial to goal configuration is computed
- MPK (Motion Planning Kit) by Stanford Univ. is used in this implementation



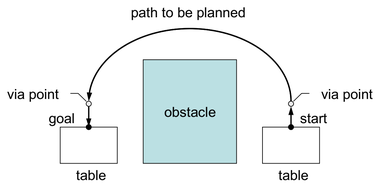
Teaching Experiments

Experimental setup

Manipulator: Mitsubishi RV-1A with Nitta force sensor
Computer: Linux PC with Core 2 Quad Q6600

Task to be taught

simple movement from start to goal configuration through two via points



Teaching conditions

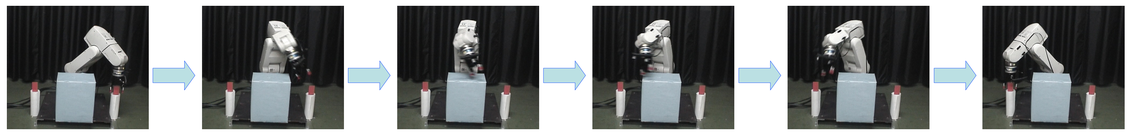
The proposed and two other conventional methods were tested:
- Robot programming by manual volume sweeping ("**Proposed**")
- Teaching playback using a teach pendant ("**Teach Pendant**")
- Teaching playback by direct teach ("**Direct Teach**")

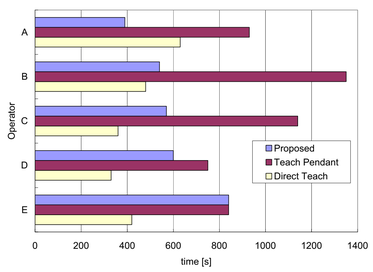
Five novice operators (A~E) performed the above three methods.

Results

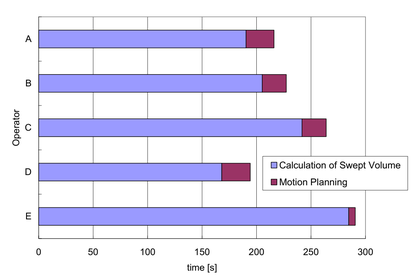
- The proposed method achieved the shortest cycle time in most cases
- Although the proposed method required extra offline computation time (several minutes), time for manual online operations were comparable to the others

→ The proposed method can generate robot motions with short cycle time by small manual operations in most cases

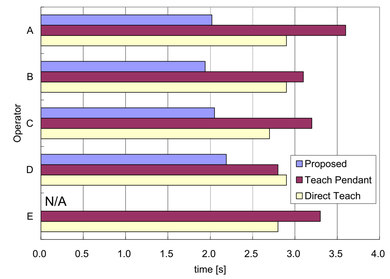




Time for Manual Operations



Time for Computation in Our Method



Cycle Time of Programmed Motions

Conclusion

Summary

- An easy robot programming method for industrial manipulators by manual volume sweeping is proposed
- The effectiveness of the method is demonstrated in teaching experiments for a comparison with other conventional methods

Future work

- More effective computation for quick motion generation
- Application to various tasks

Maeda Lab, Dept. of Mech. Eng., Yokohama National University
http://www.iir.me.ynu.ac.jp/