Human-oriented Programming Technology for Articulated Robots Using a Force/Torque Sensor

Hyo-Sig KANG*, Jong-Oh PARK*, Yoon-Su BAEK**

* Robotics and Fluid Power Control Lab.
Korea Institute of Science and Technology

** Machinery and Electrinics Research Institute
Samsung Heavy Industies

Abstract

Currently, there are various robot programming methods for articulated robots. Although each method has merits and drawbacks, they have commonly weak points for practical application, and especially the weak point can be even more vulnerable when the robot programming requires the subtle feelings of human being. This is because the movement of a human being is synthetic while the robot programming is analytic. Therefore, the present method of programming has limits in performing these kinds of subtle robot movement.

In this paper, we propose a direct robot programming method, which generates robot programs based on the force/torque vector applied to a force/torque sensor by the human operator. The method reduces the effort required in the robot programming.

Introduction

In many robotic application, we need a robot which follows a path on a workpiece. If it is possible to get all of the geometric consideration of a workpiece, these robots can be programmed off-line programming method and execute tasks based on the pre-programmed motions.

But if geometric knowledge of an actual workpiece is not available in a computer model, the most frequently used method is teach-in programming method. The teach-in programming method usually requires the tedious process of teaching many points along the desired tool path with a teaching pendant. Also this programming method is time consumming, and it is not easy for an operator to read the programed output. In spite of these drawbacks, teach-in programming method has been the most commonly used, because it is easy to use and to understand this method.

And we focus on this point mainly in robot programming.

Therefore, another method is necessary for easier robot programming. To implement the above mentioned concept, the following conditions must at least be satisfied:

- being operated by an operator's intention
- be easy to use by untrained operators.
- not to be time consumming

Considering of these situations, a direct teaching method by a human operator is one of the solutions.

The goal of this research is to develop a robot programming method based on the concept that movements of a robot are controlled in the human operator's seeing and the intentional motion by thinking of how to operate the robot in his mind.

In this paper, we propose a control algorithm for the robot programming using force/torque sensor which generates the desired motion of robot based on the force applied to the force/torque sensor by a human operator.

System description

Fig.1 shows the concept of Human-oriented programming technology considered in this paper.

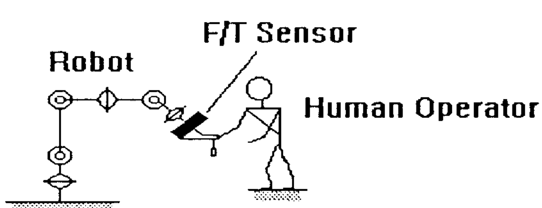

Fig.1 The concept of Human-oriented Programming

As shown in Fig.1, the human operator generates force command applied to the force/torque sensor based on the destination position of the end-effector and the present position of the end effector, that is,

$${}_TF_S = F_x i + F_y j + F_z k$$

$${}_TT_S = T_x i + T_y j + T_z k$$

where, ${}_TF_S$ is the force vector from force/torque sensor, ${}_TT_S$ is the torque vector from force/torque sensor.

The force/torque vector is transformed via matrix R into the base coordinate system to compensate tool weight.

$${}_BF_S = R * {}_TF_S$$

$${}_BT_S = R * {}_TT_S$$

where, R denotes the rotation transformation matrix.

When the operator programs the robot path using force/torque sensor, the force/torque sensor is always subjected to the gravity acting on the tool weight as well as an external force exerted by a human operator. To detect the pure external force, this must be removed. Therefore, we must subtract in real time the gravitational component on the axes. In our system, we consider the tool weight and a dispalcement vector from sensor origin to the center of gravity of the tool.

$${}_BF_C = {}_BF_S - {}_BF_{TW}$$

$${}_BT_C = {}_BT_S - {}_BT_{TW}$$

The pure external forces exerted by a human are interpreted as 6-D motion command via a chosen stiffness matrix K.

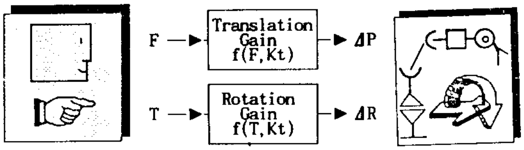

Fig. 2 Generation of Motion Data

As shown in Fig. 2, the force/torque vectors are multiplied by stiffness matrix to derive the position of the robot and the orientation vector.

The basic idea to select the stiffness matrix is as follows:

- The movements of a robot are function of sensed force/torque vector.
- The human operator do not feel uneasy in teaching .
- The speed of the robot movement is set to match the moderate speed of human motion.

To satisfy these conditions, we select stiffness matrix and speed through moderate experiments.

The results of processing the sensory data are output to the robot controller as commands of the motion, and the robot is controlled.

A robot path is automatically stored in files when the human operator moves the robot along the disired tool path, while grasping a end effector.

Once the progrmming work is ended, the operator can modifies the tool path stored in the file if he wants and the robot program is played back later.

System configuration

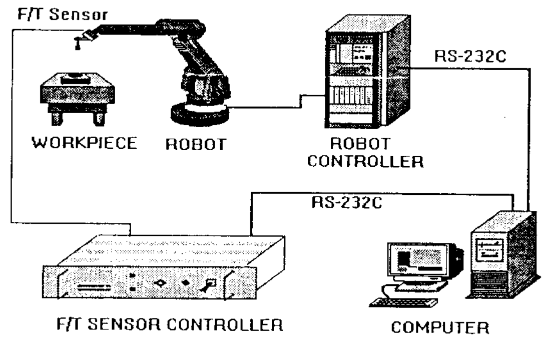

Fig. 3 System Configuration

Fig. 3 shows the system configuration of our system under development. The system consists of an ABB industial robot with S3 position controller, a force/torque sensor with a force/torque sensor controller and an IBM 386 personal computer. The 6-axes force/torque sensor mounted between the robot tool and the robot flange is used to provide for cartesian motion input. The force/torque sensor controller send data to the PC through a RS-232C port at a speed of 19200 baud rate. The personal computer serves for processing the sensory data, performing the coordinate transformation and communication with the robot controller. The robot controller communicates serially with the PC using a RS-232 C port at a speed of 9600 baud rate. This communication speed is not so fast, but we are making another method to achieve faster communication.

Conclusion

In this paper, we propose a algorithm for a robot proramming using force/torque sensor which generates the desired motion of a robot based on the force applied to the force/torque sensor by the human operator. The merits of this method are as follows :

- It requires less time and effort in robot programming.
- It is easy for an untrained operator to use.

A system for testing the effectiveness of this method is currently under development. Increasing the communication speed between the robot controller and computer, selecting more moderate stiffness gain and applying the pratical field are interesting points for future study.

References

[1] G. Hirzinger and K. Landzettel, "Sensory feedback structeres for with supervised learning", Proc. of 1985 IEEE International Conference on Robotics and Automation, pp 627-635, (1985)

[2] Udo Rentschler, "Programmieren Frei Hand", Roboter, pp 22-24,(1991)

[3] Toshio FUKUDA, "Manipulator for Man-Robot Cooperation", Proc. of 1991 International Conference on Industrial Electronics, pp 996-1001,(1991)