KINEMATIC AND GEOMETRIC MODELLING AND ANIMATION OF ROBOTS

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ABSTRACT

At present, most industrial robots are programmed in a teach mode. In the meantime, robots are called upon to perform increasingly complex tasks, which makes programming by teaching rather tedious and cumbersome. There is an increasing need for effective tools to assist in off-line programming of robots and verifying their programmed moves.

A program for modelling and simulating the PUMA 560 and ADEPT I robots has been developed. The kinematic models required for the transformation from task space to robot configuration space, and vice-versa, are briefly outlined. The robot geometric models and their graphical manipulation has been implemented using MOVIE·BYU and PLOT-10 on a Tektronix 4115-B graphics terminal and a VAX 11/730 minicomputer. The developed kinematic and geometric models are used for off-line simulation, animation and verification of robot movements during assembly operations. Sample outputs which illustrate the program capabilities such as shaded images, wire-frame animation, arbitrary point tracing, actual movement envelope and the various menus are included.

KEYWORDS: geometric modelling, robot kinematics, graphical simulation and animation, robot off-line programming.

INTRODUCTION

Robots have recently been gaining popularity and acceptance as an efficient tool for accomplishing various manufacturing tasks. Current applications include material handling, welding, painting, deburring, etc. Robots' greatest potential for increasing productivity is in the field of automated and flexible assembly. The key to their success in this area will be in integrating robots with adequate sensors and providing high level sophisticated programming tools.

One of the major goals of our current research in the Centre for Flexible Manufacturing Research and Development at McMaster University is to develop systems which can automatically synthesize programs for controlling robots performing assembly tasks with sensor feedback. The input to these systems includes:

a) specification of assembly tasks and goals, and
b) specification of the initial state of both the robot and world models.

An expert system written in COMMON LISP, currently under development, then uses the knowledge base and production rules to produce a plan for robot motions, and a robot level program in VAL II. The on-line expert system will allow updating of preplanned robot moves in response to sensor input.

Achieving this goal requires several building blocks, including:

1) Robot geometric and kinematic models,
2) Robot world geometric model, including parts and tasks,
3) Sensor models,
4) Motion planner,
5) Adaptive learning model, and
6) Knowledge base and inference engine.

Several research projects are in progress to develop these modules. This paper focusses on the generation of the kinematic and geometric models of the two robots used in the centre, and the links between these models and the rest of the modules mentioned above.

The flexible robot assembly system, installed in the Centre for FMS research and development, consists of two robot work stations, an IRI vision inspection station, a load/unload station, and a computer-controlled Bosch conveyor, with pallets, for material handling. The two robots are a six-axis articulated PUMA 560 and a four-axis ADEPT I scara robot. Both robots are interfaced with force, tactile and vision sensors for real-time adaptive control. The flexible assembly system is used for both research and development projects related to mechanical and electronic assembly.

THE KINEMATIC MODELS

Controlling and programming robots requires analytical models which relate the robot configuration space, expressed in terms of joint variables, and task space normally described in Cartesian coordinates. These models should allow efficient transformation between the two spaces since robots are usually controlled in the joint space while tasks are normally defined in the Cartesian space.

A robot kinematic model consists of two parts:

1) Forward Kinematics: which accomplishes the transformation from configuration space to task space, and
2) Inverse Kinematics: which transforms representations in task space to configuration space.

Kinematic models may be used to transform positions, velocities and accelerations between the two spaces.