INTERACTIVE DESIGN OF ROBOT WORKCELL

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Abstract: A simulation package CINDY for robot work cell design is presented. The software includes synthesis and analysis of robot systems. It gives an opportunity to create, analyze, and edit 3-dimensional cell descriptions: the robot, tooling, parts, end effectors, NC equipment, etc. Robot and equipment solid models are designed using ARCHIMEDE geometrical modeling system. The inverse kinematics problem and motion planning is solved for hyper-redundant manipulators. Path planning allows local minimum avoidance and complex path following with joint reconfiguration.

Key words: Computer Aided Design, Interactive Computer Graphics, Animation, Robotics, Hyper-redundant manipulator, Symbolic computation.

1. INTRODUCTION

The development of a robotized work cell can be a long, tedious and expensive process. A wide range of problems has to be solved designing the cell, as choice of an appropriate robot for the concrete manufacturing operation, definition of robot workspace and optimal layout of processing machines and other equipment [1]. The designer of robot work cell must take into account various limitations imposed of real production process: working place, collision avoidance between robot and equipment, consideration of extremal joint values, functional connections between equipment, technological paths and robot properties.

One approach which has proven effective for evaluating manufacturing systems to determine the relative merits, efficiency and cost effectiveness of different system design is computer simulation [2]. Computer simulation is a process of designing and constructing a mathematical-logical model of real world system and experimenting with this model on a computer. The power of the modeling increases if an interactive computer graphics is used [3-5]. It is valuable and efficacious when the experiment upon the real system is very expensive and the intuition and experience do not ensure the desired decision. A computer simulation model that accurately represents proposed robotics system can be used and exercised to predict how the designed system will perform the tasks. It allows testing and evaluation of alternative system designs under every conceivable set of conditions. Thus, it can be used to prove or disprove that a proposed design will work and to illustrate the sensitivity of the project to various machine performances, reliability, and product arrival pattern contingencies.

Interactive computer graphics allows to simulate the choice, the installation and the work of the robotized workplace. The computer model of the robot and equipment are displayed in real time and this allows timely user-computer interaction and immediately find out mistakes. That determines the great interest of robot manufacturers about interactive computer graphics. The process of creation of interactive graphics systems for robot design and investigation emerged in the 1980's. The well-known among them are CATIA of Dassault Systems [6], PLACE of McDonnel Douglas Automation Company [7,8], IRPASS [5], PreView [9], ROBOGRAPHICS of Computervision [10], ROBSYM [11] and so on. Most of them began as university research works and later they get on CAD market.

This paper presents the abilities of interactive graphics system CINDY for kinematics analysis of robots in design and studying of robotized work cell.
2. CINDY Simulation System

System CINDY [12,13] has been implemented in VAX Pascal programming language running under VMS operating system for DEC VAX computers. It possesses the following remarkable significant features in contrast with well-known similar systems.

- CINDY allows modeling of movable and immovable robots, with arbitrary manipulator structure, and without limitation of the degrees of freedom [14]. In conjunction with numerical manipulator model, an analytical one is available. That permits to use a system for symbolic computations [15,16]. The analytical description of the robot kinematics ensures qualitative estimation of the manipulator. It is more efficient during design - parameters are presented explicitly, and the user is able to appreciate their significance for the model.

- The inverse kinematics problem is solved for manipulators with unlimited degrees of freedom, so called hyper-redundant manipulators. It is achieved using the coordinate descent method. It reduces multi-criteria optimization to the single-criteria one. In the other simulation systems mentioned above the Newton-Raphson method and its modifications are used. But it put up serious problems when the number of robot links increased. The investigations in this area continue [17-20].

- An algorithms for robot-motion planning and smooth joint reconfiguration when prescribed path is followed are created [21].

- The analytical model allows hybrid, numerical-symbolical solution of direct and inverse kinematics problem. That decreases the computation time about 15% [22].

- Three-dimensional models of robots and equipment are created using geometrical modeling system ARCHIMED [23]. The modeling is carried out using eight solid models and restricted boolean operations between them. ARCHIMED allows calculation of the inertia properties and collision detection between models of the robot and equipment [24].

- CINDY allows fast wire-frame visualization, hidden line, surface removal and graphics animation of robot motions.

3. STAGES IN WORK CELL DESIGN

3.1. Robot Kinematics Design

A significant phase in designing of robots is the definition of the kinematics abilities of the manipulator which are necessary to execute prescribed technological operation. Therefore the first stage is a choose of an appropriate kinematics structure of the robot. During the robot design it is possible to experiment using existing simulation models in a data base. The model could be modified according to the manufactory task requirements. If there is no available appropriate model, a new one is created. A powerful data base with simulation models of robots is a precondition for optimal work cell design.

3.2. Work cell structure design

The typical work cell in an industrial or manufacturing environment consists of the following groups of equipment:

- material handling equipment: welding robot, painting robot, punch press, adhesive applicator, boring, turning mill and other;
- interfacing equipment: it is necessary to serve and manipulate parts or material to the process machinery: conveyors, material handling robots and rotary indexing table;
- control equipment: it is in charge of the manufacturing process and the cell components could be a robot control, a welding control, or pneumatic control;

These work cell elements, their number and the connections among them specifies the work cell structure. Work cell structure is proved to be a valuable tool in terms of safety, time and cost. The robotics work cell is created by taking the various pieces of equipment needed for the cell and
inserting them into the cell model. The equipment in the cell is then positioned according to the existing process flow. Thus the work cell is configured by locating robots and other objects in it.

3.3. Functional design of the work cell
When the initial cell layout is established, the next step is to test the functionality of the integrated robot complex, to verify that the robot can reach and interface with the equipment, and that it can perform the desired tasks. Robot can move in two ways.
- supervisor robot control. Motion description can be created "step by step". The relative translations or rotations of the joints by the use of the interactive means at every step is defined. This allows the user directly to control the position of the working point. The designer can locate and orient the end-effector in desired work point and in this manner to test abilities to reach and orient a given object.

Supervisor mode is very useful in robot motion between obstacles. Interference checking between the end effector and the work cell equipment is carried out by visually following the simulation of the robot during path generation. The main disadvantage is a fast operator fatigue.
- indication of a target points for end-effector (goal position and orientation). This approach requires solving the inverse kinematics problem. It is possible to give a set of goal points or plane trajectories described in terms of Pascal_2D language [25,26]. The main problem is the lack of algorithms for collision avoidance.

3.4. Modification and refinement the work cell
Usually during the work cell design and test, errors in its structure and discrepancy in functions of the cell elements are discovered. To correct the mistakes, the designer can relocate the robot and reposition the cell components. This cycle 3.1-3.4 continues until the cell is optimized.

3.5. Interactive task planning.
When the cell layout is complete, the designer prepares it for dynamic simulation of the robot performing the necessary tasks. A simple robot program could be created, for instance, to get a workpiece and load it into the machinetool, to unload the handled part from the machine and put it on the flow line, and so on. These motions can be stored and repeated in animation mode. This sequence of functionally completed operations could be used as a control program of the robot [27]. The user may receive information at any moment about current values of joint coordinates, Cartesian coordinates of the end-effector, links inertia moments, metric relations between objects in the work cell.

On fig.1 is presented work cell model with robot RB290, machine tool and handling object flat pallet. The robot gets the workpiece from NC-machine, then changes its orientation and puts the workpiece onto the pallet.

4. CONCLUSIONS
A system CINDY for computer graphic simulation of robotics applications has been developed. General purpose models of robots and their work cell can be created, and used by a variety of application programs. The environment supplies a host of functions to perform simulation tasks, which significantly helps to reduce the time needed for developing robot simulation programs.

The main advantage of CINDY is the ability for modeling and testing hyper-redundant manipulators, including analytical one too; solution of inverse kinematics and motion planning.

Future development is creation of collision avoidance algorithms, and modeling of laparoscopic systems, miniature dexterous manipulators for surgery and medical manipulators.
REFERENCES


Fig.1. Robot work cell