ROBOTIC MANUFACTURING SYSTEMS - MODELLING AND SIMULATION

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Abstract. This paper presents modelling and simulation techniques applicable to a wide range of manufacturing systems, where coordinated interaction of mechanical, electronic and software components is required to meet performance goals. A versatile new modelling technology was used to help design the innovative manufacturing control systems. Using models written exclusively in Delphi language, simulation-based analysis and verification were performed at both the component/subsystem and at the overall system level.

Keywords: virtual robotic manufacturing systems, solid model representation, behavior simulation

1. Introduction

One of the major problems with supervisory control applications design of manufacturing systems is from behavioural simulation, which is to be capable to determine relevant information to monitor manufactured goods and process. The robotic manufacturing system is a veritable intelligent system, as its performance depends on the highly coordinated real time behaviour of mechanical / electrical / electronic and control software components.

Automatic manufacturing is a computerized production control technique used in the production of manufactured goods to balance output of production with demand.

To computerize the manufacturing processes of existing designs is possible but the resulting operation is often unproductive and with frequent failure. The root of many these problems can be traced back to the design procedures being used.

Design for manufacture is the process by which manufacturing sequences and procedures are changed to increase the effectiveness of automated process. On the other hand, applying this approach to automation process requires a virtual model (prototype) of the manufacturing process.

The designers use modelling and simulation technology as part of the manufacturing design process [1]. This effort proves to be very much helpful to the designers, helping them to understand important component interactions between subsystems as well as to assess system-level performance correction options.

This paper describes the creation of models and simulation of the behaviour of the virtual manufacturing system. Virtual prototype improves knowledge and provides understanding of the manufacturing system. In this paper, we propose an original separated approach to behavioural simulation of a manufacturing system as system with discrete events. The implementation on an industrial example of this methodology shows her applicability.

Studying the virtual robot systems and detecting the movement of part in the virtual environment and transforming this movement into symbolic language will sustain the control decisions making.

Automatic manufacturing with robots offers many important features and advantages that are not achieved with traditional fabrication techniques.

Manufacturing automation has been not only an important but also one of the most challenging applications field for robotics. Invention of robots has brought about revolutionary changes in the field of industrial manufacturing. Robots have saved workers from tedious and dull assembly line jobs, and increased production and savings in the process. But, what's easy for a human assembler can be difficult or impossible for a robot.

There are many important research problems related to the range of manufacturing assisted by robots, from design for manufacturing, to behaviour analysis, assembly sequence planning, etc. This paper is only focused on the subject of robotic motion for manufacturing in a virtual environment.

The principal domain for manufacturing automation with robots will be applications involving high demands on flexibility. The flexibility and the reprogramming ability of robots will contribute to their extended utilization in manufacturing operations. The robots are flexible in the sense that they can be programmed to manufacture different products. Robots are already being used in the industrial manufacturing for objects handling, components insertion, assembly and inspection which require a high degree of repeatability.

2. System-level modelling and simulation

The work draws on research into product and manufacturing knowledge models. In this paper, the author has proposed a virtual prototype model of robotic automation for manufacturing system architecture. This paper presents a methodology for solid modeling in a virtual environment that is accurately performed in an intuitive manner through constraint-based manipulations. Constraint-based manipulations are realized by allowable motions for precise 3D interactions in the virtual environment. A virtual prototype system has been implemented to testify the feasibility of the presented methodology.

The virtual environment is primarily visual experience, displayed on a computer screen. The concept of the using of the virtual prototype of the manufacturing systems for performances estimating is extremely actuality.

The manipulation process is controlled by a computer model that is based on the physical description of the virtual environment. Consequently, the technology is able to create nearly arbitrarily perceived environments.

Virtual reality provides intuitive 3D interaction, direct manipulation and 3D immersion. Virtual reality may offer enormous benefits to many different applications areas.

The use of virtual reality enhances the user's understanding of a virtual object. It helps to accelerate the design process and permits designers to easily develop his concepts, thus totally developing his creativity. On the other hand, at present most virtual reality allow object creation, outside the virtual world.

This is one main reason why it has attracted so much interest. Virtual reality is currently used to explore and manipulate experimental data in ways that were not possible before [2]. Scientific visualization provides the researcher with immediate graphical feedback during the course of the computations and gives him the ability to guide the solution process.

The computation and visualization processes, provides an exploratory, experimentation environment that allows the investigators to concentrate their efforts on the important areas.

The scientific visualization helps us to interpret the lots of data.

With these considerations in mind, there should be considered several questions related to the using of the virtual robots for the optimization of the robotic manufacturing process.

A virtual robotic manufacturing prototype has been implemented for precise solid modelling in an intuitive manner through constraint based manipulations in the virtual environment. This prototype is principally used for the detailed conception stage, but it is also a support for early conceptual design.

The different pictures shown in Figure 1 are the results of the simulations and represent the animation sequences for the robot arms and for different shapes of the manufactured object.

A virtual prototype has been implemented to testify the feasibility for the manufacturing technology. The system components of the solid shapes objects are carried out in the Delphi environment.

Delphi technology provides an interactive graphical environment and a customizable set of block libraries that let us design, simulate, implement, and test a variety of time-varying systems. The modelling and simulation technology in the manufacturing design process is the most valuable used for system-level performances evaluating.

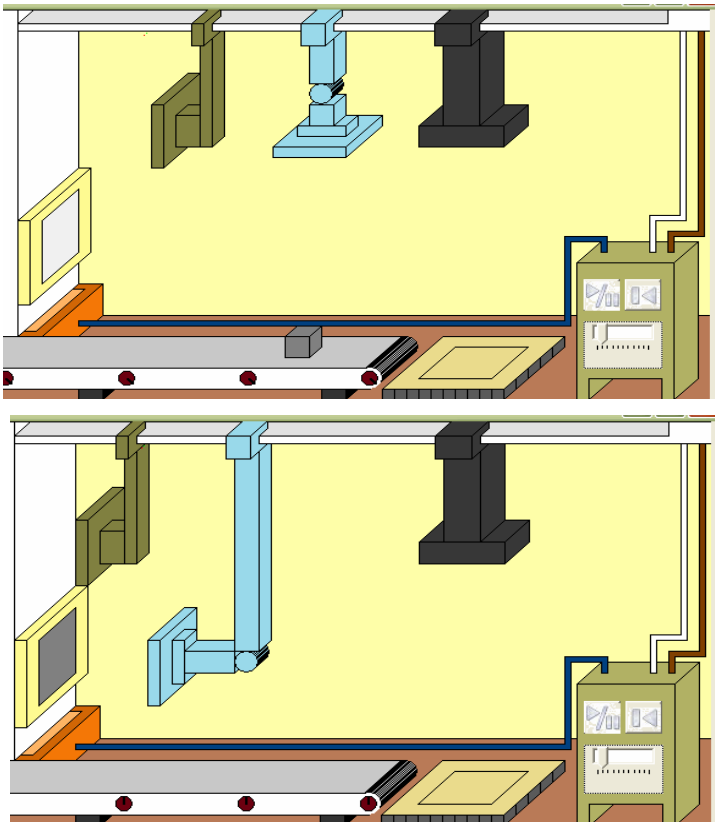
A procedure-based degree-of-freedom (DOF) combination method for constraint solving is also presented for obtaining the acceptable motions. A based constraint recognition mechanism is developed for both constraint-based manipulations and constraints integration into the virtual environment.

The study-case introduces the construction of the hierarchically structured and constraint-based data model and presents the realization of constraint-based direct manipulations.

Implementation of a prototype system and results are discussed on the basis of the Figure below**.** The virtual prototyping at multiple levels of abstraction, as well as the ability of the simulation of the discrete processes evolution, allows the news capability of the design process.

The software system provides a Delphi programming platform to assessing the control algorithm for dynamic interaction of the virtual robot arms with the manufactured object and its environment. In our example the virtual manufacturing system model includes a conveyor, two work platforms, three robotic arms and a control panel with distributed drives systems.

In this paper, the author present a case study based on a simplified virtual manufacturing system, realized in Delphi programming environment. The pictures presented were visualized for plausible tasks.



a) First picture of the animation sequence

b) Ending picture of the animation sequence

Figure 1. Virtual manufacturing flexible line for case study

Behavioural models of each robot arms, for different manufacturing cycle's phases, are included in the software system of the manufacturing process. Simulation planning processes simulation at virtual prototype level, have been established to allow planning of the motion control system.

3. Constraint-based manipulations as a means to synchronize the robots

There are some limitations with virtual reality systems. Among this, the finite resolution of virtual objects without topological information is not proper to represent solid models. The limited precision and reliability of 3D input and output strategy prevent users from precise design activities.

The actually virtual reality based modelling systems offer very sophisticated modelling tools for creating complex solid models in a virtual environment [3].

In this paper the author has used an efficient constraint-based methodology for solid modelling in a virtual environment. Solid modelling in the virtual environment is precisely performed in an intuitive manner through constraint based manipulations. A hierarchically structured and constraint-based data model is developed to support solid modelling in the virtual environment. In the virtual environment, for every object an event list is created as the attribute of this object and is attached to the object. An action list is connected to every event list of the object [4].

In this paper are created, in Delphi environment, virtual objects by means of the functions and procedures written in Delphi language. This action list shows the actions that will be done almost immediately as the events occur.

The constraint-based manipulations are realized by a basic interactive event and the actions are performed when these event happen. A basic interactive event is attached to every object.

Once a constraint is recognized, during the constraint recognition, it will be underlined and will be confirmed, by supervised system. Once confirmed it is will be inserted into the constraint-based data model. The fulfilled constraint will further restrict the subsequent motions of the object.

3.1. Representation of permissible motions

The constraints between objects are completely created by the constraint-based manipulations with automatic constraint recognition and precise constraint satisfaction [5].

The constraint reduces the DOF-s of the manipulated object and implicitly provides a restriction to the future operations applied to the object.

The remaining DOF-s defines the permissible motions of the object. The permissible motions explicitly describe the next operations and ensure that future operations will not violate the existing constraints.

For every object in a free space, its configuration space has six DOF-s: three translational DOF-s and three rotational DOF-s. To simplify the computation of the permissible motions, represented as a mathematical matrix, must be divided the configuration space along three linearly independent directions: X-axis, Y-axis and Z-axis. The three basic translational or rotational DOF are linearly independent among each other. Any remaining DOF-s used to define the permissible motions can be described by this basic DOF-s.

3.2. Constraint solving for obtaining permissible motions

Since most constraints are geometric constraints and they are shown as the limitation of relative geometric displacements between objects, i.e. the limitation of DOF-s, the constraints applied to an object can be recorded to the DOF-s of this object. In fact, the correlation from constraints to DOF-s can be extended to the correlation from a set of constraints to the combination of DOF-s.

If there are multi-constraints applied to the object, the current remaining DOF-s of the object can be obtained by DOF-s' combination. The DOF-s combination for solving multi-constraints is based on the DOF analysis for solving individual constraints.

Within the limitation of the current remaining DOF-s, determined by the current constraints, the object intends to satisfy a new constraint. The new constraint is precisely satisfied under the current allowable motions of the object and is subsequently inserted in the constraint based data model to update the current constraints applied to the object.

4. Conclusions

The paper describes the adopted solutions used to perform the constraint-based manipulations tasks, using the virtual prototype model of a manufacturing process.

The virtual prototype model has been implemented on the Delphi platform with a graphics workstation. This allows an intuitive solid modelling in a virtual environment, allowing the constraint based 3D direct manipulations.

The structured constraint-based data model represents the entire solid modelling process at different design levels. It also provides the constraints at the different levels, offering precise data to objects manipulation.

The knowledge gained during behavioural simulation allows to designers to estimate all capability of the physical manufacturing system before his built-up.

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