Application of Advanced Product Models in Robot Control

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Abstract

In this paper the authors propose and discuss a method to integrate product modeling with robot control environments in order to enhance the utilization of geometric and other product and production equipment related information in robotics. Research of the related methodology was motivated by growing significance of robots in highly flexible manufacturing systems. Difficulties of reproduction of modeled product geometry at its applications resulted growing importance of on line real time communication between a centralized product modeling and several model applications. The reported research concentrates on creation and application of model data information understandable by robot controls, on communication of model data with robot environments through the Internet, and finally on some related telerobotics issues. It covers one of the actual problem complexes in integration of engineering modeling with its shop floor level applications. Systems integration, data model, data communication and model processing have been investigated. In the paper firstly an introduction of the modeling environment is given taking into account the robot control aspect. Following this, key issues regarding robot tasks and their shape model based control are explained. Then an approach to interactive application of internet based telerobotics for product model driven control of robots is outlined. Finally, possibilities for integration of remote robot control applications with product modeling environments are discussed.

1. Introduction

Product modeling is one of the prevailing concepts in present day developments in engineering modeling. The related comprehensive, sophisticated, reference model based description of product information serves all the product related engineering activities as robotics. Advanced integrated product design and manufacturing rely upon this technology increasingly. Product modeling was developed into a sophisticated technology during last ten years. Application of robots and robot like equipment is growing in manufacturing and other product model related areas. Robotics is also an inherently sophisticated technology. Control and programming of robots have become sophisticated but waiting for their integration with product modeling is still on. The authors would like to produce a contribution to advancements in this area of importance.

The utmost purpose of researches like the author's is integration of three hi-tech areas, namely engineering modeling, teleoperation of robots and internet technology in a single but globalized system. Human ideas about products during their design and development are change even if the distance between sites of product modeling and robot intensive manufacturing is large. Application of a product model that has been created on a remote modeling system can be relied on one of the following three concepts. The first concept is the troublesome model data exchange. It requires a modeling system on the model application side that is able to reconstruct the model according the original model information and design intent. The second concept is application of agents. This is an advanced and appropriate concept but it is uncomfortable to apply at the present day continuous development of products where product design changes frequently. The third concept is teleoperation of the robot from the original modeling system in which the model has been created. This is the trend for future model applications therefore the authors would like to contribute to implementations of this concept.

Researchers are working on several aspects of the reported work. Recently, intelligent autonomous robots are based a lot of advanced methods for programming and motion control [1], [2]. Knowledge based intelligent methods as adaptive neuro-fuzzy inference [3] can be applied to assist control processes. Multiple armed and cooperating robots need intelligent methods for motion coordination [4], [5]. Previous activities of the authors in this area are modeling of manufacturing process and human intent [6]. The reported research is also connected to an earlier research on robot control [7].

This paper is about model creation, handling and communication aspects of application of advanced product modeling in robotics. Distinguished attention is devoted to shape models of mechanical parts but other partial model components of the product model defined by STEP, ISO 10303 are of equal importance. In the paper firstly an introduction of the modeling environment is given taking into account the robot control aspect. Following this key issues, regarding robot tasks and their shape model based control are explained. Then an approach to interactive application of internet based telerobotics for product model driven control of robots is outlined. Finally, possibilities for integration of remote robot control applications with product modeling environments are discussed.

2. Product model information for robot control

Produced items as well as the related production equipment and devices are modeled using systems that serve engineering design purposes. Description of parts, form features, sequence of part shape modifications, assembly relationships as well as manufacturing processes are the most important from the point of view of robotics. The related models and their associativities can be followed in Fig. 1.

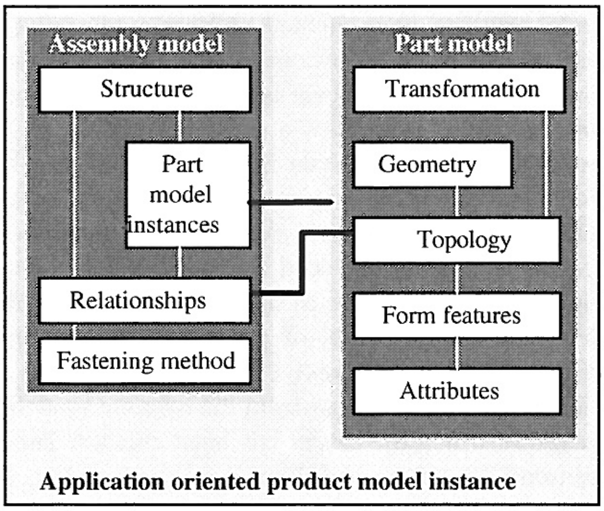

Fig. 1 Robotics related entities in typical product models

Fig. 1 outlines an advanced product model where associativities connect model entities and other associativities can be defined to connect this modeling environment with robot modeling environments. A part model involves curves and surfaces that carry useful geometric information for robot control. Topology describes place of these geometric entities in the modeled boundary structure of the part shape. Application oriented shape aspects are represented in this system as form features. An assembly model is created by topology driven relating geometric entities on the matched parts. Information description methods are applied to develop application oriented reference models.

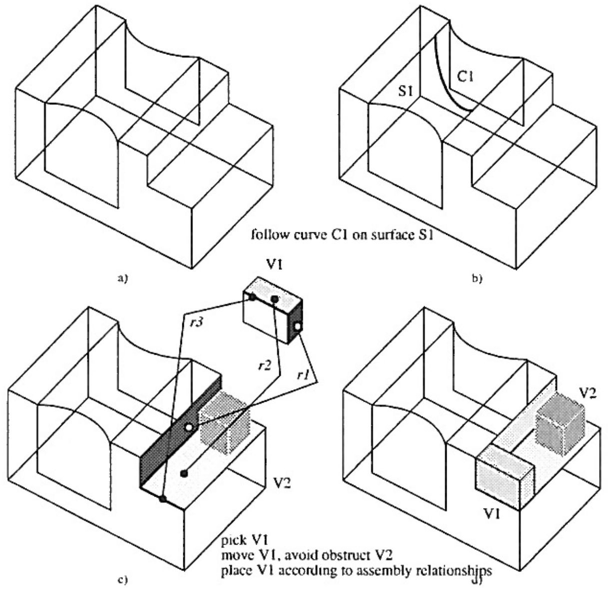

Fig. 2. Part geometry for robot control

Control of a robot is geometry centered and use information described by part geometry. Topology can be used to know where a geometric entity is in the modeled boundary structure. Fig 2/a illustrates a part that is in the working envelope of a robot. Curve C1 that lies in surface S1 is to be followed by a robot trajectory. Following this Part V1 is placed in position on the base part by using of three relationships *r1-r3*. Avoiding obstruct V2 should be taken into account at the design of robot trajectory. These are two typical operations at applications of robots.

Non uniform rational B-spline curve and surface descriptions are appropriate to any shape, from the straight line to free form curve, and from the flat surface to the free form surface. It is often allowed to simplify the curve geometry to linear. Application of this concept results polyhedral part shape description where large quantity of small flat surfaces is applied to approximate of the shape.

Robot operations need input information for the task of robot, form features on the part to be gripped, shape of obstacles in the working envelope and geometric information for path control depending on actual task of the robot. At the same time pick and place robots need not geometric information for the purpose of path control, painting or welding robots need not information about gripping of the part.

Part geometry changes during machining operations so that actual shape of the part should be communicated using machining process model information for material removals. This information is defined by form feature driven modeling of shape modifications of the part by machining and allowance values.

Despite their dedicated modules for planning of robot control, present day industrial modeling systems do not offer appropriate tools for integration of part modeling and manufacturing process modeling with robot control systems on a level necessary for a fully integrated system.

3. Modeling of robot tasks

Creating and processing of advanced product models need sophistcated modeling environment. The best appropriate modeling tools and human skill for modeling are at the design of product. Consequently, both human and computer sources of robot navigation are remote from the workspace of the robot. The alternative of on-site reproduction of these capabilities is often not available at the robot station so that they should be got by remote activity. Application of telerobotics must be considered. Advancements in internet and other related technologies give a new possibility for cooperation of product modeling and robot control. Perhaps the most important feature of these systems is that human performance can be utilized through network. The authors investigated the modeling background of remote activities in the field of control of engineering devices.

A multi-layered robot process model structure and its relationships with product model entities have been proposed by the authors (Fig. 3). Tasks, operations, actions and reflexes are on the levels of this model. This follows the command structure described in [8]. A robot can manipulate different objects described together with the manipulation strategy within a task. Operation is related to a single object. Operation consists of independently executed actions. A reflex means direct transformation of current sensor data into motion.

Approach of the authors emphasizes geometric model driven nature of task, operation and action. A task is a sequence of object manipulations, for example, at assembly, part feeding or welding. Geometric model information is required for objects to be manipulated. This information can be used at recognition of type and shape of objects, programming grippers, calculation targets and trajectories, analysis of collision, etc. A tipical simple operation is pick and place of parts. This operation can involve actions involving positioning and orientation of parts, moving parts along paths and placing them in contact. Geometric model information is necessary for environmental objets such as parts to be welded and obstacles within the working envelope of the robot. Path to manipulate an object to a goal location can be predefined or real time generated by using of geometric model data. Mobile robots require geometric information about their environment. At the same time autonomous robots can process their own visual data about the environment around their path.

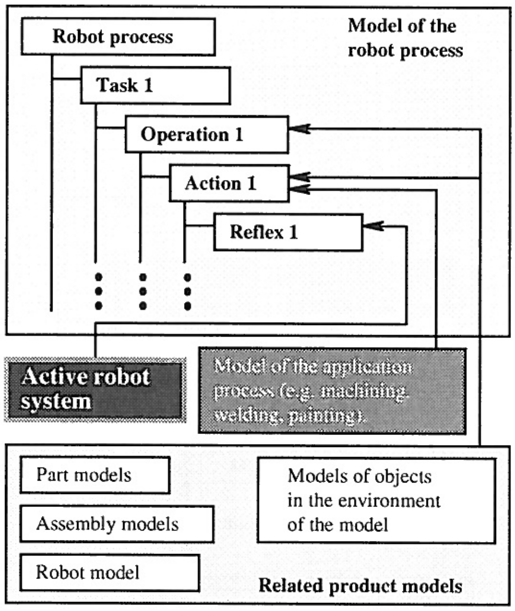

Fig. 3. Structure of the robot process model and its product model connections

4. Interactive internet based telerobotics

Taking into consideration its inherent characteristics and actual capacity, Internet can be an appropriate remote communications medium for robot teleoperation. A software at a host directs the motions of a robot connected to an other host. A main drawback of this solution is that Internet produces non-deterministic communication time delay between hosts. Moreover, time delay varies with the amount of information to be transmitted. Considering Internet, there are two alternative solutions for product model based remote control. The host, from which remote operation is done, has direct access to all necessary model data. It can transmit model data for processing to a remote model application system or it processes the model information into machine independent robot control data. The authors prefer the second solution.

Telerobotics is supposed to be coupled with autonomous robotics in the reported work. This means remote control of intelligent robots. According to the intelligence of the remotely operated system, operating mode of a telerobot can be [9] direct continuous control, shared continuous control, discrete command control, supervisory control and learning control. We share this idea at modeling of robot control. The main purpose of teleoperation is sending task related information including product model data to intelligent remotely controlled robots. At the same time some results of human decisions are communicated too. Remote control uses information feedback from the robot control. Safe operation can be achieved following this approach. Application of product models are equally important at programming, teleoperation and teleinspection of robots.

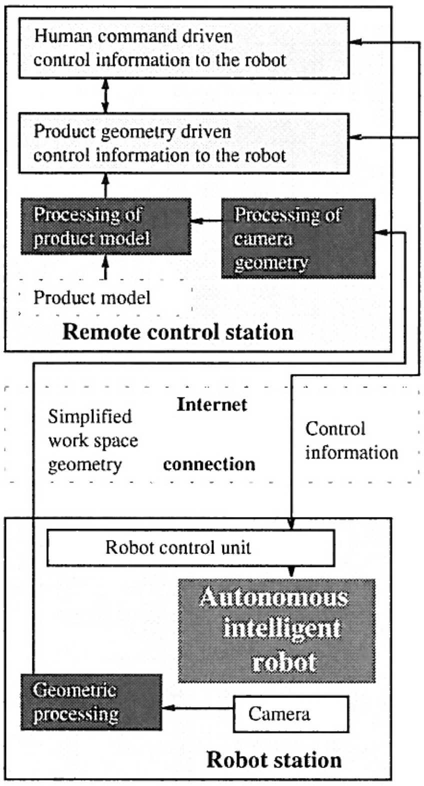

Fig. 4. The process of teleoperation of a robot

The robot control system considered by the authors can be followed on Fig. 4. Because teleoperation is driven by geometry of parts both in the product and the robot station, the model complex has components on both sides. One could think that the objective is a fully automated system, consequently remote inspection and monitoring using a vision system as used in manually controlled teleoperation are not necessary. This is a misunderstanding the real world robot control tasks. Human communication can not be omitted because human interactions are necessary. Inspections and 'dry run' tests, for example, are interactive activities. Manually controlled robot operations are necessary during manufacturing operations. In the every day practice a mix of human and model driven controls is applied. Effective user interface and visual navigation are inevitable in order to establish effective interactivity.

The second way of the communication between the product modeling and the robot control computer is about characteristic shape information gained from processing of video from the robot workspace. This information can be used for calculation of actual and real position information. Recognition of 3D curved and other objects is of basic importance. At the same time robot movements can be viewed using controls as zoom, image quality, and size. This requires appropriate speed of data transfer. Consequently, control is basically done by using of product model data while a feedback is established on the basis of characteristic elements information extracted from pictures.

Teleoperation of robots is considered to establish over the World Wide Web. Telerobotics server processes requests of the teleoperating client. Appropriate configuration and operation of a Web server are basic requirements. Web users must be able to control the robot remotely. Experiments on telerobotics to reveal some basic characteristics of the control and the related communications under given circumstances can be conducted by using of telerobotics interface to simulated robots.

5. Integration of remote robot control with product modeling

Integration of different modeling and model application procedures as part modeling, manufacturing process modeling, production equipment modeling, data and human communication modeling and robot control modeling means application of common framework, data base, user interface and other resources for these activities. Remote elements of the above outlined system complex and the related activities as telerobotics are integrated by the application of Internet technology including appropriate protocols as TCP/IP. Computer resources are distributed amongst product design sites, production planning sites, job shop level and outside robot control units. They may be installed in different buildings, in different cities, in different countries or even in different continents. Significance of teleoperation is growing because of the trend for enlarged distances between cooperating industrial organizations. Computing activities in the actual robot related task complex are distributed amongst these resources. The applied computer model can be considered as a special production model with a lot of associativity and constraint definitions.

One of main benefits of the above outlined approach is processing model data in its original creating system. Reconstruction of the exchanged model by a modeling system other than the original modeling system, with lower modeling capabilities resulting deterioration of the computer descriptions is eliminated. This solution also eliminates problems associated with entity conversions of the conventional model data translation between different modeling systems. An other advantage of the method is that original human creator of the model can be present at its application. Finally, it is generally impossible to make available as highly flexible and enough sophisticated modeling system at normal robot applications as available at product development environments. The modeling environment handles all information and software tools for simulation including description and analysis of kinematics as well as advanced graphics.

6. Conclusions

An approach and methodology have been outlined in this paper. The related research of the authors is motivated by advancements in technologies applied by Internet based telerobotics. These technologies have been developed to a level, where widespread industrial application is a realty. The authors investigated some aspects of product model driven teleoperation of robots on the basis of their earlier researches in product and production modeling as well as robot control. The final objective is to establish a robot control that utilizes advancements in product modeling and information from product models existing in engineering design environments. The main contribution by the authors is about integration of different modeling processes. A model of robot process was offered by the authors together with associative integration of robot control systems with product modeling systems. This paper outlined the problem complex and discussed some details of the related modeling. Intelligent autonomous robot system and mixed human and model driven control system with feedback are assumed. Wide range of potential applications of the method involve manufacturing such as machining, assembly, welding and painting, working in geometrically modeled hazardous environment as well as product development related robot experiments.

Acknowledgments

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