Shape Representation and Interoperability for Virtual Prototyping in a Distributed Design Environment

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Internet technology opens up another domain for building a future CAD/CAM environment. The environment will be global, network-centric, and spatially distributed. In this paper, we present an approach to network-centric virtual prototyping (NetVP) in a distributed design environment. The presented approach combines the current virtual assembly modelling and analysis technique with distributed computing and communication technology for supporting virtual prototyping activities over the network. This paper focuses on shape representation and interoperability of product models for distributed virtual prototyping. STEP standard and CORBA-based interfaces allow bi-directional communication between the CAD model and the virtual prototyping model, which makes it possible to solve the problems of interoperability, heterogeneity of platforms, and data sharing. STEP AP203 is used as a means of transferring and sharing product models. In addition, Attributed Abstracted B-rep (AAB) is introduced as 3D shape abstraction for transparent transmission of 3D models and for the maintenance of naming consistency between CAD models and virtual prototyping models over the network.

Keywords: Assembly modelling; Feature-based modelling; Network-centric CAD; STEP; Virtual prototyping

1. Introduction

Internet technology opens up another domain for building a future CAD/CAM environment. The environment is global, network-centric, and spatially distributed, which enables product designers to communicate more effectively, obtain, and exchange a wide range of design resources during product development [1]. This improved communication technology has lessened the impact of physical distances on design tasks and has resulted in the reconsideration of design activities where design tasks are geographically dispersed. One of these activities is virtual prototyping (VP) which analyses a product without actually making a physical prototype of the product. The term virtual refers to the fact that the design is not yet created in its final form but that only a geometric representation of the object is presented to the user for observation, analysis and manipulation. This prototype does not necessarily have all the features of the final product but has enough of the key features to allow testing of the product design against the product requirements [2,3].

Virtual prototyping typically involves analysing computer-aided design models for different end applications such as manufacturability or assemblability analysis. Such analyses may be performed with the aid of system modules (or agents) which can reside in a distributed fashion on the Internet. This distributed environment represents a unique application for the World Wide Web (WWW). In recent years, the Web has been used very extensively for a large variety of applications. In principle, the Web reduces the distance between:
1. Several designers.
2. Designers and software programs.
3. Different software programs that need information from each other [4–8].

Several papers have addressed ways in which a computer-network oriented design environment will be able to support product designers and suggest what a computer-based design tool or system should look like in such an environment [2,9–13]. However, these papers are conceptual in nature and do not provide well-structured representation and detailed algorithms. For instance, they have not addressed how to distribute the necessary processing among distributed components, and how to transmit the shape abstraction of 3D geometric models over the network. The shape abstraction should support efficient transmission of 3D models and contain the necessary information for supporting various distributed activities such as assemblability analysis, naming consistency between the server and clients, and 3D geometric constraint solving. For this reason, it is important to develop a well-integrated, network-centric, and agential architecture for interoperability and shape abstraction for collaborative and distributed virtual prototyping activities.
In this paper, we present a new approach to network-centric virtual prototyping (NetVP) in a distributed design environment. The approach presented combines the current virtual assembly modelling and analysis technique with distributed computing and communication technology for supporting virtual prototyping activities over the network. The approach presented is implemented in a client/server architecture in which Web-enabled NetVP clients, a neutral NetVP server, and other applications communicate with one another using a standard communication protocol for accessing remote objects.

This paper focuses on interoperability and shape representation of 3D CAD models in network-centric virtual prototyping. As a service provider, the NetVP server offers the functionalities needed for virtual assembly modelling and analysis, and it is shared among multiple clients. The NetVP server consists of four major modules: geometric computing; client-side processing; shape abstracting; and communicating. The geometric-computing module corresponds to the direct creation, modification and various geometric processing of assembly models in the server-side. The client-side processing module provides a means by which the user can perform various activities in the client-side without interactions with the server. However, for geometric processing that cannot be supported by the client-side processing module, the client can invoke the services of the geometric computing module through the channel provided by the communicating module. The shape abstracting module provides shape abstraction for transparent transmission and communication of geometric models between the server and clients over the network. The communicating module provides a "plug and play" environment in which different applications can be built, independent of both the geometric modelling system and platform.

The architecture of the NetVP which is based on the DCA concept is shown in Fig. 2. It consists of a NetVP server, a DCM server, Web-enabled NetVP clients, and a CORBA-based standard communication protocol. The NetVP server offers the functionality needed for assembly analysis and modelling and is shared among multiple Web-enabled NetVP clients. It consists of NetVP agent man-

2. System Overview

2.1 Conventional VP Model

State-of-the-art CAD/CAM technology enables the capture of user design intent through the use of assembly constraints, features, parameters, etc. However, owing to the large size of CAD models, engineers use other virtual prototyping methods for visualisation and complete assembly analysis. To do this, the CAD models are tessellated using preparation tools, as shown in Fig. 1. The mathematical surface models are reduced to triangular approximations and extensive assembly constraints are reduced to transformation matrices. Although this provides sufficient data to the visualisation program, important engineering data are lost, such as constraints and original design intent.

In the VP systems, the user has access to tools that allow the modification of data in the virtual prototyping environment. The user can select a part or subassembly and move it in the environment in a constrained or non-constrained manner. However, in order to maintain model validity, procedures must be developed to transfer these modifications back to the CAD system while maintaining the design intent of the original CAD model [9]. Another problem is that a time lag is involved since the two models are separated. For that reason, the model must be loaded into the CAD system again, the changes must be made, then the model must be regenerated, and the new geometry file must be re-imported into the VP system. This process is time-consuming since this change cannot be made and displayed in real-time. Moreover, the VP system may generate wrong information owing to the lost design intent, the model approximation, and the mono-directional information flow.

Moreover, when the system is implemented over the network, the large CAD model must be duplicated and shared by transmitting the model to the clients involved. The duplication and transmission of the original model make it difficult for the participants to collaborate with each other owing to the network delay and the overhead. Thus, the model to be transmitted must be compressed but must be compact enough to contain the necessary information for VP. Unfortunately, there are few papers dealing extensively with these issues in the network-based VP.

2.2 Proposed VP Model

The underlying principle in developing our network-centric virtual prototyping (NetVP) system lies in a distributed computing architecture (DCA). In the DCA, various computations required in virtual prototyping are distributed and decoupled between the server and clients rather than the server having the responsibility for serving all the computational requests from their clients. The DCA consists of four major modules: geometric computing; client-side processing; shape abstracting; and communicating. The geometric-computing module corresponds to the direct creation, modification and various geometric processing of assembly models in the server-side. The client-side processing module provides a means by which the user can perform various activities in the client-side without interactions with the server. However, for geometric processing that cannot be supported by the client-side processing module, the client can invoke the services of the geometric computing module through the channel provided by the communicating module. The shape abstracting module provides shape abstraction for transparent transmission and communication of geometric models between the server and clients over the network. The communicating module provides a "plug and play" environment in which different applications can be built, independent of both the geometric modelling system and platform.

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