E-manufacturing in networked virtual environments.

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Abstract

E-manufacturing as a new generation of product development solution allows manufacturers all over the world to speed up and slim down everything from design to manufacturing. It has been employed in a wide range of manufacturing activities. Networked Virtual Environments (Net-VEs) have already begun to foster an insightful, intuitive and interactive system that allows effective communication among multiple users. After exploring the architecture and features of Net-VEs, a cost-effective approach to create an e-manufacturing system in Net-VEs is proposed in this paper. The World Wide Web (WWW) as the delivery mechanism has made such system widely available and affordable. We also evaluate an e-Manufacturing system in Net-VEs by comparison with a traditional product development approach.

Keywords

E-manufacturing, networked virtual environments (Net-VEs), WWW, VRML.

1 Introduction

During the rapid evolvement of the approach to product development, enterprises attempt to create a distributed design and manufacturing environment that enables integrated concept design, process planning and manufacturing. At present, e-manufacturing has been an effective method for communication and sharing of information related to design and manufacturing throughout the entire enterprise and the supply chain via the Internet. Not only does it save money and shortens the time-to-market, but also brings significant competitive advantages.

E-manufacturing as a new generation of product development solution allows manufacturers all over the world to speed up and slim down everything from design and procurement to manufacturing and logistics. It has been employed in a wide range of manufacturing activities: product design and prototyping; factory layout design and visualization; assembly process planning and simulations; and so forth. Certain strategies and some specific technologies such as computer-aided design (CAD), computer-aided process planning (CAPP) and computer-aided manufacturing (CAM) are involved in an e-manufacturing system. An innovation technology—Virtual Reality (VR), as a 3D visual and interactive solution, has been integrated in the latest CAD/CAPP/CAM system to aid product development [1, 2]. Networked Virtual Environments (Net-VEs) allow multiple users to access and manipulate objects in a virtual world by incorporating the advanced network technology. Users, who are at distributed sites, can interact with such virtual environments through a common user-interface. Being able to deal with distributed environment and databases, Net-VEs has begun to foster an insightful, intuitive and interactive system that allows effective communication among users. The aim of our research is to propose a cost-effective approach to create an e-Manufacturing system in Net-VEs.

The following section presents the architecture and features of Net-VEs and then some challenges in this area. Section 3 proposes a cost-effective approach to create an e-manufacturing system in a Net-VE by using the World Wide Web (WWW) along with the related techniques. Section 4 summaries the advantages of an e-manufacturing system in a Net-VE. Finally, section 5 draws some brief conclusions.

2 Networked Virtual Environments

Net-VEs could provide users with an adequate level of realism, create a sense of presence along with an immersive experience from high performance computer graphics and stereo sound. Recent research has shown us Net-VEs' powerful potentials. For example,

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Flerackers et al. created an interactive drama in a Net-VE [3]. This project developed ten episodes of an interactive television drama series, which allowed children to explore opportunities for participation using a networked virtual environment. It bridged the gap between the conventionally passive medium of television and the interactive medium of Internet. Manchester Visualization Center took advantage of Net-VEs for surgical training on the WWW [4]. Moreover, most networked games such as Ultima Online [5] have served as inspirations to the Net-VEs community. They become more and more popular in game market by taking advantage of Net-VEs to attract multiple players.

Due to the involvement of the multiple independent users, it is obvious that Net-VEs not only serves for the single user as the standard virtual environments, but also benefits more users and applications. In addition, the ability to share 3D objects differentiates Net-VEs from traditional chat rooms and E-mails, and the ability of real-time interaction differentiates Net-VEs from typical Web Browsers.

There are four key components in Net-VEs. They are VR engine, VR database, interaction devices, and network connection. These components work together to provide the advantages of a Net-VE to users at different sites. Figure 1 shows the architecture of a generic Net-VE and outlines the connectivity between these main components.

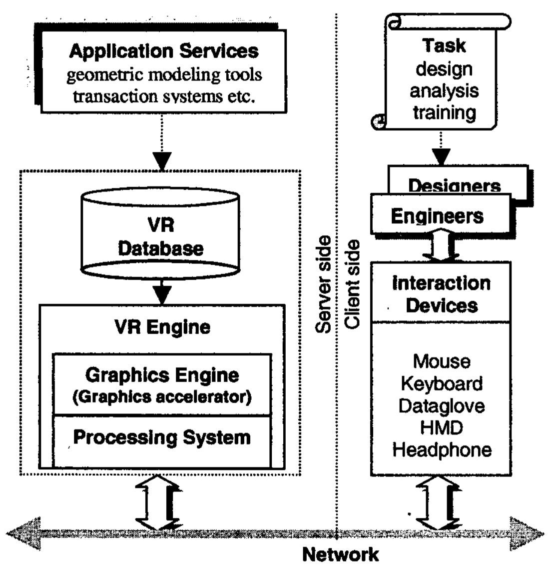

Figure 1 The integration of various components of a generic Net-VE

I. VR engine

The VR engine consists of a graphics engine and a processing system. The graphics engine is responsible for mapping, creating texture, lighting, rendering and displaying the realistic images in real time. The processing system has the ability to process huge amount of data calculation associated with object dynamics and physical constraints, collision detection, Level of Details (LOD), etc. It is also responsible for coordinating various I/O controls supplied by users and communication among multiple users. Therefore, the VR engine can be regarded as the infrastructure of a Net-VE. Normally, the VR engine can be implemented on the multiprocessor graphics workstations. With the advent of graphics accelerators, sufficient graphics capabilities have become available on standard PCs.

II. VR database

A VR system provides a domain where a virtual world can be modeled, simulated, visualised and even experienced using immersive display [6]. The computer-generated virtual world provides the domain created by geometric descriptions of objects in the real worlds. In other words, a VR system consists of a collection of 3D objects and light sources, which are manipulated by animation and physical simulation procedures. Thus, the synthetic virtual world need to be modeled off-line using dedicated software libraries and databases. Such VR database describing virtual objects is stored on disk and loaded into system memory whenever required. The more complex scenarios are needed in a VR system, the larger databases have to be created. For a very large scene, only that portion potentially visible to the user is loaded – the rest resides on disk and is copied as and when needed. In order to ensure image generation in real time, it is necessary that the size of the active part of database be kept to a minimum.

III. Interaction devices

Interactions between users and the VR engine are achieved by using various I/O and communication devices. By using the most common input devices, such as mouse and keyboard, a VR system allows the user to manipulate 3D virtual objects in real time and to navigate through the environment. In addition, there is a wide range of more effective devices available to support a VR task. Typically this includes head-mounted displays (HMD), 3D trackers, headphones, sensing gloves and even haptic devices.

IV. **Network connection**

Network plays an essential role in a Net-VE. It distinguishes a Net-VE from a standard VR. Multiple users in a Net-VE rely on the network to share and exchange information. At the same time, the network also supports audio and video communication among users.

Generally, a Net-VE should have the following common features [7]:

- All participants have a sense of being in the same space, for example, in the same workshop, laboratory, or building. The shared world must present the same characteristics to all participants such as surface properties, dynamic properties, physical constraints, acoustic properties and even illumination model.
- All participants should get a sense of presence when entering a Net-VE. They have the illusion that they are in the virtual world. All of them can manipulate virtual objects. They have the same abilities and behaviors such as picking-up, moving, dragging and so forth.
- Not only should participants be able to navigate the shared virtual world at the same time, but also they can interact with the shared virtual world in real time.
- It is necessary for a Net-VE to provide a common communication facility. This allows participants to communicate with each other and exchange information in time. It can be implemented in the form of typed text or voice.

There are some challenges in a Net-VE because of the involvement of various existing application services such as geometric modeling tools, database systems and other transaction systems. For example, because of the limitation of network bandwidth, both an over-complex 3D object with huge counts of polygons and very high-resolution image mapped on virtual objects can lead to display latency. The latency can result in the loss of the feeling of immersion. Network bandwidth is limited although it has got rapid growth in recent years, especially for the user, who connects to a Net-VE via a modem connection. Various 3D graphics data formats also create a barrier for sharing a 3D virtual world and exchanging information. In addition, a Net-VE requires a high-end, platform independent interface for the accesses of various users on different platforms such as Windows 95/98, Windows NT or Unix. If a Net-VE is executed within the Web browser over the Internet, deployment issues should ensure that the environment can easily be downloaded and is compatible with different browsers.

In addition, Net-VEs raise challenging research questions on interaction issues. Higher level interaction (e.g. cognitive, motivational) still has not been achieved in Net-VEs although researchers and practitioners have made effort underway to address the natural way of rich interaction issues [8].

3 A Cost-effective Approach to an E-manufacturing System

Exploiting the architecture of a Net-VE and its features, no doubt an e-manufacturing system in Net-VEs is a powerful solution for manufacturing applications, which demand not only the share of data at distributed locations linked by network, but also the creation of remote 3D realistic representation and real time interaction.

In conjunction with Internetworked 3D graphics techniques such as VRML, a cost-effective approach to create an e-manufacturing system in Net-VEs by using the WWW is presented here. The Web-based e-manufacturing system allows users to access integrated manufacturing environments. Such integrated environments simulate actual manufacturing applications that can be interacted with through the WWW. Figure 2 shows the structure of our e-manufacturing system. The system consists of a web server and an interface for the Internet access. The server includes a virtual manufacturing application environment along with the databases required. The system relies on the Internet as the primary medium to create a shared environment for its distribution. Using standard Web browsers as an execution engine for the e-manufacturing system, it enables multiple users such as engineers, machinists and trainees to remotely access, navigate and interact with manufacturing applications represented in 3D virtual worlds at different global sites via the Internet.

The Virtual Reality Modeling Language (VRML) as an International Standard (ISO/IEC 14772) [9] provides a tool for the description of interactive 3D scenes delivered across the

Internet. In the e-manufacturing system, VRML is used as the visualisation integration technology to present manufacturing applications on the Web. The 3D scenes in VRML 2.0 can be delivered across the Internet. A VRML world browser such as Cosmo Player can be embedded into the normal Web browser such as Microsoft Internet Explorer (IE) or Netscape to access these virtual worlds.

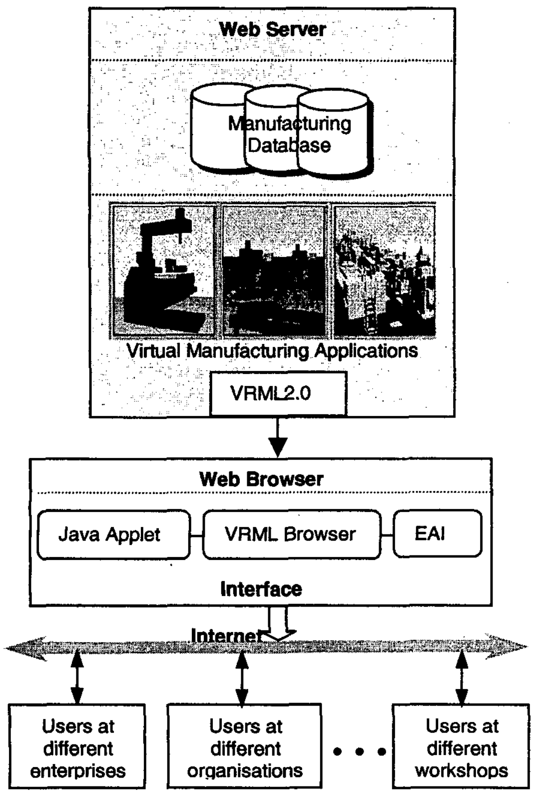

Figure 2 The structure of an e-manufacturing system in a Net-VE by using the WWW

The e-manufacturing system provides a Web-based graphical user interface (GUI) which is made up of VRML browser, Java applet and the External Authoring Interface (EAI) [10]. EAI has the mechanism to communicate between Java applet and a VRML scene graph. As an input tool, the Java applet can execute the EAI to update a VRML scene and communicate between the client and server. In this way, the interface allows users to interact and communicate with a manufacturing application provided by this system. The system focuses on the following items:

- Represent the characteristics of a manufacturing application.
- Simulate a dynamic process in a 3D space.
- Share/Interact with 3D data and information in real-time.
- Reduce the risk of setting up a manufacturing system.

Since the manufacturing activities are diverse, the following three application prototypes have been developed based on the above approach. Figure 3 shows some snapshots of virtual manufacturing worlds, which represent these manufacturing applications through the Cosmo Player.

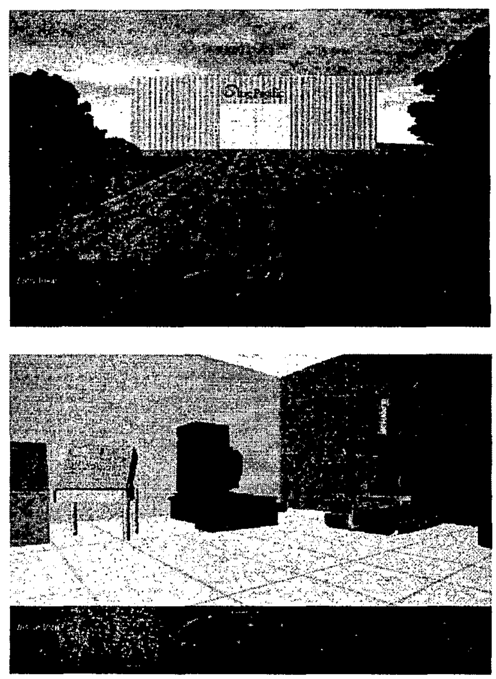

Figure 3 Some snapshots of virtual manufacturing worlds

I. Machining

This application facilities the visualisation and analysis functionality of a machine. It emulates components, tools, controllers and workpiece along with a machining process in a 3D visual way. It enables users to preview and explore a new or valuable machine in virtual environments before its purchase. It can be used to train engineers and machinists on the processes of a machine set-up, tool change and production programs.

II. Process planning

This application is designed to represent a process flow in a virtual workshop. It aids the process planning by using process flow simulation and analysis. It can be used for reducing risk and shortening the cycle of product development before establishing a real process flow.

III. Workshop layout

This application aids engineers in the design of the work places and equipment layouts prior to the start of production. An optimal factory layout design according to the rules of ergonomics could maximize the efficiency of workers and improve the equipment's performance.

In further work, more manufacturing applications will be added to enrich the e-manufacturing system. The Web-based e-manufacturing system will be improved with the advent of more effective Internetworked 3D graphics techniques [11] such as next-generation VRML (VRML-NG), MPEG-4, X3D and so on.

4 Evaluation

Compared to a traditional product development approach, an e-Manufacturing system in Net-VEs has considerable advantages:

- Permits sharing a large virtual manufacturing database on a server among distributed users by network.
- Allows interacting with a virtual world in real-time.
- Performs on a wide variety of computing platforms.
- Handles large numbers of users in a large-scale virtual environment.
- Supports multiple users access for collaboration working.

5 Conclusions

The Web-based e-manufacturing system allows engineers and designers to visualise, explore, manipulate and interact with manufacturing applications in a Net-VEs. In addition, it allows industrial users to easily apply and share the manufacturing 3D data through the WWW. By reducing costs and cycle time of product development, such an e-manufacturing system will speed up the major activities of manufacturing engineering including simulating manufacturing processes; optimising assembly lines and workshops design; integrating labor and equipment; and hence producing better quality products in a shorter time at more competitive price.

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