An Evaluation of Internet-Based CAD Collaboration Tools

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During product design, over 80% of engineering changes are needed because designed parts cannot be manufactured or assembled (Stevens, 2001). Most of the design errors are due to lack of communication between the design team and manufacturing experts. To reduce communication problems and, thereby, increase product quality and reduce production costs, industry has turned to concurrent and collaborative engineering methods (Prasad, 1996). However, in today's global market, designers and manufacturers are often geographically separated. Thus, designers, manufacturers, and suppliers need powerful communication tools so they can exchange design information effectively (Jones, Schwemin, Dorneich, & Dunmire, 2000).

The objectives of collaborative design include optimizing the mechanical function of a product, minimizing production or assembly costs, and ensuring that the product can be easily and economically operated and maintained. Effective collaboration tools can help resolve product design conflicts early in the design stage. As a result, product development, lead-time, and manufacturing cost can be greatly reduced. Thus, companies that use collaborative design tools realize many benefits. For example, by using a collaborative design tool to create its LBP-1210 laser printer, Canon was able to reduce design iterations, total cost, and lead-time (www.cocreate.com). Hewlett-Packard found that using a collaborative design tool helped immediately reduce overseas travel costs. Overall, using a collaborative design tool helped HP achieve a 135% return on investment (ROI) after one month and 240% after three months (www.cocreate.com).

Modern design teams often use CAD/CAM (computer aided design and computer aided manufacturing) tools to help facilitate their design process, from conceptual design stage to final production. Different companies or design partners may use different CAD/CAM tools. Since most existing CAD/CAM applications were designed to work in an isolated environment, inconsistent file formats often cause problems during information exchange.

Due to the now widespread use of the Internet, most companies now require CAD tools that support distributed collaborative design on the Internet (Lavana, Brglez, Reese, Konduri, & Chandrakasan, 2000). Such CAD tools should enable designers to share product models, as well as related data, from geographically distant locations (Shyamsundar & Gadh, 2001). However, integrated collaborative design capability over the Internet has not fully matured. For example, Potter (1997a) found that security and authentication are still major concerns when transferring CAD files over the Internet. Designers or companies need to protect intellectual property (Fornaro & Sanna, 2000).

This article determines the Internet-based collaborative design capabilities available in modern CAD tools, outlines the major problems that still need to be addressed (e.g., version control, data translation and repair, and security and legitimacy issues), and recommends directions for future research.

Collaborative Design

According to Wang, Shen, Xie, Neelamkavil, & Pardasani (2001), if a product is designed through the collective and joint efforts of many designers, the design process used can be called collaborative design. The collaborative design process might include all design activities from concept creation through product definition, detailed design, manufacturing, assembly, maintenance, and even product retirement. Furthermore, some companies may enhance the collaborative design process by involving their customers, suppliers, and partners, over the Internet, throughout the product development and delivery process (Waltham, 2000).

Due to the often distributed nature of modern, Internet-based collaborative design processes, many different CAD tools may be used by a collaborative design team. When design teams use different CAD tools, problems often arise because different CAD tools still use different native file formats. For example, Autodesk Inventor generates part files in .ipt file format, and Pro/E generates part files in .prt file format. If design team members must share data stored in both file formats, a problem in model consistency might exist. Data communication problems due to using the Internet as a communication channel may also exist.

Therefore, collaborative CAD tools need a common, secure communication framework and protocol so that CAD files can be transferred safely and accurately. To meet the need, many CAD tools have recently added at least some of the following collaborative design capabilities: (a) real-time communication, (b) support for various CAD formats, (c) tools for publishing 2D/3D CAD designs on the Web, and (d) tools for manipulating CAD models outside the original CAD program.

Real-Time Communication

The Internet is probably the most convenient medium available for sharing CAD files in real time. CAD program vendors have begun to

use the existing power of the Internet and many existing Internet-based communication tools to improve the collaborative capabilities of their CAD programs. For example, to help designers share design data and models over the Internet, CAD vendors have begun to incorporate Internet-based conferencing and real-time 3-D model viewing tools directly into their products (Shyamsundar & Gadh, 2001). Autodesk integrates Windows NetMeeting into the latest version of Inventor. NetMeeting includes chat, whiteboard, program sharing, file transfer, remote desktop sharing, security, and video and audio conferencing. Thus, Autodesk Inventor users have online real-time communication capability available within the Inventor design environment. Table 1 provides a summary of collaborative functions available in Windows NetMeeting (Microsoft, 2001).

Toc20151059Windows NetMeeting remote desktop sharing allows a remote user to run a CAD program, which has been installed on a local computer, over the Internet. With remote desktop sharing, the remote user can use the local CAD program, running on the local machine, without having to install a copy of the CAD program at his or her remote site. As a result, the remote user can participate in a collaborative design session while at the same time reducing CAD program investment costs.

Support for Various CAD Formats

To share CAD files, collaborative design teams often must transfer CAD data from one CAD tool to another over the Internet. To deal with the issue, collaborative designers can store design files in a neutral file format. For example, if Company A in the U.S. uses AutoDesk Inventor while Company B in Japan uses Pro/E, with current versions of Inventor and Pro/E, Company B could not read an Inventor .ipt file sent via the Internet by Company A. However, for successful collaborative design, Company A could save its CAD files in STEP (or another neutral file format) and then transfer the resulting STEP files to Company B via the Internet. Most modern CAD tools currently support several design file formats to improve their compatibility with other CAD tools. SolidWorks, for example, supports IGES, DWG, VRML, STL, VDA, SAT, DXF, and STEP file formats.

Tools for Publishing and Viewing 2D/3D CAD Designs on the Web

Distributed design teams need tools that address critical communication issues that are not addressed in stand-alone CAD tools. Often, for distributed design teams, customers, suppliers, vendors, and development partners who do not have CAD tools or CAD-tool expertise need to view and evaluate developing designs. To solve the problem, CAD vendors have begun to develop tools for publishing designs on the Web. For example, Parametric Technology Corporation () now offers a stand-alone tool called ProductView, which allows customers and other distributed design team members to preview designs on the Web, thus reducing product design and modification time and cost.

Tools for Manipulating CAD Models Outside the Original CAD System

Some CAD vendors offer stand-alone tools that provide more than just viewing capability. With tools for manipulating CAD models outside the original CAD environment, collaborative design team members without CAD tools or CAD-tool expertise can quickly and efficiently review design models. Manipulation tools allow

Table 1. Summary of Collaborative Functions in Windows NetMeeting.

FUNCTION	KEY FEATURES
Chat	Conducting multi-user real-time conversations using text
Whiteboard	Communicating in real time using graphics
Program sharing	Sharing programs during a conference
Remote desktop sharing	Operating a computer from a remote location
File transfer	Sending files in background mode during a NetMeeting conference
Security	Using security measures to protect privacy
Video and audio conferencing	Communicating on the Internet using video and audio

Table 2. Viewers Provided by CAD Companies.

Company Product	File Format Supported	Tools for Publishing CAD Designs on Web	Add Note/ Mark Up	URL
Solid Concepts SolidView	· Object (.obj) · SolidFile Exchange (.sfx) · SolidWorks (.sldprt, sldasm) · Stereolithography (.stl) · VRML (.wrl)	N/A	✔	http://www.solidview.com
Parametric Tech. Corp. ProductView	· CADD · Pro/E · DWG · SW · IDEAS · UG	✔	✔	http://www.ptc.com
EDS Solid Edge Web Publisher	· 3D IGES/2D IGES · VRML · DXF · DWG	✔	Object	http://www.solid-edge.com/
SDRC Metaphase 3.2	· BMP · DXF · CGM · GIF · DWG · HPGL	✔	Object	http://www.sdrc.com/ metaphase/index.shtml
SolidWorks eDrawings Professional	· SolidWorks 2001 SP10 or higher · AutoCAD 2000, · AutoCAD R14.x · AutoCAD Mechanical R14.5 · SolidWorks design data · AutoCAD design data	✔	✔	http://solidworks.com
SolidWorks SolidWorks Viewer	· IGES · DXF · DWG · STEP · VRML · Parasolid® · STL, ASCII, or binary format · VDAFS (VDA) · SAT (ACIS)	N/A	N/A	http://solidworks.com
Autodesk Volo View	· DWG (AutoCAD-base) · DXF · DWF · Raster drawings · Inventor (.ipt .iam .idw)	N/A	✔	http://usa.autodesk.com

users to translate, rotate, pan, zoom, and mark-up CAD models.

As an example, Autodesk offers Volo View Express, a free tool for viewing and manipulating Autodesk-format CAD files without Autodesk CAD tools installed. Volo View Express allows users to open, view, make light-weight markups, and print CAD designs. Volo View Express supports Autodesk DWG, DXF, and DWF (ePlot and eView) file formats. With an additional downloadable Autodesk Inventor plug-in, VoloView allows users to view and print Autodesk Inventor part, assembly, and drawing

files without Inventor installed. Table 2 presents a list of tools offered by major CAD vendors for viewing and manipulating CAD files and the corresponding supported file formats.

Some third-party companies also provide CAD tools for viewing and modifying different types of CAD files online. For example, OneSpace Designer (from Cocreate Corp., www.cocreate.com) and IX SPeeD Suite (from ImpactXfot, www.impactxoft.com) allow users to load, view, inspect, and modify different types of CAD files during concurrent and collaborative design projects.

Issues in Collaborative Design

Update Issues

While working on a project, collaborative designers frequently make changes to parts that are being accessed at the same time by others working on the same project. One of the biggest problems with many Internet-based collaboration tools is that they do not have built-in multi-user version control capability. As a result, users can mistakenly use an older version of a file, rather than the latest version. Drawings may be sent out and considered final when they actually are not. Therefore, efficient collaborative design tools must support inconsistency prevention and detection (Despres, Piloty, & Schellin, 1993).

Many existing single-user CAD tools allow the user to set model version numbers to help track any design changes made during the product development process. Each time a model's content is modified and saved in a working file, the tool assigns a new version number to the working file. A new version of the model is created each time the file is saved. Usually, the CAD tool, after the number of saved versions reaches a maximum limit (for example, 10 in AutoDesk Inventor), discards the oldest version of the model whenever a new version is saved. The user can then open, view, and modify any saved version of the model.

To allow multiple users to access the same files, AutoDesk added a multi-user option to Inventor. Users must select the multi-user option before starting work on a collaborative project. With the multi-user option selected, all members of a group can access the same project files. AutoDesk Inventor also enables safeguards when several users are editing the same files.

After a user activates the file reservation system and warning functions inside AutoDesk Inventor, Inventor automatically reserves any new files the user creates for that user. If another person attempts to edit a reserved file, a warning message alerts the person for whom the file is reserved.

Data Translation and Repair Issues

In a collaborative design environment, team members might use different design software when working on a model. A major problem with using various heterogeneous CAD programs is lack of interoperability between the systems (NIST). Data translation issues cause many concerns (Potter, 1997b). For example, a designer could receive three parts from three different design team members in three different file formats, e.g., an Inventor (.ipt), a Pro/E (.prt), and a STEP (.stp) file. To combine the three parts into a single design, the designer would need to translate all the files into a format supported by his or her CAD tool and then import the parts into his or her CAD tool.

The design team could eliminate both the problem due to mismatched file formats and the time required for data translation by saving and transferring CAD part designs in a neutral file format (e.g., STEP or IGES). However, saving and transferring CAD files in neutral file format does not remove problems with internal data consistency.

Since different CAD tools often use different internal accuracy levels, a target system may not be able to recognize an imported model as a solid body after data conversion. Errors such as cracks, degeneracy, duplication, holes, and overlaps usually occur in the models when users import them from other CAD tools (Barequet & Kumar, 1997). Upgrading a low-resolution solid model into a high-resolution solid model can be a difficult problem. Often, users need an expensive repair and healing tool to make the model usable (Farrell, 1999). In addition, state-of-the-art healing tools often cannot successfully repair imported CAD models.

A 1999 study by RTI International (http://www/rti.org) estimated that imperfect interoperability imposes costs of at least $1 billion per year on the U.S. automotive supply chain alone; other industries face similar difficulties.

Internet Security and Legitimacy Issues

With the explosive growth in Internet use, network security has become an inevitable concern for a growing number of organizations (Yu & Le, 2000). Since CAD files often serve as legal documents, cautious CAD users may not be willing to use any tools that create a risk of exposing their designs to outsiders (Hauck & Knol, 1998). Users often express concerns about having their files stolen during transmission (Farrell, 2000), and many people are not totally comfortable when sending information across the Internet. Users often believe that if a file is sent over the Internet, someone might steal or modify the file. Indeed, some surveys already indicate that many companies are not willing to use the Internet to transfer their CAD data (Potter, 1997a). Thus, in the future, collaborative CAD tools must offer more capabilities for securing files and encrypting models.

Speed Issues

Speed is another issue facing Internet-based CAD researchers and developers. Today's fast Internet connections allow almost immediate response for low-density data. However, CAD data generally contains a large amount of information in every file. As a result, current collaborative CAD tool users need to, but currently cannot, see design animations in real time. Without even higher-speed Internet connections, collaborative CAD users might find their modeling experiences very frustrating. Therefore, in order to manipulate CAD models in real time, more advanced communication hardware and software are required.

Conclusion

Growing Internet use has led to Internet-based collaboration functions in major CAD packages. With currently available capabilities, users can exchange and share CAD files in real time using Internet-based conferencing utilities. Furthermore, some major CAD vendors now offer tools for publishing 2D/3D CAD designs on the Web and for viewing and manipulating CAD models outside the original CAD program. With CAD model Web publishing, viewing, and manipulating tools, collaborative design team members can communicate effectively, even from different geographical locations, without purchasing or installing separate copies of the CAD tool(s) used. Most major CAD tools now offer support for saving and importing CAD files in several different file formats (in particular, neutral file formats such as STEP and IGES), which is a critical feature for collaborative design. With neutral file format capability, collaborative CAD file exchange over the Internet is becoming easier.

Remaining problems facing collaborative CAD tool researchers and developers include technical difficulties related to data translation and file security. Data translation often leaves cracks, degeneracy, duplications, holes, and overlaps in models. Security issues on the Internet leave many companies concerned that their designs might be lost, stolen, or modified when transferred over the Internet.

Improved Internet-based collaborative CAD tools can enhance communication in the CAD/CAM industry. As a result, collaborative CAD tools can also reduce product development and manufacturing costs. As Internet use becomes more widespread, Internet and computer networking capabilities will continue to improve. However, capabilities in collaborative tools for CAD/CAM design need to improve as well. A review of current collaborative CAD capabilities shows that although some capabilities exist, further research and development is needed, particularly in the areas of data repair, data integrity, and data security.

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