

# Inter-enterprise collaborative design and manufacturing via WWW/Internet<sup>†</sup>

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## **Abstract**

This paper firstly discusses the architecture on inter-enterprise collaborative design and manufacturing. Secondly, it discusses synchronous and asynchronous collaboration for collaborative design and manufacturing. Then, a tool set for collaborative design and manufacturing by means of audio/video multimedia facilities is conceived and a case study is given.

## **Keywords**

**World Wide Web, Internet, collaboration, enterprise integration  
concurrent engineering, design and manufacturing**

## 1 INTRODUCTION

Manufacturing enterprises today are faced with challenges to reduce product development time, improve product quality, and reduce production lead-time and

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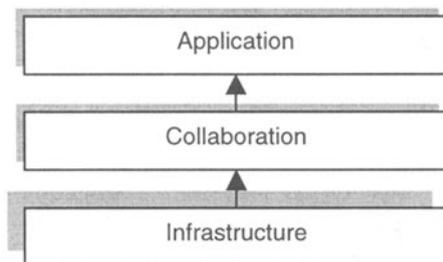
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cost. Increasingly, these challenges cannot be effectively met by isolated effort in a single enterprise. This, in turn, increasingly transforms the above challenges into problems of establishing collaborative efforts among a group of enterprises which consists of a *host enterprise*, a chain of *supply enterprises*, and a cluster of *selling agencies* (Deng, 1997). Those enterprises may *geographically be widely distributed*. Thus, one of the important problems is how to effectively integrate those enterprises, or specially, how to effectively collaborate product design and manufacturing among those enterprises.

## 2 ARCHITECTURE ON INTER-ENTERPRISE COLLABORATIVE DESIGN AND MANUFACTURING

Obviously, those geographically widely distributed enterprises need to communicate with each other to enable their collaboration. Thus, a communication infrastructure is the basic necessity as shown in the lower part of Figure 1 where it is depicted as an *infrastructure* layer. For the purpose of wide area communication, the Internet/WWW (World Wide Web) can be used. The Web provides the most globally available and accepted environment for accessing distributed information sources. The primary success factors of the Web are: (1) its easy-to-use and hypertext-based interface, (2) its increasingly enlarged community, and (3) its platform independence.

To work on collaborative design and manufacturing, *applications* for computer aided design (CAD), production planning and control (PP&C), computer aided process planning (CAPP), numerical control programming (NCP), shopfloor control (SC), cell control (CC) etc. are necessary. Those applications are installed and run on various workstations in various enterprises and communicate with each other via communication network. They reside in the upper layer of Figure 1.



**Figure 1** Collaboration architecture for inter-enterprise integration.

To accomplish collaborative design and manufacturing, in addition to the necessity of communication enabling support, it needs also the aid from *collaboration* tools such as ICQ (I seek you), Microsoft NetMeeting, VDOPhone, Cu-SeeMe (SeeYou-SeeMe), BSCW (Basic Support for Collaborative Work), etc. Those tools reside in middle layer of Figure 1. They are also installed and run on various workstations supporting collaborative CAD, PP&C, CAPP, NCP, SC, or CC applications among enterprises or inside an enterprise.

Actually, those tools themselves are also applications. The difference between the tools and applications mentioned above, CAD, PP&C, ... is that the former is collaboration oriented applications, and the latter is manufacturing oriented applications. And the latter needs the support from the former to realize geographically distributed collaborative design and manufacturing. For distinguishing, we refer the manufacturing oriented applications to as *applications*, and the collaboration oriented applications to as *collaborations*.

### 3 SYNCHRONOUS AND ASYNCHRONOUS COLLABORATION

Collaborations via WWW/Internet can be categorized into *synchronous collaboration* and *asynchronous collaboration*.

*Synchronous collaboration* means that geographically distributed partners of a collaboration team are working in an *on-line* mode. They are working collaboratively at different locations but *at same time*. In some cases, it is called a meeting or a conference. During the meeting, partners can see each other by means of video display on the screen, talk with each other by means of audio phone, exchange ideas by using text or white board, and collaboratively design and manufacture via *application-sharing* mode, or *joint-working* mode.

The meaning of *application-sharing* is that when the "leader" of the meeting is working at an application, e.g. designing a product by using a CAD application, the partners from their own screen can see a copy of what is being displayed on the leader's screen. Meanwhile, the partners can give opinions on the leader's design by means of audio, text writing, white board drawing, etc. to comment that design, but *not directly modifying* the design.

The meaning of *joint-working*, however, is that the partners can also *directly join in on the modification* of the design, in addition to functions of *application-sharing* mentioned above.

*An asynchronous collaboration means that partners* of a collaboration team work in an *off-line* mode, i.e. the partners *do not need to work at same time*. In many cases, the off-line working mode is much preferable, because different people may have different time schedule in daily work and it is difficult to find a commonly agreed period to have a meeting. In such cases, they will preferably work in asynchronous collaboration mode.

In asynchronous collaboration mode, one can work alone, for example, design a product alone. After s/he has completed the work, s/he may store her/his file in some shareable location, then send a message to inform other partner asking her/him to fetch the design data from the shareable location for further working (comment or modification). After further working, the partner, in turn, can store the resulting file into the shareable location, and send a feedback message to the original designer informing her/him that a comment or a modification has been done.

Certainly, after several iterations of asynchronous working, for finalizing the design, it may require to have a synchronous meeting.

To summarize, we would say that both synchronous and asynchronous collaborations are necessary for collaborative design and manufacturing.

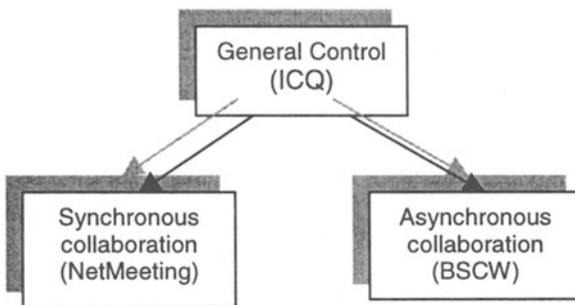
#### 4 TOOL SET FOR COLLABORATIVE DESIGN AND MANUFACTURING AND CASE STUDY

For meeting the requirements of *synchronous* collaboration, Microsoft NetMeeting, Cu-SeeMe, or ICQ can be selected. Taking Microsoft NetMeeting as an example, it's functions of audio chat, text chat, video conferencing, application sharing, whiteboarding, and file transfer (O'Donnell, 1997) will meet the requirements of synchronous collaboration.

For meeting the requirements of *asynchronous* collaboration, BSCW or ICQ can be selected. The BSCW supports group work over the Internet by providing a shared workspace system. BSCW extends the browsing and information download features of the Web with more sophisticated features for document upload, version management, member and group administration, etc. (Bentley 1997).

The ICQ program facilitates the Internet as a two way, interactive, person-to-person global communication system. It enables you to "dial" almost anyone on the Net at your discretion, *without having to make any prior arrangement* with her or him. ICQ supports a variety of popular Internet applications and serves as a platform from which one can launch any peer-to-peer application (such as Microsoft NetMeeting or Netscape Cooltalk). The ICQ program *runs in the background and waits quietly* without interrupting any other application in use. (<http://www.icq.com/whatisicq.html>, 1997).

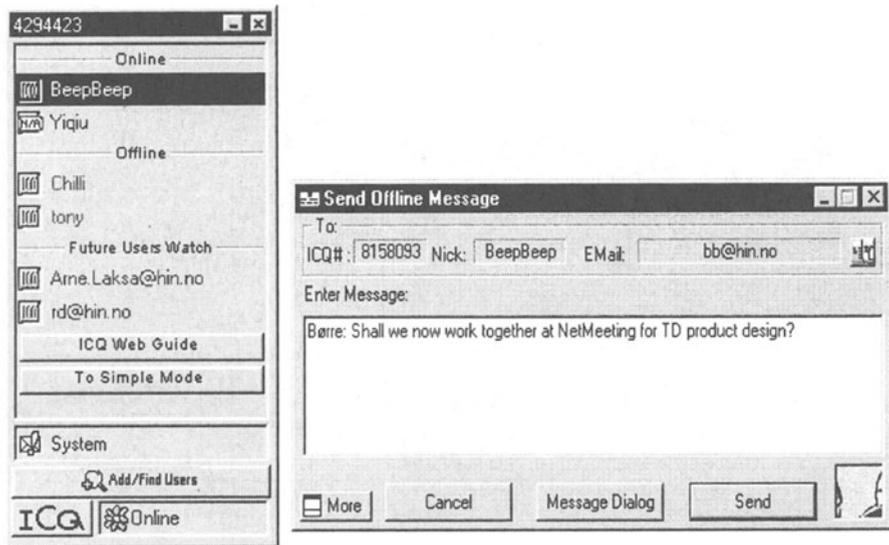
From the discussion above, the authors have conceived to choose ICQ, Microsoft NetMeeting, and BSCW shared workspace system as *a set of tools* to cope with synchronously and asynchronously collaborative design and manufacturing via Internet/WWW. As shown in Figure 2, the *ICQ provides a basic environment and plays a general control role* from where it may switch your work into synchronous collaboration mode by making use of NetMeeting program, or into asynchronous collaboration mode by making use of BSCW program.



**Figure 2** A set of tools at the collaboration layer for supporting synchronous and asynchronous design and manufacturing.

The ICQ program normally waits in the background without interrupting any other application in use. Then, if a member in a working group wants to launch a synchronous collaboration with another member, s/he can send an ICQ message to her/his peer inquiring to start the NetMeeting program. Figure 3 shows ICQ

operations at the launcher side. At the other side, the message will pop up on the screen because the ICQ has continuously waited in the background. Then they may both switch into NetMeeting program and start their synchronously collaborative design and manufacturing.



**Figure 3** Launching an ICQ message.

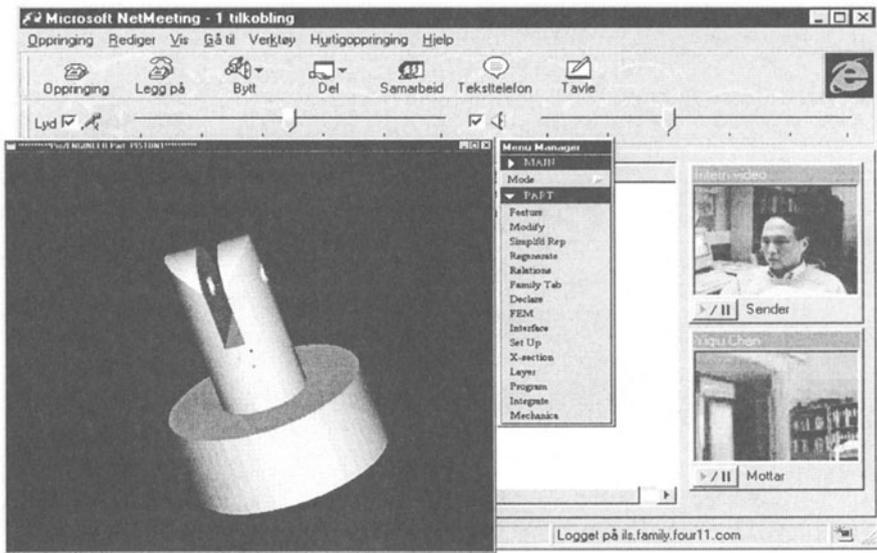
Taking collaborative design as an example, at the launcher side one may run a CAD program (e.g. ProEngineer), and either click the *share* button (see upper part of Figure 4 where *share* is expressed as *Del*), or click the *collaboration* button (see upper part of Figure 4 where *collaboration* is expressed as *Samarbeid*) on the NetMeeting window. Then, the CAD display window will also appear on the partner's screen. From here, they can work together to design a product. Figure 4 shows the launcher side's screen-display and Figure 5 shows the partner side's screen-display.

In case the launcher wants to work in asynchronous collaboration mode, s/he firstly works independently on her/his own side. After finishing her/his work, s/he uploads her/his result to a BSCW shared workspace and sends an ICQ message to inform her/his partner that a shared file has been uploaded asking for further working.

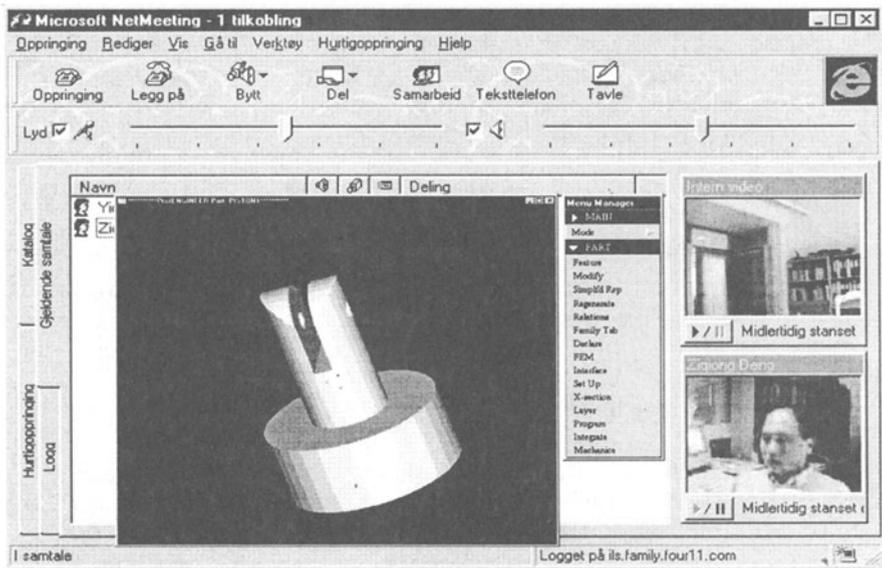
This message will then pop up on the partner screen. The partner may at some time later download that file from the BSCW shared workspace and work on it. After the work has been done, the partner uploads the modified file back to the BSCW shared workspace, and sends an ICQ message to inform the launcher that a modified file is available for the launcher.

Figure 6 shows a BSCW page displayed on the launcher's screen in where a shared folder, *First\_tst*, and a shared file, *teknologidager.prt.3* (a ProEngineer CAD file), are displayed. Figure 7 shows that this folder and file are defined to be

shared by two owners and three members. Note that even the shared folder and file are displayed on the client's (launcher's and partner's) screens, but they reside in the BSCW server.



**Figure 4** Screen display at collaboration launcher side.



**Figure 5** Screen display at collaboration partner side.

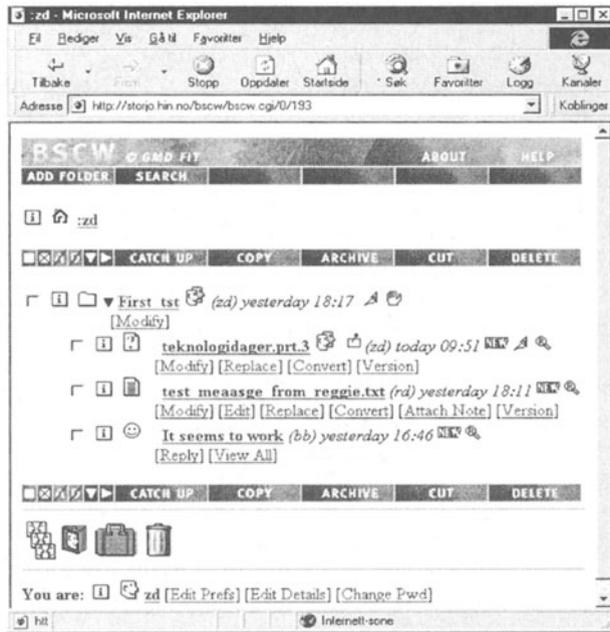


Figure 6 A BSCW page displaying the shared folder and file.



Figure 7 A shared workspace is defined to be shared between five members.

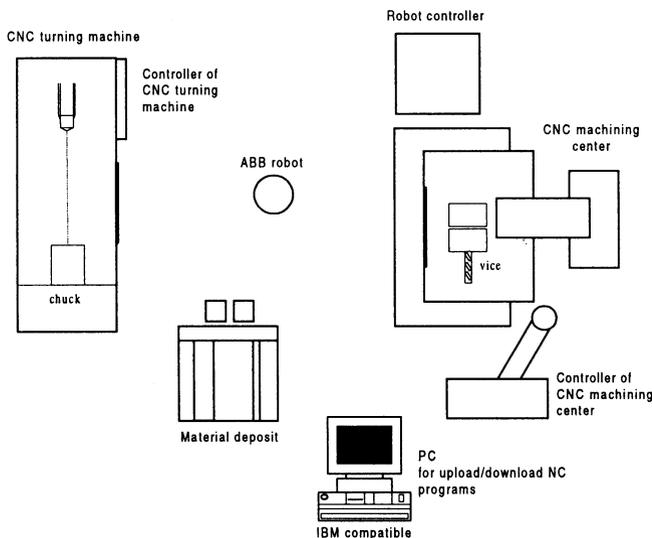
Note also that the shared folder and file will be displayed on all owners' and members' screens whenever they are running BSCW program, from where any owner or member may download that file for further processing while needed.

It is worthwhile to note as well that both in synchronous design mode and in asynchronous design mode, the partners in a meeting or members in a shared workspace may not only be the product designers, but also production planners, process planners, NC programmers, shopfloor controllers, even product dealers. They work together concurrently according to concurrent engineering principles.

## 5 INTEGRATING MANUFACTURING WITH DESIGN

After collaborative design is finalized, the product file will be transferred to manufacturing workstations such as *PP&C workstation*, *CAPP workstation*, and *NCP workstation* for production planning, process planning, and NC programming. After those activities done, the production order, process plan, and NC programs will be completed and transferred to shopfloor controller and cell controllers. All such transfers can also make use of ICQ, BSCW, or NetMeeting tools (supported by WWW/Internet, Intranet, or local area network) to accomplish the transfers.

The NC programs will be further downloaded to NC machines from the cell controller, normally by means of point-to-point communication instead of using Internet or local area network. Thereafter, the cell controller starts to control and coordinate the inter-machine related activities according to the received production order and process plans.



**Figure 8** Layout of flexible manufacturing cell at Narvik Institute of Technology.

In our case, we take the flexible manufacturing cell (FMC) of our laboratory for case study (shown in Figure 8). The FMC consists of three manufacturing units,

one CNC machining center (refer to right part of Figure 8), one CNC turning machine (refer to left part of Figure 8), and one industrial robot for material handling (refer to middle part of Figure 8).

For the equipment control, each unit has its own controller such as CNC turning machine controller, CNC machining center controller, and ABB robot controller (refer to Figure 8).

At the cell level control, because the ABB robot controller is capable of coordinating its activities with other machines (CNC turning machine and CNC machining center), we currently make use of this extra capability of the ABB robot controller combined with one PC (refer to lower part of Figure 8) to perform the cell control tasks.

The PC is connected to the campus network and so it can join the design and manufacturing collaboration with higher level workstations such as CAD, PP&C, CAPP, and NCP workstations as discussed above.

The NC programs that have been created at the NCP workstation will be downloaded from the BSCW server to the PC. Then the PC downloads them to the individual machine (CNC turning machine or CNC machining center) via point-to-point communication for product machining. Thus the PC plays the NC program distribution role, and the robot controller plays the inter-machine coordination role, in addition to its own equipment's control tasks.

## 6 CONCLUSION

Although at the present stage, we mainly experiment collaborative design and manufacturing inside our campus as discussed above, it is obvious that the methodology and tools discussed above can be used in collaborative design and manufacturing among geographically widely distributed enterprises, because ICQ, NetMeeting, and BSCW tools (based on WWW/Internet) enable collaborations globally.

However, two kinds of questions, *bandwidth and security*, arise. When you work at synchronous collaboration mode to transmit audio and video data over the Internet, you will soon run into problems with *bandwidth*. Because audio and particularly video are fairly bandwidth intensive, it is sometimes hard to get a quality signal and quick connection.

Taking our environment as an example, the local area network of our institute has a connection into UNINETT (the part of Norwegian Internet which connects Norwegian universities together) with a bandwidth of 256 kbps.

In average, transmitting audio data requires around 8 kbps bandwidth. Transmitting a small frame (40mm x 30mm) of video, such as the pictures shown in Figures 4 and 5, requires around 24 kbps bandwidth. Thus, transmitting both audio and video data at same time requires around 32 kbps.

If eight users in our institute transmit audio and video data at same time over the Internet, consequently they will completely utilize the whole 256 kbps (32 x 8) bandwidth resource. With the number of users further increasing, the quality of audio and video signal will be getting poorer and poorer, and the data transmitting speed will be getting slower and slower.

As for the *security* problem, we know that when we use NetMeeting to have a network meeting, we can control whoever can join the meeting. However, during the meeting, the exchanging data will be transmitted and travel a long way through the Internet which may be read by a third party during the transmission.

Also, when we work with BSCW program to share a workspace, we can control whoever can access the shared workspace. But, when you upload data to or download data from the workspace, again the data will travel through the Internet and same security problem exists.

To summarize, *standing on enterprise utilization point, looking at the bandwidth problem*, we deem that it is necessary to further investigate how to thriftily upgrade bandwidth of existing Internet connection, and how to thriftily and effectively introduce new technology, such as ATM, broadband ISDN, etc. into enterprise integration.

*Looking at security problem*, we deem that it is necessary to further search security tools on effective cryptographic service for inter-enterprise collaboration via WWW/Internet.

## 7 ACKNOWLEDGEMENT

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