Concurrent Manufacturing on the Web

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Abstract: This article presents a system for the concurrent support of the manufacturing life cycle in a distributed enterprise. The World Wide Web is used as a knowledge transport mechanism to access distributed sites and data files, and the Netscape browser application is used as a file and data serving agent on the Web. A client helper has been implemented to provide a visual language interface to the Web, called XConMap, which allows users to dynamically link concept nodes in a concept map editor to Internet sites and files. In supporting and linking the data sets presented, the system is shown to be flexible and extensible through its open architecture, and is demonstrated working with existing application software and protocols.

1 Introduction

Concurrent engineering (CE) is a philosophy and methodology of considerable interest in the manufacturing engineering community (Kusiak, 1993). Concurrent engineering, also referred to as simultaneous or parallel engineering, is a process which attempts to incorporate various life cycle decisions in the design of a product from the earliest stages onward. These stages include, but are not limited to, manufacturing, assembly, and maintenance. Knowledge based methods are increasingly used in order to ensure that all design changes and implementations are cohesive and complementary, and can be implemented with minimal effect on other stages of design and manufacture.

As the modern industrial environment moves towards a *post* mass-production paradigm (Tomiyama, 1992) issues like product maintainability and manufacturability become increasingly important. This importance is mainly in terms of achieving high levels of efficiency and marketability. Product cycle times and development times must be shortened and these activities made more efficient. In order to achieve the design goals of the concurrent engineering philosophy, several disparate groups and systems must be able to work together on a product, sometimes with competing goals, and almost always with highly diverse backgrounds. If concurrent engineering practices are to succeed, methods of knowledge representation and knowledge sharing must be applied to effectively utilize these human, technical and informational resources.

One approach to managing the information load and communication issues in a concurrent engineering endeavor is Mediator (Gaines, Norrie and Lapsley, 1995), developed as in the GNOSIS Consortium in the international Intelligent Manufacturing Systems (IMS) research program (Gaines and Norrie, 1995). Mediator is an open architecture information and knowledge management system designed to provide a flexible technology to support the management of complex distributed activities. It has been applied to supporting manufacturing activities throughout the product life cycle (Gaines et al., 1995), and to distributed education through the learning web (Norrie and Gaines, 1995). Mediator was originally implemented using custom software on local area networks. This article describes Mediator1, an implementation on the World Wide Web supporting international collaboration in distributed concurrent manufacturing.

2 Mediator Architecture

Figure 1 shows the original Mediator architecture (Gaines and Norrie, 1994) on the left and the web implementation on the right.

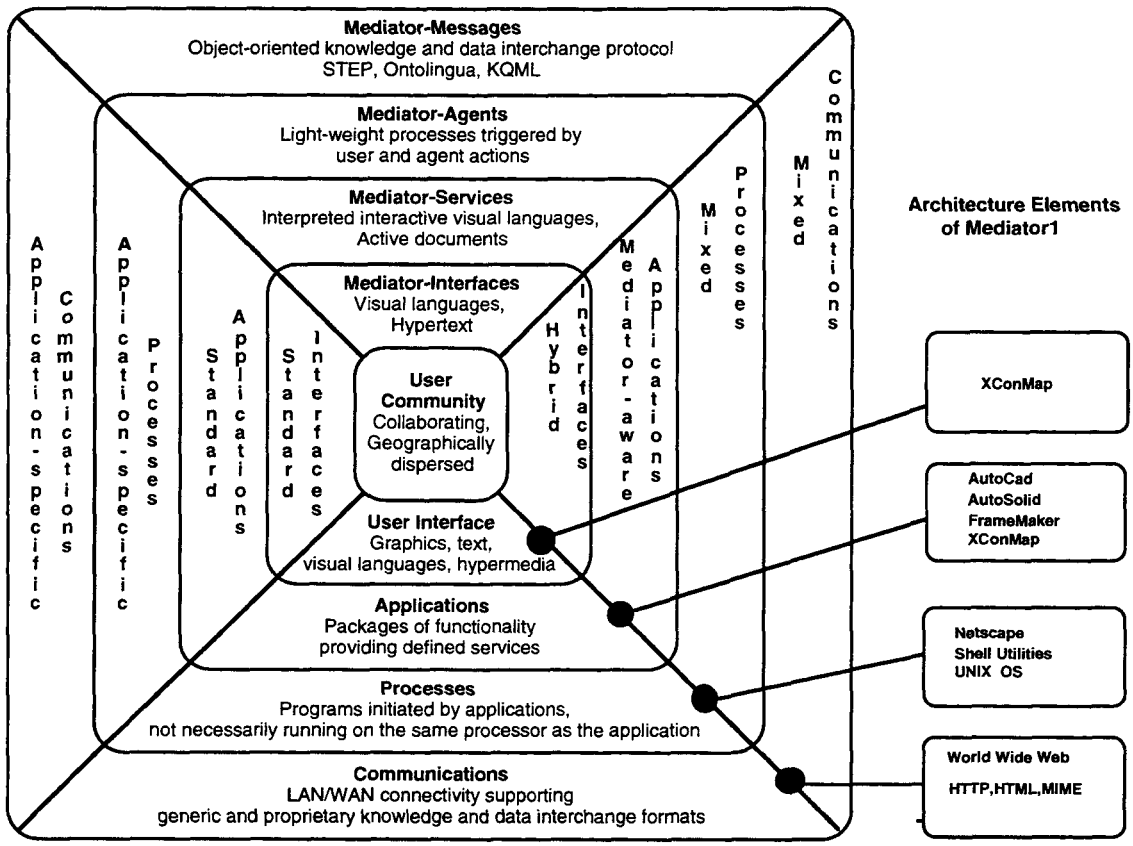

Figure 1 Mediator implementation on the World Wide Web

The major features are:

User Interface: At the center of the Mediator architecture is a user interface based on an interactive visual language tool supporting active concept maps (Gaines and Shaw, 1995a). This user interface, XConMap, was original software developed for the purpose of this thesis. XConMap is a recursive, network aware, object oriented conceptual map editor and browser which is the interface to Mediator1, and the only stand-alone piece of applications software created for this implementation.

Applications: Interaction with Mediator1 occurs predominantly through pre-existing applications software. In the design and creation of Mediator1, the use of as much pre-existing software as possible was a design goal, due to the intended use of Mediator1 by industrial as well as academic partners within the IMS consortium. To satisfy the design objective of utilizing as much pre-existing software as possible, software packages were chosen that operated on multiple platforms, had data sets that were transferable across platforms and could be manipulated by the web.

In Mediator1, this architectural aspect is supported by the following list of applications:

- **XConMap**—XConMap has the dual role of acting as the user interface as well as acting as a supporting member application. When a user accesses an XConMap file, (or a concept map file from another platform) the XConMap editing environment is automatically loaded and the data viewed within it. This is the reason that the application XConMap is referred to as recursive, because it can load, through a node, a concept map and all of its constituent Internet links.
- **Netscape**—Netscape, beside helping to fulfill some of the communication protocols of the lower levels of the Mediator architecture, also acts as a supporting application allowing the display of multimedia files.
- **AutoCAD**—AutoCAD files are stored throughout the Internet and linked to by the nodes in XConMap. When the links are followed the AutoCAD data is served by the process and communication layer of Mediator, and the AutoCAD application is launched to allow the user to interface with the accessed data.
- **AutoSolid**—In much the same manner as AutoCAD, links to AutoSolid files across the Internet are maintained by the XConMap interface, and when these links are followed, Mediator serves the data to the

interface on the desktop by launching an AutoSolid modeling instantiation for the user to interact with the accessed data.

- **FrameMaker**—FrameMaker data is accessed in the same manner as AutoCAD.
- **CNC Tools**—The data from existing CNC editors and applications can also be served up with an HTML interface via Netscape for display and interaction.
- **Process Planning Software**—As with the data from existing CNC editors and applications, the data from existing Process Planning software can also be served through an HTML interface via Netscape for display and interaction.
- **Simulation Software**—The data from existing simulation applications can also be accessed through the Netscape application interface.

Processes and Communications: The process and communications layers of Mediator1 is implemented through the web browsing application, Netscape, which communicates with XConMap through their respective application programming interfaces. The use of the Internet protocols supported by Netscape together with its capability to activate client helper applications greatly simplified the overall implementation of Mediator.

3 Managing the Manufacturing Life Cycle with Mediator

The use of Mediator to manage a distributed concurrent manufacturing activity will be illustrated using example data sets for an engine mounting block. The stages in the product development cycle are: the requirements specification stage, a STEP specification, design drawings (created in AutoCAD), and the manufacturing specifications, which include the Inspection Process Planning and manufacturing Process Planning. These stages are represented in the concept map shown in Figure 2 which is implemented as an interactive diagram in XConMap.

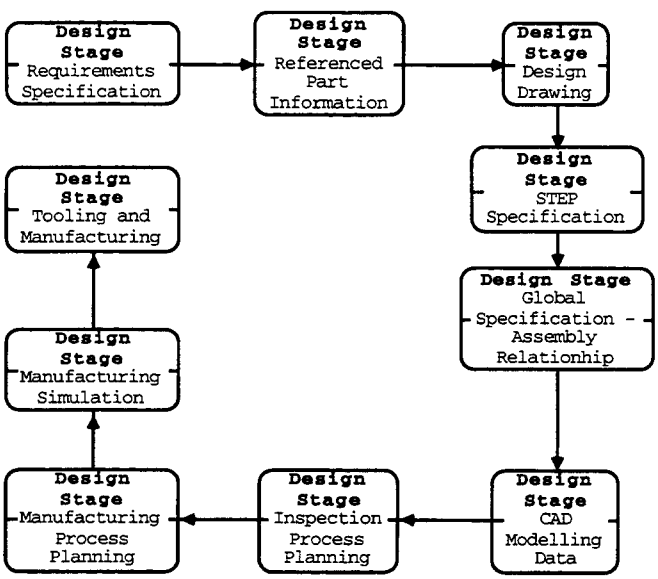

Figure 2 Manufacturing life cycle represented in XConMap

In the life cycle of a product, the first stage is the recognition of a need for that product. With the proliferation of planning and organization software on the many platforms available to design and manufacturing engineers, the various means that such a need could be expressed are almost endless. In the case of the sample part the requirements specification is expressed in a document processing application (FrameMaker) that itself supports group access and interaction.

Figure 3 shows the requirements specification in FrameMaker. It was fetched by clicking on the top left node of the concept map of Figure 2 (shown open in XConMap at the top right of Figure 3). XConMap retrieves the URL from its database and passes it to Netscape with a request to fetch the file. When Netscape does so it determines that the file should be opened in FrameMaker and does so. Once this document becomes static rather than dynamic and editable, it could logically be represented in HTML, with its own hypertext links to supporting documentation, references or previous drafts.

After the requirements have been proposed and specified through requirements documentation and part referencing, a simple sketch of the product, fitting these requirements, is created. This diagramming can be done in a technical drawing package and in this sample data case, AutoCAD is used. Figure 4 shows the AutoCAD drawing to which the "Design Drawing" node is linked.

STEP (Gu, Zhang and Norrie, 1993) provides an excellent parts description language for product and part information, due to its existence as a global standard. The next stage in the product life cycle is the STEP specification shown in Figure 5. These data are wrapped in HTML tags for easy viewing on the web.

XConMap data files can be fetched and opened in XConMap thus allowing concept maps to be linked to one another. Figure 6 shows a process planning concept map fetched across the web by clicking on a node in the life cycle map and then opened in XConMap with active nodes that can themselves be clicked to open other linked files.

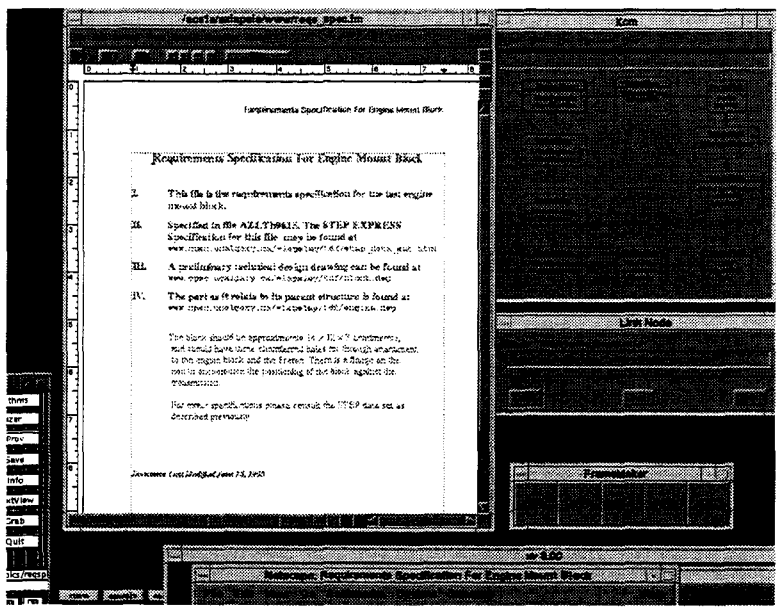

Figure 3 FrameMaker requirements document fetched and opened by XConMap

Figure 4 AutoCAD product design drawing fetched and opened by XConMap

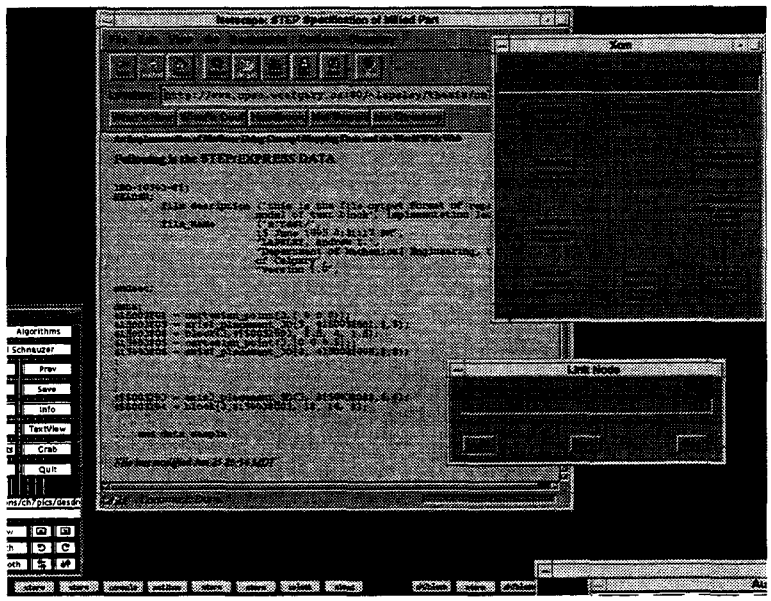

Figure 5 HTML STEP specification fetched and opened by XConMap

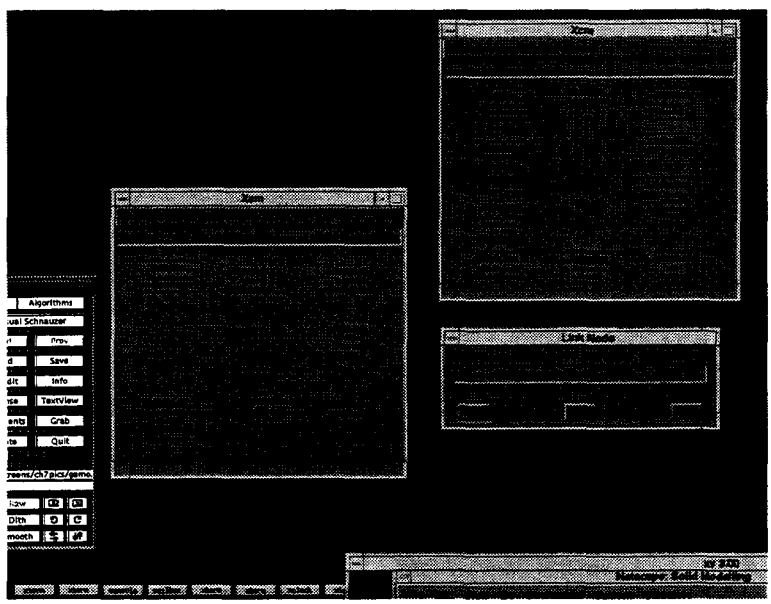

Figure 6 XConMap process planning map fetched and opened by XConMap

5 Conclusions

This article has presented a usable and portable implementation of Mediator1, a Mediator system for the representation of knowledge and the computer support of diverse manufacturing endeavors. The World Wide Web has been used as a knowledge transport mechanism, and the Netscape browser application has been used as a file and data serving agent on the Web. A new application has been created and implemented to provide a visual language interface to Mediator1, called XConMap. XConMap is a recursive, network aware object oriented concept mapping environment built with an eye towards future enhancement, development, and long term cross platform compatibility. This article has shown Mediator1 in use with data sets coordinating inspection process planning, manufacturing process planning, and a complete product manufacturing life cycle.

The existing World Wide Web technologies already provide a major research for the supported of distributed concurrent manufacturing. Further developments are required to fully implement the Mediator design. On major

issue is that of awareness in a distributed community—when someone in Canada comes to work in the morning how to they know what their colleagues in Japan and Finland have done overnight without exhaustive search and without requiring those colleagues to take special action to inform. CHRONO (Chen and Gaines, 1996) is a chronological awareness tool that is being developed as a component of Mediator to allow members of a community to maintain awareness of relevant activities.

XConMap and our other concept mapping tools on other platforms have compatible file structures but operate as client helpers. WebMap (Gaines and Shaw, 1995b) is a tool for delivering the concept maps as clickable GIFs to users that do not have a concept mapping client helper. A universal concept mapping tool is under development in Java that will enable concept maps to be used and edited by those with any browser that supports Java. This will provide a visual language interface to Mediator that can be used in a wide variety of applications.

The original implementation of Mediator supported synchronous editing at multiple sites. Group brainstorming and discussion is desirable at various stages of the manufacturing life cycle and it will be important to extend web technology to support synchronous interaction including voice communication. A version of Mediator is being developed based on an integration of GroupKit (Roseman and Greenberg, 1992) with World Wide Web that will support synchronous collaboration.

Acknowledgments

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