VIRTUAL CO-LOCATION AND REMOTE ENGINEERING IN THE COIL WINDING INDUSTRY

Michael J. Pellegrino

Consultant/Software Engineer
Logikos Systems and Software Inc.
Fort Wayne, Indiana

KEYWORDS

Virtual Co-location, Remote Engineering

ABSTRACT

The coil winding industry is like many others in that it shares distributed work sites tailored to specific tasks. Information sharing among these distributed work sites has proved to be challenging at times and restrictive at others. In addition, product design in this type of distributed environment is not easily manageable as constant communications must be maintained. This paper presents two maturing computer technologies, virtual co-location and remote engineering, that help alleviate the problems faced by today's distributed company.

INTRODUCTION

The world is becoming increasingly smaller as companies become more globally diverse in their basic daily operations. Aided by a surge of new technology in the computer and telecommunications field, the normal production cycle of a company has changed from what was traditionally considered. No longer is information stored in huge corporate libraries and no longer are products designed in the same building, site, state, or even country. Companies realized the benefits of distributing their operations across differing locations; however, they experienced synchronization and management problems among the distributed sites. Furthermore, there were no tools to perform the interactive design of products among these various sites.

This paper addresses the obstacles found in the traditional model of company operations. Armed with the latest in computer technology, the synchronization and management problems inherent in distributed company operations are analyzed and attacked head-on. The end result is that the current antiquated company operating methods are thrown out in favor of distributed computer network technology, namely, virtual co-location and remote engineering.

TRADITIONAL COMPANY MODEL

There was a time when most company communications were handled using some sort of transferable medium to move information from one party to the next. This medium, whether it was paper, micro-film, or the coffee napkin from the restaurant across the street, contained important information that relayed some idea, design, business strategy, or contact name. However, this system was based on participant locality—if more than one person needed access to some piece of information, copies, telephone calls, and even trips were executed to distribute it. While this system worked well for some companies (and probably still does), it did not scale well for larger organizations as storage and synchronization issues arose.

A key problem with locally based systems emanated as people in different departments made asynchronous deletions and modifications to initially synchronized information. For example, changes to a product in the design department might not have been received by the manufacturing department. A motor whose bearing type was changed in the design department for increased efficiency never filtered down to the manufacturing department. Since the manufacturing department worked from an older design with a different bearing, the motor that was generated did not conform to the new design specification, thereby charging the company excessive time and money to amend as their clients demanded the more efficient models. The same type of scenario could have occurred in the design department. If the manufacturing department devised a more cost-effective approach to producing a part by modifying some of the original design (e.g., a different bearing would make the motor run more efficiently), then the design department needed to know so changes could be made at the higher level. Most companies, when they relayed this information, used package deliveries, physical contact, telephone calls, and lately e-mail.

Many times, paper correspondence needed to be saved or logged to track product contacts, modifications, for patent and legal purposes, and design schedules for reference in future endeavors. Storage requirements presented a significant challenge to the company necessitating the implementation of corporate libraries (e.g., the design library, the manufacturing library, etc.) to effectively manage the volumes of acquired information. Apart from the real estate that had to be maintained to hold all this information, there was a greater issue: how was this stuff digested once it was stored? Historical or statistical searches were a nightmare because of the sheer volume of information and the fact that all searches were performed manually. Indexes helped and quickly became the norm, yet indexes spawned a new species of data to digest that consumed even more resources to maintain and search. What this amounted to were volumes of information that served only to index the even larger volumes of information. The problem was only compounded as divisions in different locations maintained redundant copies of the data for local reference.

As technology, like mainframes and local area networks (LANs), became available, there was a greater degree of flexibility granted to companies as they moved their operations away from paper. Data was centralized and updates were synchronized across the entire division Historical and statistical searches could be performed while the administrative tasks became easier to manage. However, these LANs and mainframes were generally limited in scope to a particular company site, building, or task due to specific hardware requirements (e.g., an electron microscope required a PC to run). Instances of different LANs running in the same room for the purposes of controlling different hardware was the norm. [1] Naturally, there was no common gateway or interface between the differing systems restricting data synchronization to specific divisions. The only available methods for moving information between the LANs involved physically copying files to removable media or manually entering data at network nodes.

The traditional company model, in addition to being deficient in its information communication facilities, did not capitalize on the power afforded by the computer with respect to product design procedures. Lets suppose that a group of engineers was trying to create the next generation electric motor. The manufacturing team was in a single location, but the design and testing teams were at another. As the product matured, there was increased communications traffic among the three divisions to verify manufacturing feasibility, available resources, costs, ideas, and schedules. Design meetings and travel expenses were normal practice as the various divisions converged in meetings to finalize design details. In addition to the cost of the travel expenses, there was also the cost of the employee time needed for travel and time away from the office.

The problems with the traditional company model were not contained wholly within the company's boundaries—after all, the company was in constant contact with its clients. All this interaction was subject to the limitations previously described. Fortunately, the same types of solutions (or subsets of these solutions) could be applied to client interactions with the same benefits that a company realized with internal installations. Whatever the solution might have been, the following questions needed to be addressed: what would supersede the current model; what were the realized and opportunity costs; and what were the advantages that made it a more sound solution than the traditional model?

Virtual co-location and remote engineering answer these questions. Virtual co-location and remote engineering use state-of-the-art computers and networks to merge information and engineering systems through easy-to-use interfaces. As Gedeon observed in [1], "the primary reason for automation is to improve capability," and virtual co-location and remote engineering promise to take the company to the next level by promoting efficiency and the assurance that they can provide their clients a more reliable and effective product. [2]

VIRTUAL CO-LOCATION

Virtual co-location attempts to remove the limitations imposed by the traditional model in the corporate structure by synchronizing and distributing information across all divisions of a company. Users access this data through workstations or notebook computers using standardized networked software tailored to the needs of the company (figure 1). Issues of synchronization wither away as all data is stored at key sites tailored to specific tasks. If there is a plant in Kentucky that performs manufacturing operations, then that site would maintain all pertinent data on its processes. If the Kentucky plant made motor armatures, then that plant would maintain all information on the companies' motor armature manufacturing processes, specifications, etc. Any sort of statistical or quality control data can be maintained and managed at this site although virtual co-location and remote engineering support remote site management. The same type of order is imposed on test and data acquisition centers. As the data is processed in the testing phase, automatic publication of the results is immediate throughout the network through the local network point of presence.

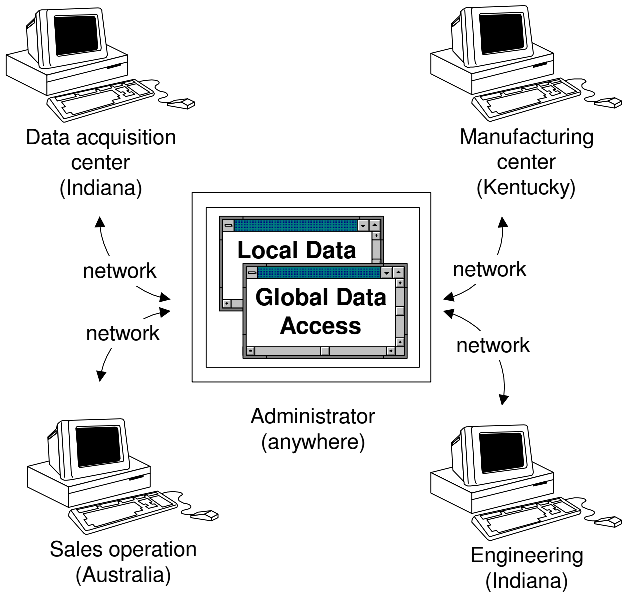

Figure 1: System overview of virtual co-location

The physical storage requirements for data (e.g., rooms filled with books) drop as there is no longer the need for the company or division library. All data is published online reducing the data's space requirements to the size of the workstations and data servers. Through the use of data entry operators, the voluminous amounts of static historical data can be placed online as well using CD-ROM towers and jukeboxes. The move to shared digital mediums serves a number of purposes. The first is that the huge stockpiles of paper and books that are currently maintained at each site can be removed allowing for more effective use of the building space. For example: a company maintains volumes of books with nothing but wire specifications as their content. These books might consume three cubic feet of storage space to store. The same type of information can be stored on a CD-ROM disc with a physical space requirement of 0.00597 cubic feet (assuming the CD-ROM is in a case). The second purpose is that the company can provide a single interface to all data, no matter where it is located or how it is stored. Employees in other company locations can access library data without having to move physical copies from one site to another. In fact, employees need not be on the company premises to access the system as telecommuting is a direct benefit of a virtual co-location system [3]. Employees can work from their home, from a hotel room, or even on an airplane or beach using cellular technology.

The interface to a system such as this might share the physical resemblance of the supporting company. All portions of the company are modeled in the software based on physical layout. For example, the company has a corridor where there is a lab and a testing facility two doors down; therefore, when the software models the building, the model corridor has the testing facility two doors down from the lab. A system modeled using a metaphor based on the company greatly reduces the learning curve and makes the information easier to process because everything is already familiar to the user. If the real world process of material testing includes the moving of a sheet of data from one division to another, then the same operation can be modeled in the software. To the end user, the order of operations is the same and only the interface changes. This reduces the learning curve typically associated with other forms of corporate computerization such as new database and testing systems while providing the necessary functionality for virtual co-location. Users will no longer have to learn multiple software packages and interfaces because as they move about the various departments, the software remains constant.

Statistics based on the current company operating methodologies, testing practices, materials data, sales information, and company efficiency are much easier to produce when the data is online. The traditional model is to manually insert the data into a spreadsheet or statistical package and perform the necessary processing of the data. While this system works, there are still data synchronization issues and the possibility that data can be miskeyed upon system entry. Virtual co-location eliminates error-prone manual data-entry tasks by accessing the online stores of information directly. Since the data is already online, statistical and historical processing is just a matter of pointing the necessary software in the correct place.

Yet another benefit of a virtual co-location is the removal of differing networks within the same company (and sometimes, even the same room). All data is processed by nodes of the same network. In addition to removing a plethora of administrative burdens that arise when dealing with multiple networks and protocols, the overall cost of the system is lower. The lower system cost is made possible by the removal of administrators that must be proficient in different network technologies and the hardware costs associated with supporting multiple hardware devices and gateways (i.e., supporting an Ethernet and Token Ring network at the same time).

REMOTE ENGINEERING

Remote engineering is similar to virtual co-location in that they both share the global distributed network paradigm. Remote engineering is different from virtual co-location in that it deals with the real-time, interactive, engineering of company products without necessarily being in the same room, building, or site. Products are engineered in real time by a group of distributed participants who communicate in real time through a remote engineering software system. The communications may include talk and textual material, but the real power of remote engineering for participants is the ability to interactively design a product with another individual without being in the same location.

Remote engineering is analogous to the common conference call where everyone agrees to meet at a known time and place to have a shared telephone conversation. Like the conference call, people would communicate ideas, concerns, questions, and the like. Unlike conference calls, the participants can immediately see the impact of their conversations. For example, suppose that there is a group of engineers working on an electric motor design with a client at the same time, but all participants are in different locations. The engineers and client, perhaps using a virtual drafting table (figure 2), might all be looking at the same CAD drawing of that motor design. The client and engineers need to finalize the design, but there are still questions that must be answered. The clients might field engineering questions in the following scenario: engineer A points with his mouse at the motor's shaft hole and feels that there should be a beefier bearing there to support the load. All other participants (who are looking at their respective computer screens), see a representation of engineer A's mouse caret pointing to the bearing. At the same time the participants see engineer A's mouse pointer move, they also hear what engineer A is saying and can react in real time to it. Engineer B recommends another bearing size, but the client interjects stating that they do not want to use engineer B's new bearing. Finally, engineer C, who has been idly sitting by listening the entire time, makes a modification to the drawing moving the motor face 4mm forward providing more support for the bearing. In one pass, engineer A's and the client's requirements are satisfied without ever having to travel or mail a package.

A more advanced form of this system would be to use virtual reality systems to perform the participant interactions. [5] Instead of seeing the mouse pointer of the remote participant performing some drawing modification, you might see a representation of the participant drawing or erasing an engineering drawing on a virtual drafting table like you would see in a real-world non-computerized drafting room. If there were test data to view, the data could be visualized to re-enact the test with clients while engineers stand by to view the results. Participants could poke their heads into the test playback and see internal interactions not possible to see in the real world. [4] As these internal interactions occur, design decisions can be made on the fly thereby saving the company time and money while providing a higher quality product.

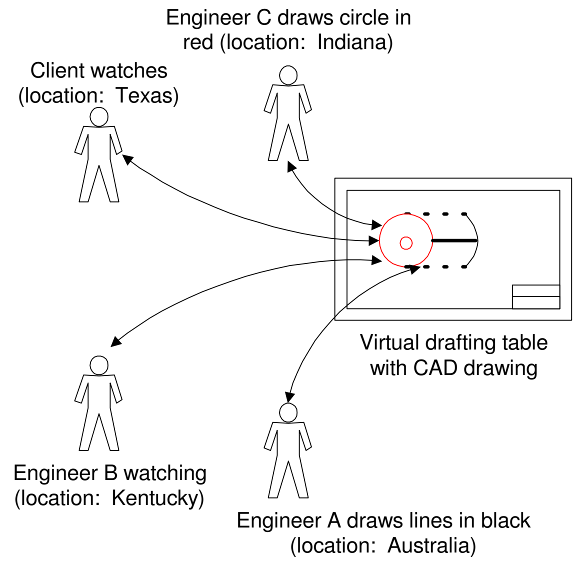

Figure 2 Remote engineering system overview

Immediate questions arise with the described course of actions. How is participant control arbitrated (who "has the floor at any given point in time")? How are the different participants represented on remote displays? And how effective is the interaction among the participants?

Unlike the real world, interaction can be controlled in a remote engineering session. Specific tasks can be granted permission controlling who can perform what in the system (e.g., modify a drawing, delete an item, participate in a meeting). If the supervisor of a job needs for all engineers to participate in a design presentation for a client or supervisors, the supervisor might have the engineering team on hand to participate in the meeting, but not modify any of the design's contents. Another scenario would be a brainstorming session among all engineers and the supervisor to design the next generation motor. There could be a "free for all" on the virtual drafting table and participants could draw and modify at will the design on the drafting table. After a certain time, the supervisor might say "okay, only I can draw now" where only the supervisor would be allowed to modify the drawing. Participants can still interact in the session, but can not make design modifications.

Representation of the participants is not as complex a problem to solve as control arbitration. In figure 2, there are four participants at four locations making changes to the drawing. Each participant might be represented by different colors so that lines drawn by engineer A appears in black while the lines engineer C draws are red. In virtual reality systems, more flexibility is granted as participants can be modeled with different physical appearances (although design or drawing data would still be reduced to color schemes due to its two dimensional nature).

Remote engineering is made possible through the use of real-time software. As with most pieces of real-time software, there are ensuing time constraints that must be handled for the software to work as expected. If a remote engineering software system were to work as previously described, the acceptable latency for participant interactions would be no more than few seconds—anything more would render unacceptable results. If engineer C modifies the motor face, then the modification must appear to happen instantaneously to the other participants. If engineer C modifies the motor face and the rest of the participants do not see any sort of updates for a minute or more, then the advantages of remote engineering dwindle. As the session continues, the delays will perpetuate until the interactions become very choppy and out of synchronization with the voice communication. Engineer B would move a line on the motor face and the other participants would notice the movement later when the conversation was already on another topic.

Remote engineering is more bandwidth intensive than virtual co-location and other network applications. While virtual co-location needs large bandwidth amounts to transport images and data, the traffic patterns tend to be in bursts. However, remote engineering involves the real-time transfer of participant coordinates, states, interactions, and object manipulations. This transfer, while not consuming much bandwidth, requires low latency network connections to be effective. As an example, lets look at a participant who moves a line on the virtual drafting table. The only data that need be sent are the points of the line which might be a few bytes of information. However, as this line is moved, constant updates of its position are broadcast so high-speed/low latency networks are essential. The amount of bandwidth required for remote engineering will vary with the complexity of the virtual environment modeled by the system. If the virtual design room is essentially bare, consisting of only a drafting table, then communications are focused more on the design and participant interactions. However, if the room is more interesting (more objects that can be manipulated), then more information must be sent which consumes more bandwidth. In addition, the performance of a remote engineering system will vary based on external factors to the system such as the number of participants and the amount of unrelated traffic on the network. Further information on the performance of some experimental remote engineering systems can be found in [4] and [5].

COSTS

In order for virtual co-location and remote engineering to be viable solutions, they must be cost effective. If the solution to making the company more streamlined is more expensive than the current model, then it deserves serious consideration as to whether it is a suitable solution. The costs of implementing such a system will vary based on a number of key items:

- Current hardware available to support the system
- Current manufacturing processes
- Current software base
- Current qualified personnel to manage the system

A company that is completely paper based is going to make a huge capital investment to make the system work. Networks must be installed, servers and workstations must be purchased, and communications' links among the various sites must be in place to serve as the backbone for the virtual co-location or remote engineering system. If much of this equipment is already installed or can come from existing inventory, then the overall hardware cost of implementing the system is reduced.

Manufacturing equipment will play a crucial role in how well the transition to an automated system will be. Machinery that supports direct computer interfacing (via RS-232, etc.) will support reliable autonomous processing of data. The other option is to manually enter data—a process that is both time consuming and error-prone.

The current software base will also dictate how much the system will cost to implement. If the majority of the software used is proprietary and lacks standardized interfaces (e.g., ODBC), then there must be gateways to merge the software. Open systems are easier to integrate and will make the transition much easier and less costly. Furthermore, the type of software described in this paper exists in pieces spread across various software vendors and research facilities, but there is no integrated solution. Complete implementations of this type of custom system lie in the hands of consulting firms due to the system's specific nature. With this customization and specificity comes a price tag that's higher than a generic software package, but that must be tolerable.

People are the most expensive resource that a company has. Each minute an administrator or employee consumes performing repetitive tasks or detecting faults in a patched system costs the company money. The quality of the personnel using and administrating the system will have the largest impact on the cost of the system and its success. If the administrators find the system easy to manage, they become more effective and can resolve problems more quickly. Users who are proficient with the system will be able to perform their jobs quicker and with greater precision.

CONCLUSION

The traditional company model has lived a long and fruitful life. For a single site company, it may continue to live on without much opposition. However, for companies that have distributed their operations across multiple states or countries, there is increased communications traffic and increased chance for errors and miscommunications. What they need is for a more reliable system to be enacted that is both efficient and cost effective to help streamline the company.

Virtual co-location and remote engineering provide the necessary solution for the distributed company. Virtual co-location removes data synchronization issues, increases data processing capability, and phases out the corporate library while making more efficient overall use of corporate resources. Remote engineering eliminates locality of company personnel as a factor in the design and production of products. Engineers, designers, manufacturing employees, and administrators can all interactively participate in the design of products without being at the same building site. This locality removal not only minimizes travel expenses, but also provides a more reliable operating paradigm that reduces product cycle time.

ACKNOWLEDGEMENTS

The following were instrumental in one form or another for the writing of this paper and deserve recognition here:

- Don R. Disque, Phelps Dodge Magnet Wire Company
- Richard B. Duke, A-Z Tech Inc.
- John C. Kauffman, Phelps Dodge Magnet Wire Company
- David W. Myers, Phelps Dodge Magnet Wire Company
- Don Skaar, San Diego State University

REFERENCES

[1] Gedeon, David V., “Systems Integration for Manufacturing”, ***Proceedings of the 1992 Electrical Manufacturing & Coil Winding Conference***, pp. 75-82.

[2] Diachin, D. L., L. Freitag, D. Heath, J. Herzog, W. Michels, and P. Plassmann. “Remote Engineering Using CAVE-to-CAVE Communications.” ***Virtual Environments and Distributed Computing at SC'95.*** edited by H. Korab and M. Brown, ACM/IEEE Supercomputing '95, p. 41.

[3] Evard, Remy, “Collaborative Networked Communication: MUDs as Systems Tools”, ***Proceedings of the Seventh Systems Administration Conference***, November 1993, pp. 1-8.

[4] Diachin, D. L., L. Freitag, D. Heath, J. Herzog, W. Michels, and P. Plassmann. “Collaborative Virtual Environments Used in the Design of Pollution Control Systems” to be published July, 1996.

[5] Disz, T. L., M. E. Papka, M. Pellegrino, and R. Stevens, ``Sharing Visualization Experiences among Remote Virtual Environments,” ***Proceedings of the 1995 International Workshop on High Performance Computing for Computer Graphics and Visualization***, edited by M. Chen, P. Townsend, J. A. Vince, Springer-Verlag, pp. 217-237.

[6] Hazelton, S., and M. Margitan, “State of the Art Information Systems for Manufacturing Electrical Products”, ***Proceedings of the 1994 Electrical Manufacturing & Coil Winding Conference***, pp. 303-310.

[7] Phelps Dodge Magnet Wire Company, Interview, May 24, 1996.

[8] Primrose, R. A., “Hypertext in the Coil Winding Industry”, ***Proceedings of the 1994 Electrical Manufacturing & Coil Winding Conference***, pp. 17-21.