ACCESSFABRIK
Researching and Developing New Tools for Collaborative Design and Communication

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Abstract: Through a review of literature and experimentation with enabling technologies, it was concluded that the Access Grid (an open-source, videoconferencing platform) held significant potential to facilitate the sharing of audiovisual material in the area of collaborative industrial design; however, it would have to be extended to allow for high-definition visualization and remote desktop control. As a result, researchers in Canada and Germany developed new tools to accomplish this, and utilized them to remotely manipulate industrial designs in real-time and with very low latency. Additionally, automated captioning and translation services were developed to better facilitate cross-cultural business-to-business collaboration. Future research directions for this project involve the continued prototyping of these tools, leading either to their deployment within industry or further improvement within the Access Grid Community.

1 INTRODUCTION

This paper partially serves as a "technology roadmap" for an international joint research initiative of Ryerson University in Toronto, Canada and the Fraunhofer Institute for Industrial Engineering (Fraunhofer IAO) in Stuttgart, Germany. The overall purpose of the project was to study the impact of emerging and convergent web and broad-based communications technologies on collaborative industrial design and manufacturing. Our primary work focused on creating new tools to better facilitate collaborative design and engineering, and this involved extending the Access Grid (AG), a robust, open-source videoconferencing platform, to bridge geographic divides in the design process. We also sought to reduce cultural barriers to communication through automated captioning and translation services; in doing this, we hoped to further enhance international business-to-business collaboration.

Although the focus here is on improving distributed collaborative visualization, this project also sought to make the collaborative process more "intelligent" using semantic web services and a combined technology known as the "semantic grid". However, due to space constraints, we are not able to discuss this aspect of the project at length within, but have instead relegated such material to a separate paper (see Murphy, Dick, & Fischer, 2008). It is also important to note that our work was primarily focused on the impact to industrial design and manufacturing projects to meet the immediate needs of our industrial partners. However, we do consider other applications outside this domain where possible, including usage of the Access Grid to improve visualization in healthcare, the natural sciences, and distance education.

In section 2, we outline our inspiration for this project, namely the current state of the Canadian automotive sector and broader trends in videoconferencing adoption and predicted adoption that we can ameliorate through the development of new technology. The Access Grid, other forms of distributed and collaborative visualization (and implementations thereof within and outside of the

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engineering domain) are the focus of section 3. Building off this, we then detail the work researchers on this project have completed thus far in improving such environments in section 4, while areas for future work are presented in section 5. General conclusions (section 6), and a list of references will complete the paper.

2 INDUSTRY PERSPECTIVES

First, we consider some details on the automotive sector in Canada (as informed by our industrial partners, who contribute to the GDP of this industry). We will then proceed with a brief look at how collaborative visualization and shared-space tools have evolved to meet new industrial trends, most notably in the realm of videoconferencing.

2.1 The Canadian Automotive Sector

According to the Conference Board of Canada, $111 billion worth of autos and auto parts were produced in this country in 2005, utilizing 1.5 per cent of the total workforce. Nevertheless, anticipated risks, particularly increases in the cost of materials by as much as six per cent through 2010, have significant potential to minimize the Gross Domestic Product of key players if methods for managing the design and manufacturing process do not evolve in the coming years (Conference Board of Canada, 2006). Certainly, the ever-present economic difficulties faced by auto manufacturers and the sectors that supply parts for them has been well-documented in the popular press in recent years and is, in essence, common knowledge.

The fact that trends also indicate increasing interdependency amongst parts manufacturers, suppliers and automotive manufacturers/assemblers only exacerbate the financial risks described above. More specifically, the Conference Board notes that parts manufacturers in particular are, in some cases, taking a leadership role in actually designing products for their customers, rather than simply manufacturing items to the automaker's specifications (2006). In other words, it is becoming more commonplace for the auto manufacturer to outsource the design process to the component's manufacturer. Logically, there are cost-savings attached to this move, but risk presents itself in the form of collaboration in that the automaker and parts manufacturer must bridge geographical, technological and even linguistic and cultural divides in order to ensure the industrial design and manufacturing process proceeds to each party's specifications and requirements. There is little room for ineffective communication and collaboration in the just-in-time environment that defines this sector, since errors in design, and the time taken to correct them, can spread through the supply chain quickly. In essence, this changing economic model is dependent on the collaborative process as being an asset, rather than a liability – this is the impetus for our work with the Access Grid.

2.2 The Impact of Videoconferencing

Technology advancing to meet the new economics of industrial design, manufacturing, engineering and procurement in the automotive sector is also at the core of this research project and paper. As mentioned, we will look at the progress made thus far on the Access Grid as the technology is introduced; however, it is important to consider the state of the broader technologies upon which related concepts and applications are derived. Specifically, we must first consider to what extent videoconferencing, distributed and collaborative computing and new web services are being adopted by our primary end-users.

In their most recent reports, the Gartner Group, a leading corporate research firm, notes that the concept of "ubiquitous collaboration" may have a "transformational" impact when it reaches its plateau of mainstream adoption in five to ten years (2006). Videoconferencing, presence and open-source team collaboration are also purporting beneficial change, although the timeframe to adoption is predicted to be less than five years. This essentially means the time is ideal for mainstream organizations to consider deploying collaborative visualization tools, such as the AG, as the cost to benefit ratio is high: investment now will position the company ahead of competitors and give them an edge when the technology becomes commonplace in future. We consider this a favourable analysis and have thus proceeded to review and refine research agendas concerning this ICT accordingly.

3 THE ACCESS GRID

The Access Grid (AG) is a robust, open-source videoconferencing platform that is a suitable solution for the level of distributed and collaborative visualization required in this project; as such, we hypothesized that it would prove to be a key enabling technology to meet the challenges described above. In this section, we will: present background information on visualization and presentation environments; trace the history of the Access Grid and outline its operation; describe similarities and differences to commercially-available videoconferencing systems; show how the technology has been adopted in a variety of industries; discuss the necessity to extend the Access Grid to enable collaborative engineering and, as such, the requirement to consider integration with new web and other technologies.

3.1 Visualization Environments

Tools such as the Access Grid are rooted in the broader discipline of computer visualization techniques. Visualization can be thought of as "distributed" (data processing is spread over different computers to improve performance, the notion of "Grid computing"), "collaborative" (audiovisual communication, shared whiteboard applications, etc. – the notion of computer supported cooperative work, or CSCW) or a combination of both (Brodlie, Duce, Gallop, Walton, & Wood, 2004). Visualization can be further distinguished by the presentation environment and viewing experience: constrained technology and bandwidth provides for the ever-familiar "postage stamp" quality one often finds in streaming video, while improving quality has made the "television experience" more commonplace in videoconferencing platforms; the "theatre experience" offers greater depth and user-engagement, while the "immersive experience" is tantamount to all-out telepresence or even virtual reality, in which a virtual environment envelops the user so that he or she may grasp subtle nuances of imagery such as texture (Mayer, 1997 as cited in Brodlie et al., 2004). Generally speaking, the size of the display correlates positively with the level of quality, so long as the amount of bandwidth is appropriate for the task at hand.

For our purposes, the Access Grid is both "distributed" and "collaborative" as its purpose is to allow interaction across a dispersed network (geographically and in terms of resources) to shape the final output. Further still, it can be classified as providing something equivalent to a "theatre experience", as the present (and evolving) technology allows for videoconferencing and shared visualization within applications with considerable fidelity, as will be discussed. However, it should be noted that the AG is not a virtual environment/"immersive experience" at present and, with this project, we are not attempting to achieve this (rather we are taking steps to make the technology, as it is now, more applicable and usable within the automotive sector and engineering domain). Our usage of the AG here is representative of presence, though it is admittedly not the most appropriate example of all-out telepresence.

3.2 History, Components & Operation

The Access Grid was developed by researchers at the Argonne National Laboratory in Chicago, an organization that continues to provide the majority of the momentum and coordination for the project through annual retreats and a website, www.accessgrid.org. Although use cases have broadened over the years, and continue to through our work, the AG was developed primarily as a vehicle for researchers to share data and videoconference over high speed, multicast networks in ways that resemble face-to-face collaboration, but also as an enabling technology for remote education (Connolly, 2001).

At the heart of the Access Grid is a "node", a descriptor for each institution's respective setup of the technology that encompasses the hardware, software and network on which it operates. Hardware requirements for a node are neither highly-specific nor proprietary; as such, the actual needs of each end-user, as well as their budget, can be taken into account in the design process. At a minimum, the hardware must provide for two-dimensional display space (larger screens are preferred because they are key to the "theatre experience" discussed previously), live video camera transmissions and two-way audio (Conte, 2003). Generally speaking, this is best accomplished through combinations of consumer video cameras, microphones and projectors: for example, one node at Ryerson University uses two table-mounted microphones for audio pick-up, an echo cancellation device, one to three high-definition camcorders to provide different viewing angles and up to three projectors controlled by computers to enable a display screen of sufficient size. Regardless of the specific hardware setup, software allows the node to seek out and connect to other nodes over the AG; in other words, the software is used to link a grid (or network) of nodes so that each one may "access" others as desired. The most important application that facilitates this is referred to as the "venue client"; it is written in Python, can be downloaded for free from the Access Grid website and will run on any of the major operating systems. Once logged in, the user can locate people of interest within a specific venue (e.g. an online meeting space or "lobby" which an institution has created) and engage in the sharing of audio, video, text and application data (the venue client can actually be considered a "wrapper", as it integrates stand-alone applications like Jabber, Videoconferencing Tool (VIC) and Robust Audio Tool (RAT) to enable text chat, video and audio conferencing respectively). In spite of generic hardware and rather simplistic software requirements, the Access Grid does require a specialized broadband network upon which to operate. More specifically, the AG operates over multicast networks (MBone) and generates at least 20 Mbps of traffic; by contrast, most Internet Service Providers and many organizations limit their Internet traffic to unicast (and with significantly less speed) so as not to overwhelm routers in use today (Hanss, 2001). The bandwidth and multicast demands of the AG are what allow multipoint collaboration, but also form an inherent limitation in deploying the technology in broader settings due to the limited availability of MBone combined with the cost of bandwidth. An explanation for this disparity between academia and industry may rest with the fact that the AG, along with other experimental digital video projects conceived under the moniker of "Internet2", was initially developed on the assumption that such networks would be ubiquitous in everyday computing in the near-future (Hanss, 2001; Simco, 2002). However, since this is not the case within industry, we remain aware of this limitation to the deployment of the Access Grid and continue to look at ways deployment issues can be overcome as they arise.

3.3 Relation to Videoconferencing

What makes the Access Grid so unique is its ability to transform an entire room into a facility that allows multiple people to videoconference with many others simultaneously. It is, essentially, a software-based solution to videoconferencing, since the venue client leverages multicast network resources to allow the sharing of whatever is at the other end of the hardware components (that is, audio, video or computer applications) with as many users as the available bandwidth will allow. This sets the AG apart from more well-known software-based videoconferencing tools such as Microsoft NetMeeting or your favourite instant messaging client, since their focus is on point-to-point communication (i.e. two people), albeit over a unicast network and likely with even cheaper hardware (while it is possible to operate an AG node using a single webcam, it is contradictory to the goal of using the technology for room-based conferencing environments).

One similarity of all these software-based methods (including the VIC application with the AG toolkit) is that most rely on H.261 standards, resulting in encoding and decoding that, while of relatively high quality, is not broadcast-quality and thus not appropriate for all applications. That said, using the AG with sufficient bandwidth and quality equipment does provide for a productive videoconferencing experience and, perhaps more importantly, in a multipoint environment. In our lab at Ryerson, we are working to provide an alternative to VIC, a VLC-based application that will provide H.264 (part of MPEG-4) video transport for the AG, thus resulting in broadcast-quality, high-definition-capable visualization.

Before the Access Grid was introduced as a software-based solution, multipoint conferencing could only be achieved through proprietary, and very expensive, hardware setups. Even now, many companies are opting for multipoint control units from vendors such as Polycom, VCON, Picture-Tel, Radvision and HP, which cost $100,000 US or more, depending on the number of simultaneous users desired (since every participating location will require similar conferencing equipment; Hanss, 2001). Even the AG itself has a direct commercial counterpart, the inSORS Grid from inSORS Integrated Communications, wherein the hardware, software and network interface that would be separate components of a node are combined into one portable "magic box" that can be utilized when needed by an organization (Brodlie et al., 2004). While these "ready-made" solutions may seem convenient for businesses, the time spent investing in a customized Access Grid node is worthwhile considering the cost savings and inherent flexibility. For example, an engineering firm could design its own AG node using off-the-shelf components most appropriate for their collaborative needs with considerably less capital investment; moreover, the open-source nature of the AG would allow them to modify software interfaces and add as many users as their bandwidth allows on an as-needed basis for no additional material cost. The initial investment in the AG node thus provides a return on investment (ROI) over time; moreover, since the node is largely based on consumer and prosumer technologies, even these initial capital costs will go down as the constituent products become more popular and mainstream.

3.4 Evolving Usage & Recent Events

The Access Grid has evolved over the past few years to facilitate distributed collaboration and communication in other fields. Even though it has still not seen widespread adoption, some of the arguments below combined with the low start-up costs described above should prove valuable to companies looking to make informed decisions concerning the technology.

Limited usage of the Access Grid in healthcare and various scientific fields demonstrates a clear business case for adopting the technology, especially in terms of long-term cost savings. Scientists at Australian universities, for example, have combined the AG with telepresence equipment to operate equipment remotely: their first successful trials allowed researchers in Melbourne to control an expensive electron microscope in Sydney, suggesting that sharing arrangements such as these will allow the cost of expensive capital investments to be defrayed by multiple parties (Luntz, 2005). Usage of the AG in healthcare is also exemplary of the technology's ability to reduce the enduring costs of time and opportunity by serving as an important link in vital, time-critical situations.

While such examples do not directly involve the automotive industry and/or the manufacturing sector, the accessibility of the Access Grid with respect to fulfilling urgent needs ad hoc should be attractive to our target businesses, since the just-in-time model permeates the entire supply chain and mistakes can obviously be costly.

A final argument for adopting the Access Grid in business involves an issue that is very much in vogue – the environment. While travel, particularly by air, will always remain a necessity for some meetings and conferences, organizations are finding it important to take steps to reduce their carbon footprint by restricting such travel. However, this need not reduce their ability to hold conferences, since our previous discussion demonstrates that the AG is a viable vehicle for international conferences since it simulates in-person collaboration and communication. Indeed, a genomics conference was facilitated over the AG recently, and organizers estimated that approximately 900 tonnes of travel-related carbon dioxide emissions were averted based on the number of participants and the distance they would have travelled (presumably by airplane) to reach the conference site in person (Reay, 2003). And while this, in itself, is also a cost-savings for any company as it reduces expensive travel, the public relations benefit is, perhaps, greater; therefore, the Access Grid serves both as a tool for maximizing cost-effectiveness in the collaborative process, as well as being an important conduit for meeting corporate social responsibility objectives.

3.5 The Need for Future Extensions

As of this writing, 267 Access Grid nodes were in use across 27 countries worldwide (AccessGrid.org, 2008). As discussed above, this number is likely to grow (and span more industrial sectors) as the reputation for the technology begins to solidify, thus justifying the start-up expenses (however cost effective they may already be). While the quality of video and the availability of multicast networks/bandwidth are some of the only general limitations to the AG concept, its application to industrial design, particularly in the automotive sector, will be improved if extensions can be developed to make the videoconferencing and overall collaboration process more "intelligent" and aware of the real-world impact of manipulating what is being visualized on the manufacturing supply chain. Semantic technologies – the semantic web and semantic web services – are posited to be a viable solution for meeting such a requirement to extend the Access Grid (this is entrenched in the concept of a "Semantic Services Broker" as introduced in Fischer, Murphy, Tippmann, & Ayromlou, 2006; see also Murphy & Fischer, 2006 for further explanation of the enabling technology).

As mentioned, a separate paper authored by our lab provides a freestanding introduction to semantic technologies, reviews attempts to merge the semantic web with the AG, and theorizes their applicability to our target industry (see Murphy, Dick, & Fischer, 2008). For now, we continue with a more detailed examination of the new audiovisual tools developed for the Access Grid Community (as first presented at the 2008 Access Grid Retreat; see Murphy et al., 2008).

4 IMPROVING THE GRID

Most of the work on our end involved improvements to the Access Grid that would make the process of distributed collaborative visualization more useful, while meeting the specific needs of our research partners. Specifically, we will discuss in this section our work towards enhancing the quality of video transmitted over the AG, as well as reducing cultural barriers to collaboration through an automated captioning and translation service. Finally, we will proceed with an assessment of worthwhile future research directions and concluding remarks.

4.1 Enhancing Video Quality

As discussed, the video application within the Access Grid, VIC, utilizes a standard of video known as H.261; unfortunately, this codec does not provide enough resolution (352 x 288) for our industrial partners, all of whom are transmitting audio, video and industrial designs to each other. As well, VIC is generally “buggy”, inflexible (does not support plug-ins to suit the specific needs of its users), and lacks support for current-generation codecs that would enable streaming in higher resolutions. To improve audiovisual transmission over the AG, our team decided to develop a new tool that would integrate VIC and RAT (audio) and, at the same time, allow us to take advantage of a newer codec, MPEG-4, which can produce high-definition-quality imagery (in either 720p or 1080i). We have also been exploring methods to deliver this stream over the multicast network, outside of the existing Access Grid Toolkit wrapper. One of the more promising applications that facilitate this is VideoLAN Client (VLC), a cross-platform, open-source offering that is already well-established in the consumer marketplace; therefore, several options for technical support are available, and IT professionals are welcome and encouraged to develop plug-ins and wrappers that may be of particular use to their organization.

The final element of our work in refining the videoconferencing element of the AG involves remote desktop control: such a feature was a specific request of our partners, and we responded by developing a Java applet that, when run alongside the VLC stream (and encoded through FFmpeg), affords the receiving side the ability to take control of the host’s system and manipulate the design being shared on screen. With this, collaborative visualization and manipulation of industrial designs can occur with a level of quality not available to organizations using VIC, VNC or any remote desktop client presently on the market. As a proof-of-concept demonstration, researchers in Toronto and in Stuttgart, Germany, recently used this system to engage in the collaborative visualization and manipulation of auto parts designs. This test session, conducted in August of 2007, demonstrated high-resolution video and audio with joint desktop control, and was conducted with very low latency (and less than 5 Mbps of bandwidth over the 100 Mbps CA*Net 4 research network was consumed).

4.2 Captioning & Translation Services

In order to increase efficiency in videoconferences over the AG/VLC solution, our team has also begun to experiment with voice recognition software, so as to enable automated captioning of the audio feed. Our trials thus far have utilized commercial offerings, namely Dragon Naturally Speaking, to convert speech to text and display it on the screen through the use of a custom script written in Python. In some trials, we have further attempted to send the text through a web-based, machine translation service (such as Google Translator) and have the end result displayed on screen. Logically, our level of success with both of these projects has depended largely on how well-trained the voice recognition software is relative to the present speaker; additionally, the well-known limitations of machine translation are still present in such a system. That said, we feel that such a captioning and translation system holds promise, since we were able to utilize it to display and translate (into French and German) general aspects of certain meetings with an acceptable degree of accuracy for all stakeholders.

5 FURTHER RESEARCH

In addition to continuing our work on improving distributed collaborative visualization techniques, we do believe that more can be done to help implement a level of semantic “intelligence” to the design and procurement process. For now, we are most concerned with further improving the basic Access Grid extensions and enhancements we have described above. Our main industrial partner in Canada continues to express an interest in working with us to improve the technology package, in possible preparation for an eventual transfer. However, our continued tests of the tools between their international facilities (Canada, the United States and China) have identified new concerns regarding implementation across firewalled, unicast networks. Therefore, our immediate next steps are to work with our industrial partners to find a mutually acceptable solution to such concerns, whilst proceeding to condense the technology into a compact prototype device.

Alternatively, these enhancements can remain an integral part to the open-source Access Grid community. In either instance, many of the tools could also be used outside of the realm of industrial design to facilitate other forms of media creation and interaction, namely collaborative performance and shared-space artistic installations

6 CONCLUDING REMARKS

This paper has presented state of the art surveys of distributed collaborative visualization environments, as well as the technologies upon which they are based. More specifically, we explored the Access Grid by discussing its past, present and predicted use within business. Finally, we compared this research with the greater aims of our work at the AccessFabrik Laboratory in creating new AG-based tools for collaborative design and communication; we outlined some of our work in reaching these goals, and suggested areas we feel are worthy of future exploration. Throughout this paper, we attempted to relate our key points using non-technical language, so as to make this document more accessible to its readers.

We consider the major conclusions from this research to be as follows: first, significant change is occurring in industrial sectors that are heavily dependent on industrial design – new methods of conducting business in the auto industry are, for example, resulting in the increased geographical distribution of resources, coupled with increased heterogeneity amongst organizations in the value chain; and secondly, we understand that technology needs to be improved by research communities like ours in response to this – advanced videoconferencing solutions like the Access Grid are assisting a variety of organizations in collaborating on projects at all stages in their respective life cycle. Each organization or industrial sector will need to analyze their own particular situation and determine whether or not new tools like the ones we have described within have the potential to help leverage technological change to their benefit.

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