Advanced Tools for Enhancing Control Room Collaborations

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Abstract

The US National Fusion Collaboratory (NFC) project has been exploring a variety of computer and network technologies to develop a persistent, efficient, reliable and convenient collaborative environment for magnetic fusion research. One goal is to enhance remote and collocated team collaboration by integrating collaboration software tools into control room operations as well as with data analysis tools. To achieve this goal, the NFC recently introduced two new collaboration technologies into the DIII-D National Fusion Facility tokamak control room. The first technology is a high-resolution, large format shared display wall. By creating a shared public display space and providing real-time visual information about the multiple aspects of complex experiment activity, the large shared display is playing an important role in increasing the rate of information dissemination and promoting interaction among team members. The second technology being implemented is the "tokamak control room aware" Instant Messaging (IM) service. In addition to providing text-chat capabilities for research scientists, it enables them to automatically receive information about experiment operations and data analysis processes to remotely monitor the status of ongoing tokamak experiment. As a result, the IM service has become a unified portal interface for both team collaboration and remote participation.

Keywords: National Fusion Collaboratory; remote participation; shared large display, Instant Messaging; Jabber

1. Introduction

Due to the highly collaborative nature of fusion energy research, remote participation and collaboration has a long history in fusion community. Over the years, a variety of collaboration tools have been deployed and are playing an important role in advancing magnetic fusion research. However, observations show that several limitations exist with the existing remote participation and collaboration infrastructure. The first limitation is that deployed tools are mostly targeted to collaboration between remotely distributed groups. The local collaboration needs of large groups within control rooms are not well addressed. The second issue is that current remote participation software tools are mostly standalone programs and are not well-integrated into experiment facilities, control room and data analysis tools, which make them hard to use. Existing remote participation tools, i.e., audio/video conferencing software, often require fast computers and high bandwidth network connections. When computer speed and network bandwidth requirements are not satisfied, these remote participation tools are impossible to use. Although

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severities differ, these problems need to be addressed in order to create an efficient and reliable collaborative fusion research environment.

The US National Fusion Collaboratory (NFC) project [1] has explored a variety of technologies to develop a persistent collaborative and computational infrastructure for magnetic fusion research. Its "Collaborative Control Room" initiative tries to alleviate the current limitations of remote participation tools mentioned above and is creating an efficient collaborative infrastructure that matches the needs of the tokamak-centric, fast-paced, cyclical, large-team environment. Its ongoing effort includes deploying several new computer-based collaboration software tools for fusion research. The idea is not simply to use the computer research results at the control room, but to effectively extend and customize the emerging technologies for the benefit of tokamak control room collaboration.

This paper reports the work that the NFC project has accomplished for the deployment of two new advanced collaboration technologies. The first technology is the shared display wall system to support team collaboration within the tokamak control room. The second technology is an Instant Messaging (IM) system to support the text message exchange and experiment status update. As case studies, we will share our experiences in deploying these technologies at the DIII-D National Fusion Facility. We will comment on the applicability of these two technologies to the fusion control room and discuss future work based on the lessons learned.

2. Shared display system

The size of magnetic fusion experimental facilities is growing and the number of diagnostics as well as the complexity of related data analysis is increasing. As a result, the effective collaboration and group status awareness among research team members, who have different specialties, are becoming increasingly important. Moreover, comprehensive analysis of complex data depends on detailed visualization. This necessitates not only the support of collaboration among geographically distributed researchers, but also the enhancement of collaboration and visualization infrastructure within the tokamak control room.

A wall-size shared display has potential benefits for the collaboration activities of a collocated large group working towards a common goal. It offers high pixel resolution space for displaying detail-rich visual information that normally doesn't fit on one computer screen. It is large in size so that the displayed information can be easily seen by a large group. These benefits can foster the group activity awareness and improve the interaction effectiveness among a tokamak experimental team comprised of 20-50 people.

Although the potential benefits of a shared display in promoting group collaboration within a tokamak control room are obvious, the selection of visual information to be displayed and the effectiveness of interaction are critical for successful deployment. Information that is related to group activity and the common interest of the team members needs to be identified. The understanding of group interaction practices and development of easy-to-use software are also needed.

3. Case study: shared display wall system at DIII-D National Fusion Facility control room

3.1. System description

A low-cost, shared display wall system has been constructed at the DIII-D National Fusion Facility control room. Three 127-cm Toshiba P500DL data wall cubes have been chosen for the screens due to the small projection distance and the thin 1 mm gap (mullion) between screens . Placing these cubes side-by-side, a 381 cm wide, 76.2 cm tall, seamless, high-resolution (3840x1024 pixel) tiled display wall has been created.

A 3.06 GHz Xeon dual processor Dell Precision 650 workstation with three-headed Matrox Parhelia 256 graphics card has been used to drive the shared display. A single computer-based system has been chosen over a cluster-based system for two reasons. First, the graphics card has enough (3) outputs to drive all display units. Second, computational power of the computer and hardware-accelerated graphics support are powerful enough to render the visualization jobs of the fusion software applications. RedHat 9.0 Linux is the underlying OS of the system.

In order to effectively utilize the shared display, appropriate visual information that is helpful to control room collaboration needs to be displayed. Our implementation process has been a two-step approach. The first step is identifying the most valuable data sets, in which a majority of team members have a common interest. The second step is developing new software or customizing existing desktop software tools to visualize the data on the shared display wall environment. As a result, several data visualization tools have been made available for DIII-D shared display wall (Fig. 1).

3.2. Software tools for DIII-D shared display system

Plasma shape movie player. Fundamental to tokamak experimental research is the detailed knowledge of magnetic field topology (plasma shape), since the tokamak magnetic field is generated in part from currents flowing in the hot plasma. The real time visualization of the temporal evolution of the magnetic field topology is important to guide the research and is a common interest of team members in the control room. A magnetic flux surface visualization code – Efitviewer [2] was developed at DIII-D in the late 90s and was primarily used in a personal desktop environment. The original code is GUI driven and works interactively, in which the user needs to specify the plasma shot number and other equilibrium fitting parameters in order to visualize the magnetic field. Modifications have been made to the code to be used on the shared display. The first modification is automating the Efitviewer's visualization process with MDSplus events. The modified version listens to "efit data available" event message from the MDSplus [3] system after the plasma equilibrium data is acquired. Whenever this event is received, Efitviewer reads the data from the latest shot, generates a time-varied plasma shape visualization movie and repeatedly display it until MDSplus sends another "efit data available" event for the following plasma pulse. Thus, scientists in the control room can always monitor the newest plasma shape movie after each plasma shot is completed. Another change to the code is eliminating the GUI control widgets so that only the visualization window is displayed. To enhance the visibility of the image, the colour, line thickness and annotation label sizes of the visualization image have been customized for the shared display environment.

Electronic log ticker application. Records of formal decisions during the DIII-D tokamak experi ment are documented using the electronic logbook [4], which is a widget-based IDL [5] application used for entering and viewing the scientists' comments. The data entered through the logbook are stored in a relational database and viewed by all team members in real time with the help of its built-in data sharing capability.

While the electronic logbook is a very convenient tool for collaboration, sharing the log entries on shared display is more effective. First, displaying the logs on the shared display eliminates the necessity of displaying them on each individual desktop screen, which can save screen space in the user's computer. Second, it reduces network traffic and the number of applications running on the central server. Therefore, the electronic log ticker application was created, which displays the log entries on the shared display. The ticker mainly reads the newest log data from the relational database and displays it as a horizontally scrolling text across the display wall.

Data analysis monitor status reporter. Tokamak operation is a complex process. Each pulse involves thousands of measurements, hundreds of megabytes of data and several large data analysis codes. To automatically detect the discrepancies in diagnostic measurements and data analysis process in this complex environment, a centralized monitoring system is needed.

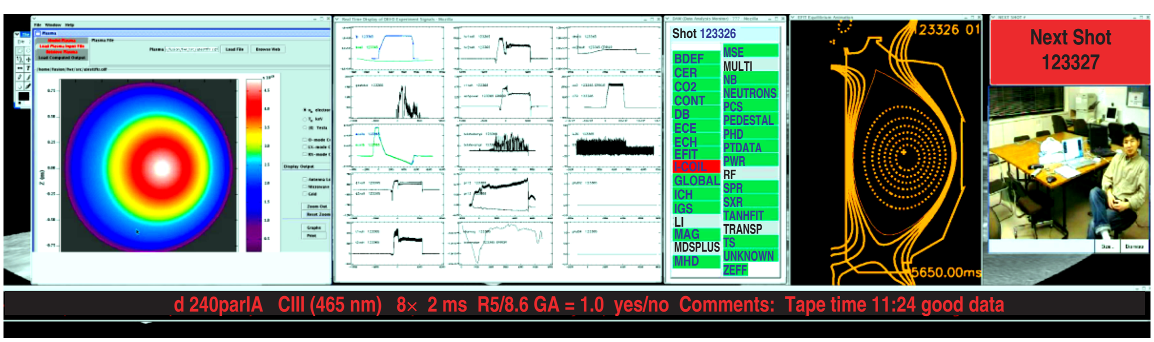

Fig. 1. Screen shot of DIII-D shared display wall. Displayed are (left to right) a shared data analysis result submitted by a scientist, the real time plasma control signals, DAM report, the plasma shape movie player, and a video image of a collaborating scientist from a remote site. Displayed on the bottom is the electronic log ticker application.

The data analysis monitor (DAM) [6] system was designed several years ago for this purpose and is being used to allow scientists to monitor the status of between pulse data analysis at DIII-D. Since data analysis monitoring is critical for normal tokamak operations, the reports created by the DAM system is of common interest to both the physics and operations teams. This makes DAM another important candidate to be displayed on the shared display. However, the DAM system client was originally developed as a web application based on clickable hyperlinks and is not suitable for use directly on the shared display. Therefore, a new shared interface for DAM has been created. The reporting scheme also has been modified so that it reports data analysis results by large data categories and visualizes the data analysis status by a pre-defined colour scheme. In this scheme each data category item displayed in one of the 3 colours. Grey colour means data analysis is "in progress", green colour means "success", and red means "error".

Data analysis results sharing system. In the DIII-D control room, scientists share data analysis results and make collaborative decisions in order to change plasma control parameters. The old fashion method of data analysis sharing among team members is where one scientist invites others to look at his screen. In this method of interaction, due to small size of desktop screen, the number of invitees always has been limited. Therefore, multiple small-group discussions had to be held before the final decision was made. To make the group interactions more effective, a shared display based information sharing mechanism has been implemented and integrated into a number of DIII-D data analysis applications. This system consists of two parts. The first part mainly captures the snapshot image of the user's desktop as a whole or partly defined by the users, and transfers it to a specified web server. This part runs on Unix/Linux servers at DIII-D and is called by various data analysis codes. The other part is a webpage displayed on the shared display computer. The web page automatically updates itself with "client pull" mechanism. By using this mechanism, any team member easily share the snapshot images of data visualization windows from his screen at any stage of data analysis process. Other users can view the shared information on the shared display or save it as an image file to their local directories if they choose to do so.

3.3. Shared display-based remote collaboration support

Although the main purpose of the shared display is to support the interaction among the scientists collocated in the control room, the shared display also played an important role in enhancing the collaboration between control room and remote participants. The video window of Access Grid [7] and VRVS [8] software have been presented on the shared display when scientists at remote sites lead the DIII-D experiment. The large video image of a remote scientist has given the impression to local scientists that he was sitting in the control room. This made the remote collaboration more natural. A high-resolution pan-tilt-zoom camera has been installed on the opposite side of the control room facing the shared display, which enables remote scientists to monitor the information on the display. It has allowed them to view their own results shared through the data analysis sharing system described above (like having moveable eyes in the control room).

4. Instant messaging service for collaboration

Recent advances in computer and network technologies have made various new tools available for collaboration. Access Grid and VRVS are two important examples of these tools and that are often being used in fusion research collaboration. However, the encoding and decoding of audio/video streams needs relatively fast computers, and the transmission needs a high-bandwidth network. Since fusion research is a worldwide effort involving thousands of researchers and hundreds of institutions dispersed in multiple countries funded by different agencies, it is hard to keep upgrading the computational infrastructure at the same speed. Moreover, high-bandwidth network cannot always be guaranteed, especially between the institutions located on different continents. In order to support the collaboration among a variety of institutions, collaboration software tools that are less-dependent on computer speed and network bandwidth are needed.

Jabber [9] is a set of XML streaming protocols and technologies that can enable remote parties to exchange information. As a text-based instant messaging communication technology, it can provide a lightweight collaboration channel for fusion research. Although it doesn't have a real-time audio/video conferencing feature, Jabber provides researchers with a reliable information exchange mechanism that works even in a low-end computer and a low-bandwidth network environment. As an open standard and extendible technology, it provides convenient mechanism for customizing a control room-based collaboration environment.

5. Case study: DIII-D National Fusion Facility IM service

5.1. System description

A recent effort of the NFC project has been utilizing IM technology for remote participation and collaboration purposes at the DIII-D National Fusion Facility. A 3.06 GHz single processor Dell precision 650 workstation with RedHat 9.0 Linux OS was dedicated for the IM server. The Jabberd2.0 [10] open source server software was installed and the communications was secured with SSL. To conveniently identify and organize the IDs of users from multiple institutions, a user ID convention was recommended so that users register accounts with <institution_prefix>_<last_name>@jabber.gat.com format. Two permanent public chat rooms, "D3D room" and "DAM room", have been created on the server. The server also allows users to create a temporary chat room and invite others to private discussions.

5.2. Control room operations aware IM service

In addition to providing text-chat capabilities, a service that facilitates message exchanges between Jabber conferencing rooms and tokamak experiment related software tools has been implemented. Using Jabber is not only for exchanging text messages among scientists, but also for monitoring the status of ongoing tokamak experiments (Fig. 2). As a result, the IM service has become a unified portal interface for team collaboration and remote participation.

Since Jabber is based on open standard XML streaming technology, connecting the existing DIII-D data analysis tools to IM service has been a straightforward task. Every Jabber session runs on a single TCP connection and uses XML elements as the communication media. All actions and text messages are described in XML format. Any program can communicate with the Jabber server if it is able to initiate TCP connections and construct XML formatted data. A shared C++ Jabber client library that can send XML streams over TCP sockets was created. It has functions for logging in/logging out, subscribing/unsubscribing, message sending/receiving and presence notification in XML format.

By calling the shared Jabber client library routines, several DIII-D data analysis tools have been enabled to send experiment related information to IM users. Now, the plasma control computer posts experiment status information in quasi-real time. The

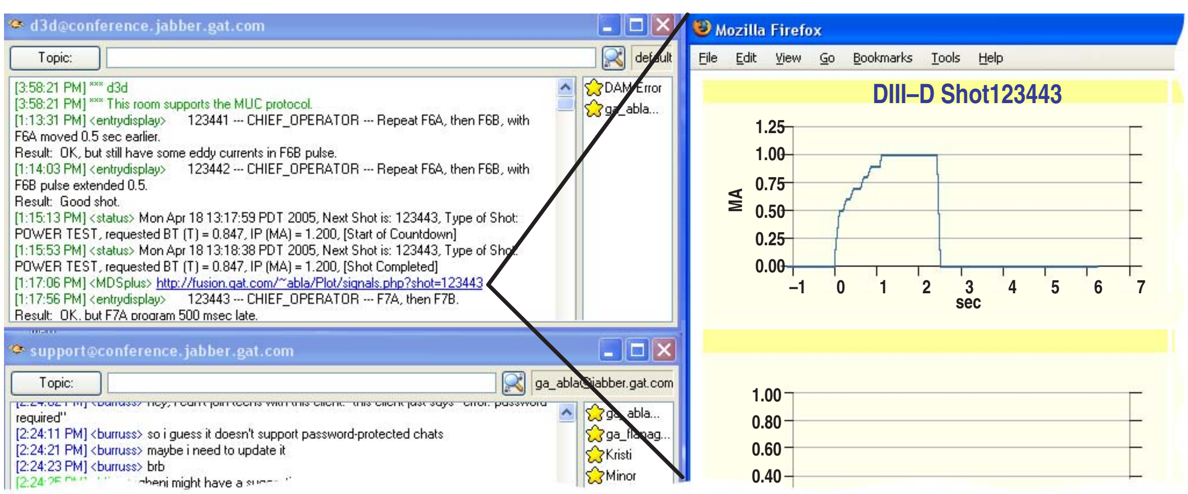

Fig. 2. Partial snapshot image of a DIII-D Jabber user's computer screen. Displayed clockwise are "d3d public chat room", real time plasma signal plot page linked to the hyperlink in the d3d room, and a private chat room.

electronic logbook automatically sends log entries. DAM also notifies users with error messages whenever an error occurs.

Another application of the DIII-D IM service has been making 2D data plots automatically available after the completion of each plasma shot. An application program listens to the MDSplus events, which sends out a URL when it receives a "signal data available" MDSplus event. The URL appears on all IM clients and is linked to a server side CGI program that plots MDSplus data. Users can view the signal plots on a web browser by clicking the URL link.

6. Lessons learned and future work

The design and implementation of these technologies has been an iterative process. Almost every implementation step is the result of many interactions and testing between computer science researchers and fusion researchers.

The testing and real world usage of the above technologies have taught us several lessons. First of all, any effective collaboration technology needs to be easy to use. For example, the Data Analysis Results Sharing code originally has been implemented as a standalone program. Users needed to execute it through an X11 terminal command line in order to share his analysis results. Being not very convenient, it hasn't been used much until integrated into regular data analysis tools and offered as menu options in existing applications. The second lesson we learned is GUI programs designed for desktop computers are not applicable for shared display-based collaboration. The layout, interaction method, fonts and size of the GUI should match the control room environment. Another lesson we learned is, a collaboration tool shouldn't undermine the researcher's original work environment. At one point, AG/VRVS audio output has been connected to the control room speaker system expecting all control room-based scientists to participate in discussions. However, tests have suggested that control room discussions are amongst small groups not the entire team.

The large shared tiled display technology for control room based group interaction and the IM technology for fusion experiment centric collaboration have proven useful and has been well received by the scientific team. Furthermore, we believe that this technology will scale to next generation devices such as ITER. Although successful, there is still more work to do. A short-term plan is making the data analysis result sharing mechanism of large shared display wall among multiple users more robust and easier to use. The NFC project is also working on a multi-cursor X window manager that enables multiple users to concurrently interact with the large shared display contents [11].

Acknowledgments

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