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SHARED DISPLAY WALL BASED COLLABORATION ENVIRONMENT IN THE CONTROL ROOM OF THE DIII-D NATIONAL FUSION FACILITY

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ABSTRACT

At the DIII-D National Fusion Facility control room, a large format shared display is being used in the control room to support routine collaborative scientific investigation during experimental operations. The US National Fusion Collaboratory Project conducted an observational study in order to identify the best ways of utilizing the shared display wall for control room collaborations. The findings of the study motivated the deployment of shared display-based software tools in three categories: 1) visualization tools that provide up-to-date information about experiment status and group activity, 2) data analysis sharing tools that enable researchers to move the information from personal desktop screens into the large shared display wall, 3) advanced remote participation and video conferencing tools that present the life-size video of remotely participating core team members.

1. INTRODUCTION

The DIII-D National Fusion Facility carries out complex scientific research activities on the DIII-D tokamak. The tokamak operates in a pulsed mode producing plasmas of up to 10 seconds duration every 10-20 minutes, with 25-35 pulses per day. Each pulse produces hundreds of megabytes of data acquired from up to 10,000 separate measurements. Rapid analysis needs to be completed using the acquired data within the approximate 20-minute between-pulse interval in order to prepare new machine parameter configurations for the next pulse. Decisions for parameter changes are collective results of discussions amongst the members of the large experimental team, comprised of 20-50 people, which are not only collocated within the control room but also participating remotely.

Due to the complex nature of fusion control room operations, successful research depends on effective communication and collaboration during the experiment. Multiple aspects of experiment status and group activity need to be always readily available so that all team members can maintain awareness and collaborate with each other. Each team member has different skills and responsibilities that need to be shared effectively during the between-pulse interval so that the best decisions are made based on a collective data analysis effort. Finally, since the role of remote team members is as important as on-site team members, the communication between local and remote participants needs to be efficient.

The capabilities of wall-size shared display system can improve collaboration activities of a large fusion experimental team working towards a common goal. Its high-pixel resolution not only enables the scientific team to study the fine details of density-rich visual information without loosing the overall picture, but also creates a space for simultaneously visualizing the multiple aspects of experimental operations. It is large in size so that the displayed information can be easily seen by a large group of people in the control room. By functioning as a public presentation space, a shared display system fosters group activity awareness and improves the interaction effectiveness among experimental team members.

Although the potential role of large format shared display system is obvious for the collaboration activities, the real benefit to effective collaboration depends on how well the information is presented on the wall and how effective the shared display wall software tools are designed. The US National Fusion Collaboratory Project conducted an observational study in order to identify the best ways of utilizing the shared display wall for control room collaborations. The findings of the study motivated the deployment of shared display-based software tools in three categories: 1) visualization tools that provide up-to-date information about experiment status and group activity, 2) data analysis sharing tools that enable researchers to move the information from personal desktop screens into the large shared display wall, 3) advanced remote participation and video conferencing tools that present the life-size video of remotely participating core team members. As a result, the shared display wall system has become one of the most important building blocks of the “collaborative control room” and has been well received by fusion researchers.

In this paper we describe our work on deploying DIII-D shared display wall system. Section 2 describes the DIII-D shared display wall system setup. Section 3 discusses visualization software tools. Section 4 describes shared display wall-based data analysis sharing tools. Section 5 describes advanced video conferencing tools integrated into shared display wall. Then we will present software tools developed or customized for shared display wall and control room environment. At the end, at section 6, we will discuss the learned lessons together with visions for future work.

2. DIII-D SHARED DISPLAY WALL SYSTEM

The DIII-D Shared Display System is built by placing three 50-inch, 1280 x 1024-pixel, Toshiba P500DL data wall cubes side-by side at the front of the control room. It is a 50 inches wide, 30 inches tall, seamless, high-resolution (3840 x1024 pixel) tiled display system and large enough to be easily seen from most parts of the control room. The shared display system is driven by a dual-processor Dell Precision 650 workstation with three-headed Matrox Parhelia 256 graphics card. RedHat 9.0 Linux is the underlying OS for the system. Figure 1 is a photograph of the shared display wall system in DIII-D control room environment.

Fig. 1. The DIII-D control room environment including shared display wall system.

A high-resolution pan-tilt-zoom network camera (Sony SNC-RZ30N) has been installed on the opposite side of the control room facing the shared display. Although not physically connected to the shared display wall, it made shared display wall system useful to remote participants enabling remote scientists monitor the information presented on the display through web-pages.

3. DIII-D SHARED DISPLAY WALL-BASED VISUALIZATION TOOLS

To work effectively as a team, the team members must be able to refer the same information about the ongoing experiment. The large-format shared display wall offers public presentation space and multiple datasets from the experiment can be presented to the large group of scientists in the control room. However, since an endless stream of information is arriving from thousands of sensors, an extensive data fusion and information selection is needed in order to present the true picture of overall control room activity.

At DIII-D, the most valuable data sets that represent the overall experiment status and group activity have been identified. Multiple visualization software tools have been developed to present the identified data sets on the shared display wall environment.

3.1. 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 magnetic field topology over the duration of each shot is important to guide the research and is a common interest of all team members in the control room. A magnetic flux surface visualization code – EFITViewer [2] has been developed at DIII-D in the late 90s and has been primarily used in a personnel desktop environment. The original code works in ‘in-demand’ and interactive mode, in which user needs to specify the plasma shot number and other equilibrium fitting parameters. Modifications have been made in the code in order to be used at the large tiled display. The first modification is making the EFITViewer read data and update the visualization automatically without human intervention. It listens to event messages from the MDSplus [3] data system. MDSplus sends out an “EFIT data available” message just after the plasma equilibrium data is acquired. If EFITViewer receives the “EFIT data available” message, it reads the data from the latest pulse and generates the time-varied plasma shape visualization movie. This movie is played until MDSplus sends another “EFIT data available” message for the following plasma pulse. This way, scientists in the control room always can monitor the newest plasma shape movie just a few second after each plasma shot. The second modification is the adjustment of GUI so that all user interface control widgets are hidden but the visualization window. To enhance the visibility of the image, the color, line thickness and annotation label sizes of the visualization image have been customized to the shared display environment as well.

3.2. The Electronic Log Ticker Application

Records of formal decisions during the DIII-D tokamak experiment are documented by using the electronic logbook [4]. The electronic logbook is a widget-based IDL [5] application used both for entering and viewing the experiment comments. The logs entered through electronic 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 in two ways. First, displaying the logs on the shared display eliminates the necessity of displaying them on each individual desktop screen, which means saves screen space on the user's computer. Second, it reduces the number of applications running on the central server and reduces network traffic. Therefore, the Electronic Log Ticker Application, which displays the log entries on the shared display wall, has been implemented. It mainly reads the newest log data from relational database and displays it as horizontally scrolling text across the display wall.

3.3. Data Analysis Monitor Status Reporter

Tokamak operation is a complex process. Each pulse is involved with thousands of measurements, hundreds of megabytes of data and several large data analysis codes. In order to automatically detect the discrepancies in diagnostic measurements and results of physics analysis codes in this complex environment, a centralized monitoring system is needed.

The Data Analysis Monitor (DAM)[6] system has been originally designed several years ago for this purpose and being used to allow scientists to monitor the status of between pulse data analysis codes at DIII-D. Since data analysis monitoring is critical for normal tokamak operations, the reports created by DAM system is a common interest for both physics and operations teams. This makes DAM another important candidate to be displayed on the Shared Large Tiled Display. However, the DAM system was originally developed as a web application based on clickable hyperlinks and is not suitable to use directly on the shared display. Therefore, a new-shared display based DAM interface has been created. The reporting scheme also has been modified so that the data analysis results are now reported by large data categories and the status is visualized by a pre-defined coloring scheme. Grey color means the data analysis is "in progress"; green color means "success" and red color means "an error occurred".

4. DATA ANALYSIS SHARING TOOLS

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 has been performed by one scientist inviting others to look at their screen. In this method of interaction, due to the small size of the 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.

In order to make group interactions more effective, we developed two types of shared display wall-based collaboration software. The first one is a mechanism that enables users to quickly display individual data analysis results on the shared display wall. The other tool is a multi-cursor environment that allows multiple users to control the shared display wall application simultaneously.

4.1. Data Analysis Results Sharing Mechanism

This system consists of two parts. The first part is mainly to capture the snapshot image of the user's screen as a whole or partly, and transfer it to the web server. It is implemented on the Unix/Linux servers and integrated into series of DIII-D data analysis applications. The other part is a webpage displayed on the shared display computer and updates itself with "client pull" mechanism. By using this mechanism, any team member conveniently can share text messages or the snapshot images of data visualization windows at any stage of the data analysis process. Other users can view the shared information on the shared display or save it as an image to their local directories if they choose to do so.

To allow for sharing dynamic content we have been developing a second version of this system. It is based on Virtual Network Computer software (VNC) with modifications that allow the sharing of individual applications. Normally VNC shares a user's entire desktop, but in a collaborative environment, there is typically content a user wants private, such as email, and content they want to share, such as data plots. To accommodate this we modified the VNC protocol to allow users to share individual windows from their desktop to the shared display. A specialized VNC client running on the shared display puts each shared window in its own frame that can be positioned or sized independently. We call this project SharedAppVnc and are beginning to deploy it to the control room.

4.2. Multi-cursor X Window Manager

Another collaborative requirement is to allow multiple users to simultaneously interact with the shared display. Existing windowing systems assume a single user model with a single cursor, keyboard and input focus. To address this we have developed a multi-cursor X window manager [9]. This window manager provides for multiple simultaneous cursors on the shared display and allows multiple users to concurrently interact with applications, system menus, and window positioning. When a scientist at a workstation moves their mouse pointer off the top of their workstation screen, it appears on the shared display as a uniquely colored cursor. Applications on the shared display that users interact with will be highlighted in that same color. With the ability to point to and modify views simultaneously, scientists can more effectively describe their results.

5. REMOTE PARTICIPATION AND VIDEO CONFERENCING TOOLS

Remote participation is increasingly common in fusion experiments. The role of remote team members is always as important as on-site team members. Therefore the communication between local and remote participants needs to be as efficient as among the collocated team members.

At DIII-D, a variety video conferencing and collaboration tools, such as Access Grid and VRVS, have been used for the past several years. Until recently, they mostly have been used in personal desktop environments. The shared display wall provided a large screen space. Therefore, the video window of Access Grid [7] and VRVS [8] software have been displayed on the shared display when scientists at remote sites led the DIII-D experiment. The large video image of a remote scientist has given the impression to local scientists as he has been sitting in the control room, which made the remote collaboration more natural.

6. LEARNED LESSONS AND FUTURE WORK

A large format shared display wall system has been installed and varies software tools and mechanisms have been developed. By creating a shared public display space and providing real-time visual information about the multiple aspects of complex experiment activity, the large format shared display is playing an important role in increasing the rate of information dissemination and promoting interaction among team members. Figure 2 is a partial snapshot of the DIII-D shared display system.

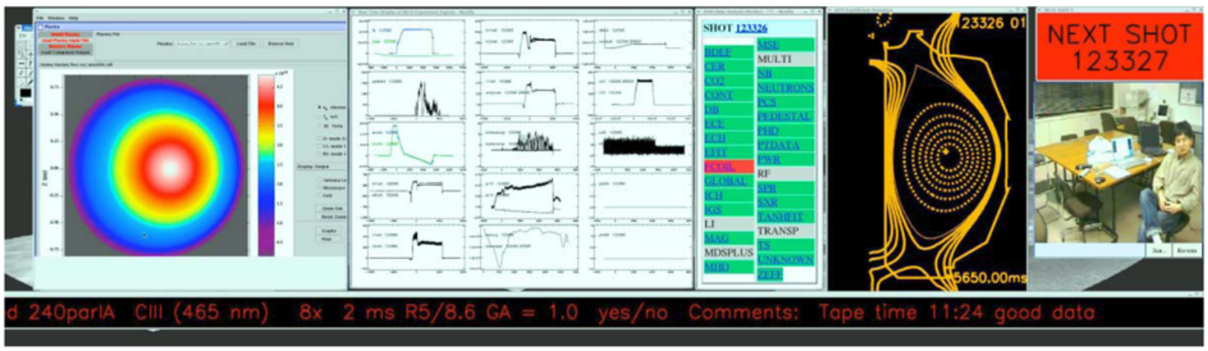

Fig. 2. Partial screen snapshot of DIII-D shared display wall. Displayed are (left to right) a data analysis result being shared, the real time plasma control signals, Data Analysis Monitor report, the plasma shape movie player, and an Access Grid video image of a collaborating scientist from a remote site. Displayed on the bottom is the electronic log ticker application.

The design, implementation and deployment of software applications for control room-based shared display wall system have taught us several lessons. The first lesson is that a shared display wall system is more useful when scientists can efficiently and conveniently read the information content. This can be accomplished through effective use of GUI layout, color, font size, and font style of the visualization. Another lesson is that software tools for collaboration must be very easy to use and easy to interact with the shared display wall system. Collaborating via shared display wall should not hinder the normal data analysis activities of a scientist.

In the near future, we will focus on improving the robustness and effectiveness of the shared display wall software. The effectiveness of shared display environment also depends on better user training, education and documentation.

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