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A REMOTE CONTROL ROOM AT DIII-D

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ABSTRACT

This paper describes a remote control room built at DIII-D to support remote participation activities of DIII-D research staff. In order to create a persistent, efficient, and reliable remote participation environment for DIII-D scientists, a remote control room has been built in a 640-square-foot dedicated area. The purpose of this room is to experiment and define a remote control room framework that can facilitate the remote participation needs of current and future fusion experiments such as ITER. A variety of hardware equipment has been installed and several remote participation and collaboration technologies have been deployed. Objectivity and practical consideration have been the key while designing the room and deploying the technologies. Although, the DIII-D remote control room is still a work in progress and new software tools are being implemented, it has been already useful for a number of international remote participation activities. For example, it has been used for remote support of the EAST Tokamak in China during the startup operation and proven effective for other collaborative experiment activities. The description of the remote control room design is given along with technologies deployed for remote collaboration needs. We will also discuss our recent experiences involving the DIII-D remote control room as well as future plans for improvements.

1. INTRODUCTION

In the last few years, participation in remote experiments by the DIII-D staff have been increased and became a routine activity. Until recently, using general conference rooms plus temporarily installed communication tools and computers have been the main remote participation environment. Although, these remote participation environments have been useful, the quality of collaboration has varied from case to case. This is due to the following two reasons. First, since the conference rooms are designed for general meetings, the working environment has not always been suited for data analysis and research activities; the access and display of experiment-related information have been limited. Second, the *ad hoc* setup of remote participation tools decreased the reliability and efficiency of communication. While there are many remote collaboration technologies and software in existence, very few are applicable to the unique remote participation needs of experimental fusion research.

The idea of creating an environment in which the DIII-D staff can reliably and efficiently participate in remote fusion experiments motivated the building of a dedicated remote control room at DIII-D. With the support of the U.S. National Fusion Collaboratory Project [1], we started by identifying the remote participation needs of the research staff.

The work of building a remote control room had three main aspects. The first aspect was to identify appropriate remote participation technologies and hardware tools. The second aspect was to design the remote control room layout as a practical working environment and install the hardware. The final aspect was to customize the existing tools and develop new software for the experiment-centric remote collaboration. The whole process involved identification, deployment and experimentation of suitable collaborative technologies in this remote control room in order to fill the distance-generated gap between DIII-D scientists and remotely located fusion experimental facilities.

The construction began in early 2006 and the lab was partly usable in the summer of the same year. The room layout has changed several times since then. Figure 1 shows the current layout of the remote control room. Figure 2 is a photograph of the right half and Fig. 3 is a photograph of the left half of the remote control room. Figures 2 and 3 also show the technologies deployed.

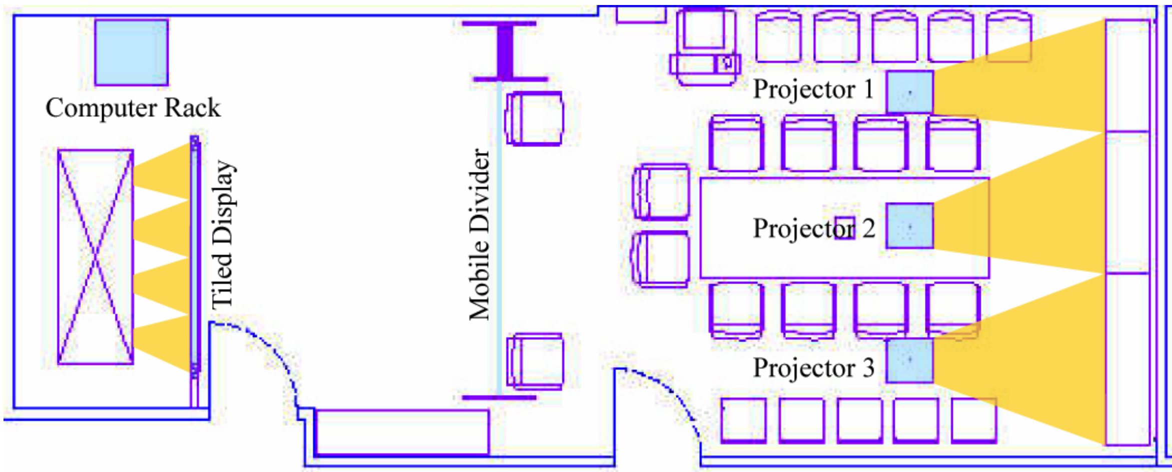

Fig. 1. Layout of the remote control room at DIII-D. On the left is the rear-projection tiled display system. On the right are a three-projector screen and a meeting table. A portable divider is also provided.

Fig. 2. The 10.5 MPixel high-resolution tiled display demonstrating the remote participation and collaboration tools in the remote control room. The upper half of the tiled display, from left to right, displays the RealTime Boundary Display application, a visualization application window shared from a remote computer via SharedAppVNC, Data Analysis Monitor, and a Ganglia-computational resource monitoring webpage. The lower half of the display shows the streamed video of the PCS signal screens located at DIII-D.

Fig. 3. The three projector screen is shown. On the left, a VRVS-based videoconferencing video is displayed. In the middle a shared presentation is displayed. On the right the Polycom H.323 interface is displayed.

2. DESIGN OF THE REMOTE CONTROL ROOM

From the beginning, we expected that the remote control room should have the following functionalities. First, the remote control room allows DIII-D scientists to access the information in a manner that is similar to what is available in the control rooms located at remote experimental facilities. Second, it facilitates the reliable collaboration between scientists sitting in this control room and other control rooms. The third function of the remote control room is to provide a comfortable working environment so that scientists can perform extensive data analysis or even take shift duties.

In order to provide visual information of the ongoing experiment, a large tiled display was constructed (Fig. 2). The tiled display is composed of 8 projectors with a total resolution of 5120 pixels by 2048 pixels. There are three reasons for building one large tiled display instead of several individual computer screens. First, the large screen space is flexible and displays a variety of information. It can be used to display individual computer screen information as well as high-resolution images that require more than one screen resolution. The second reason is that the entire high-resolution pixel space can be driven with one computer with multiple graphics cards, which is more economical and space efficient than a cluster of computers. Since the resolutions of the individual images to be rendered during experiments are not very high, the visualization does not require the power of a computer cluster. In our case, the tiled display is driven by a graphics workstation with four two-headed PCI-Express graphics cards.

A video conferencing hardware and a computer for software based videoconferencing were provided. A large screen driven by three projectors was installed to display the life-size video of remote collaborators and presentation viewgraphs (Fig. 3). The projector installation and wiring are flexible enough in enabling users to easily switch projector inputs among video conferencing device, presentation computer as well as user’s laptop computers.

A significant effort was made to create an effective working environment for researchers who perform various data analysis during remote experimental participation. The room is equipped with three telephone lines with echo cancellation speakerphones, a computer workstation, wireless and Ethernet connections. A large table is equipped with network switch and interfaces that provide Internet connection, microphone connection and VGA interfaces. Via the VGA interface, users can quickly display their laptop screen contents on the screen. The room layout accommodates different sizes of groups. Currently it supports up to 7 working scientists and approximately 15 meeting participants.

A high-resolution Sony SNC-RZ25N [2] Internet camera was utilized to display handwritten documents and projected screen contents to remote researchers.

3. COMMUNICATION AND COLLABORATION TECHNIQUES

The Internet has made remote participation and collaboration possible. New collaboration protocols and tools emerge almost daily. However, not every tool is necessarily applicable to the remote participation and collaboration needs of fusion researchers due to the unique characteristics of the experiment-centric fusion research environment. Research was performed to choose and customize existing collaboration techniques that are deployable in the remote control room. Several new software tools were also developed to support remote control room-based collaboration. Two main principles guided our decisions in choosing and deploying the techniques. The first principle is that the techniques should be reliable and easy to use. Researchers should always be able to rely on the deployed tools and should not be overwhelmed with complex technology and user interfaces. Another principle is that the collaboration technique should be practical and acceptable by remote experimental institutions.

Two groups of techniques were deployed. The first group targets providing realtime information and visual data regarding remote experiments. This group includes screen capture broadcasting, realtime boundary display, and computational status monitoring techniques. Another group facilitates the collaboration among researchers located at the remote control room and experiment facility. This group includes H.323-based video conferencing, Access Grid and VRVS-based videoconferencing, Shared AppVNC and Multi-cursor Window manager Software.

3.1. SCREEN CAPTURE BROADCASTING

In every fusion experimental facility, some critical status information is displayed visually. Providing similar visual information in the remote control room in real time is necessary for the remote team. In order to receive and display a variety of information, a screen capture broadcasting method is needed. Although there are various tools that can be used for screen capturing, we prefer VGA2USB [3], a VGA screen capturing device, to capture the screen, encode the image, and transmit with QuickTime broadcaster. The resulting video is streamed on the web via a streaming server. The advantage of this method is twofold. First, the broadcasted image quality is very high. Second, the VGA2USB device can capture any computer screen regardless of the operating system and computational power of the computer and is easily deployable in remote experiment facilities.

One problem with this method is the ~10 s delay introduced by the existing encoding programs, such as QuickTime broadcaster. In order to eliminate the delay, an application is being developed. In this application, the captured image sequences are saved in PNG format and streamed through the web server in real time. Remote viewers receive the screenshot images with a minimum delay, but in reduced fame rate.

3.2. REALTIME PLASMA BOUNDARY DISPLAY PROGRAM

The RealTime boundary display program is an OpenGL application that displays the plasma boundary shape based on Plasma Control System (PCS) [4] reconstructed MHD equilibrium. It also displays several other scalar data from the Tokamak, such as plasma current, coil currents and cyropump status while the plasma pulse is progressing. Just after the plasma pulse, it displays the analyzed equilibrium data stored in MDSplus repository [5]. Since the RealTime Plasma Boundary application receives data from two popular applications, PCS and MDSplus, it is applicable to any fusion experiment that uses the similar PCS and MDSplus software.

The earlier version of the code displays visualization results on the local screen. Therefore, viewing the results on remote computers relied on X-windows forwarding. The newer version of the code utilizes client-server architecture. Data is transferred to the visualization client computer via TCP/IP sockets in real time and displays the rendered image locally. Therefore, the data service is detached from the visualization process and the computational and graphics power of the visualization computer are well utilized. A multi-threaded data server program can serve multiple visualization clients simultaneously.

3.3. COMPUTATIONAL RESOURCE MONITORING AND DATA ANALYSIS MONITORING

The computational resource-monitoring technique reports and visualizes the realtime information about computational resources. This technique allows researchers to monitor the health of data acquisition computers and between shot data analysis computers. At DIII-D, the monitoring infrastructure has been deployed by utilizing an open source cluster monitoring software Ganglia [6]. Its report includes a variety of performance metrics, such as memory, CPU load, and network statistics with a very low computational overhead. The graphical view of the report is posted on the web-server in real time. Although Ganglia is a computational resource oriented monitoring system, it is expandable and very easy to customize. At DIII-D, it has been customized to report disk, MDSplus, and IDL software usage. It is also possible to customize the system to monitor any time-varied scalar data directly related to the experiment device.

Another system used to allow scientists remote monitoring of the experiment status is the Data Analysis Monitor (DAM) [7]. DAM was developed at DIII-D several years ago and is being used to monitor the status of between pulse MDSplus dispatched data analysis codes. By combining code run status, analysis tracking, log file access and expert system capabilities, it reports the progress of diagnostics and analysis codes. Its web-based front end is suitable to remote displays. DAM consists of a tiled display-based reporting scheme with results presented in data categories and predefined color codes.

3.4. H.323-BASED VIDEOCONFERENCING

Face-to-face conferencing is one of the most important collaboration channels during the experiments. While there are many videoconferencing techniques available, we chose H.323 as our main videoconferencing technique [8]. There are two reasons with H.323: (1) Due to its longest history in the videoconferencing world, H.323 protocol-based products are relatively reliable and easy to use. (2) H.323 is the most used videoconferencing technique in fusion research institutions worldwide. In the remote control room, we installed a Polycom VSX7000e and integrated it with multiple cameras and echo cancellation audio systems. One of the front projection screens has been used to display the video of remote collaborators.

When there were more than two parties, the video Bridge from ESnet Collaboration Services [9] was used. The ESnet video Bridge provides multi-user conferencing functionality as well as hybrid bridging of video conferencing and telephone conferencing.

3.5. ACCESS GRID AND VRVS

Access Grid [10] and VRVS [11] are two of the most used free Internet-based software communication systems. Although developed by different groups, they have similar features for the end user when they are used only for videoconferencing. Both systems are virtual room based/meet-me-there systems. Both systems use the same M-bone tools for audio and video capabilities, which means similar computer hardware can be used for both systems.

In the remote control room, an AG/VRVS node was installed and integrated with multiple cameras and room audio system. With support from the U.S. Fusion Collaboratory project, a significant effort was made to improve the Access Grid and develop collaboration applications, such the MDSplus signal browser.

3.6. SHAREDAPPVNC

SharedAppVNC [12] is a collaboration tool developed by the U.S. National Fusion Collaboratory Project. In a typical usage scenario, two or more remote collaborators would run SharedAppVnc on their computers while using other conferencing tools. SharedAppVnc allows the sharing of visualization results. It is based-on VNC, but with a modified protocol that allows window sharing instead of entire screen sharing. SharedAppVNC consists of two components, a server and viewer, and by running both, collaborators can share multiple applications during the data analysis process.

3.7. MULTI-CURSOR WINDOW MANAGER

The Multi-Cursor Window Manager [12] is another software application developed by the U.S. National Fusion Collaboratory project. It allows multiple users to interact simultaneously with one screen, which is situated locally or remotely. By running Multi-Cursor window manager, large tiled displays can accept mouse clicks or keyboard entries sent by multiple users who are sitting at local control room or remote control room.

4. EXPERIENCES AND DISCUSSIONS

Two open house technology demonstrations have been held for users. A web-based remote control room reservation system is also in place in order to effectively use the remote control. Priority is given to the remote experiment participations over regular discussion meetings.

Since the primary purpose of the remote control room is to create a dedicated working environment for remote participation, the furniture arrangement and technology development have been a recursive process. We tried to refine the environment after every remote participation event. We also tried to bring in and experiment with almost all the collaboration technologies available but avoided overwhelming users with numerous complex technology interfaces.

The remote control room was successfully used during several significant remote experiments. One example was remote support of initial operation of EAST, the superconducting Tokamak in Hefei, China, in the summer of 2006. During the first plasma operation of EAST, DIII-D staff used H.323, large screens, SharedAppVNC along with other regular UNIX tools such as X-window, ssh, sftp to remotely support the experiment. Another example is the successful remote participation in the “Development of high beta_N scenarios without ITB” experiment at JET by the DIII-D staff, February 2007. The experiment was delayed and its pulse schedule was intermittent due to hardware problems. The DIII-D staff adjusted their schedule accordingly and fully participated during the whole experiment. The ability to rapidly adjust to varying experimental schedules when compared to the fixed schedule of international travel plans made the remote experimental participation successful. During the experiment H.323, large screen, Web-cam as well as hardware tools have been used. While not all of the deployed tools were useful in every event, different events used different combinations of technologies depending on the collaboration needs.

Providing additional technologies, such as secure and easy data access tools for remote experiments are another aspect of the remote control room. Web-based experiment data visualization and analysis tools will make the remote participation even easier. Coordination among multiple fusion institutions and setting up common data access protocols are prerequisites for developing such tools and avoid repetitive work. Although some existing common infrastructure, such as MDSplus and PCS provided similar infrastructure, more work is needed in this area.

5. CONCLUSION

A dedicated experimental remote control room has been built at DIII-D. By analyzing remote participation scenarios, a variety of applicable remote participation and collaboration technologies have been identified and deployed. Some software tools are still being developed. Although, still a work in progress, the remote control room played an important role in major international collaborations. Further effort is required in order to accommodate the needs for full remote participation that includes leading and taking on shift duties at remote experiments.

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