Research on Collaborative Technology in Distributed Virtual Reality System

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Abstract. Distributed virtual reality technology applied to the joint training simulation needs the CSCW (Computer Supported Cooperative Work) terminal multicast technology to display and the HLA (high-level architecture) technology to ensure the temporal and spatial consistency of the simulation, in order to achieve collaborative display and collaborative computing. In this paper, the CSCW’s terminal multicast technology has been used to modify and expand the implementation framework of HLA. During the simulation initialization period, this paper has used the HLA statement and object management service interface to establish and manage the CSCW network topology, and used the HLA data filtering mechanism for each federal member to establish the corresponding mesh tree. During the simulation running period, this paper has added a new thread for the RTI and the CSCW real-time multicast interactive technology into the RTI, so that the RTI can also use the window message mechanism to notify the application update the display screen. Through many applications of submerged simulation training in substation under the operation of large power grid, it is shown that this paper has achieved satisfactory training effect on the collaborative technology used in distributed virtual reality simulation.

1. Introduction

In order to improve the immersion sense, distributed virtual reality technology applied to the joint training simulation not only needs real-time uploading target motion data and uses CSCW (Computer Supported Cooperative Work) terminal multicast technology to display, but also takes into account the engineering simulation (HLA / RTI) technology to ensure the temporal and spatial consistency of the simulation. Because HLA has been widely used in joint training, distributed virtual reality development is required using of CSCW’s technology to develop real-time RTIs under the overall architecture of HLA and enabling the RTI to support both collaborative computing and collaborative display.

Real-time RTI development technology in the field of high-performance simulation has been made a lot of research, for example, using shared memory technology[1] to improve the real-time communication RTI performance or building an infiniband network and using direct memory access (RDMA, Remote Direct Memory Access) communication mechanism[2] to optimize the RTI. These studies replace the underlying communication code of RTI using shared memory or memory mapping, but the joint training simulation is done in a TCP / IP-based LAN environment, which requires extending the underlying communication code of RTI, instead of replacing it.
Based on the virtual reality technology, this paper discusses how to combine CSCW and HLA / RTI technology to improve the fidelity of multi-person collaborative training simulation in 3D virtual scene.

2. Virtual reality application background

Based on the virtual reality of the transformer equipment operation and maintenance simulation training system application architecture shown in Figure 1, including substation equipment, virtual reality (VR) helmet and the grid computing server. Each substation equipment, the grid computing program, trainer with a VR helmet and the teacher constitutes a federated member of HLA [3]. There are many visualization model components of electrical equipment in a substation, and to achieve immersive real-time rendering of virtual reality, at least to ensure that the graphics refresh rate of not less than 60 frames / sec, so in order to achieve real-time display of three-dimensional scenes need to use real-time communication technology.

![Figure 1. VR-based operation and maintenance training structure of substation equipment](image)

The current high-speed Ethernet up to 1GbE or even 10GbE, need to reduce the delay from the target to choose, and the delay related to the two issues are transmission and serialization, but in the delay time serialization time only a small part. The huge delay of the connection layer is mainly introduced by the interface and the system at each end of the connection. For a particular package, it is 135 microseconds through a 1GbE connection, and it can only fall to 75 microseconds through a 10GbE connection, and most of the other costs are from the device in both ends, not from the connection itself.

In this paper, a 1GbE network card and network cable are used to build high-speed Ethernet, and the speed of the two-way transmission between the two nodes is 75 microseconds, which is higher than the speed measured in the literature[2] with high-speed RTI to update the object properties. So it can use CSCW multicast technology to real-time communication.

3. CSCW real-time communication mode

CSCW's three elements are cooperation, coordination and communication, CSCW cooperation mode from time and space, can be divided into synchronous mode, distributed synchronization mode, asynchronous mode and distributed asynchronous mode[4][5]. Among them, the synchronous mode system is used for the local group (LAN) between the face-to-face real-time collaborative operating system, which is required to achieve "You see that I see" [6] [7]. CSCW in the collaborative operation will inevitably encounter multiple users to operate on the same object, so how to ensure that these operations are necessary to orderly implementation is necessary, at home and abroad for collaborative editing, collaborative design, web conferencing and other collaboration Concurrent control on the work system has been studied. The concurrency control method of the shared object is divided into the following typical concurrency control method [8]: token control method, locking method, operation information serialization, concurrency control based on operation conversion.

CSCW's communication method adopts the terminal system multicast mode. The terminal system multicast is a practical multicast system developed by Carnegie Mellon University (CMU), including
member management and packet copy. This transition from router-supported multicast to multicast supported by the end system can solve most of the problems of IP multicast (transmission unreliability). The multicast tree is the core structure of the terminal system multicast. Its creation is divided into two steps: first initialize a mesh (Mesh), so that each node in Mesh is connected; then create a spanning tree on Mesh. Spanning tree to the corresponding node on Mesh as the root node.

HLA uses the LBTS algorithm to achieve the federal members of the time and space consistency, to ensure the correctness of the simulation logic, but at the expense of the real-time simulation. Because the realization of LBTS algorithm can only use a centralized star network topology. Obviously, the star library topology, which does not communicate with each other in the RTI library components, increases traffic and reduces the rate of information exchange among members. The CSCW terminal multicast mode is introduced for this purpose, and the above coordination problem faced by CSCW can be solved by the time management of HLA. The CSCW multicast communication used in the training simulation only completes the unsupervised and restricted message sending and receiving of HLA, Extended RTI communication as shown in Figure 2:

![Figure 2. Terminal multicast extension RTI communication architecture](image)

Where the box represents the service process of the RTI, and the circle represents the libRTI thread called by the federated member. The left star topology in the graph preserves the function of all six categories of HLA / RTI services, while the mesh communication topology (Mesh) between the four new federated members on the right shows the terminal multicast function of CSCW Federated members interact with each other's three-dimensional drawing information, which does not affect the temporal and spatial consistency of the simulation event, but only to achieve the co-simulation system visual "you see that I see", used to improve the virtual reality environment immersive fidelity.

4. RTI and CSCW communication topology

The open source CERTI is modified to extend the libRTI thread using the HLA service supported by RTI which adds the CSCW terminal multicast function. The libRTI library of the CERTI contains two interface of the RTI member ambassador and RTI callback ambassador. The application uses the RTI callback ambassador interface to define their own function, which can be queried and executed by calling the RTI member ambassador interface tick or by responding the message sent by the libRTI thread. The tick interface implementation includes the realization of time management that meets the space-time consistency of the callback event and implements the corresponding callback interface using the LBTS algorithm. The transmission of real-time data of interest in this article is executed by responding to a message from the libRTI thread.

The first step is to establish a dynamic terminal multicast network, including the establishment and deletion of member multicast links, which can be implemented through the subscription and distribution functions of RTI's declaration management and object management. When a federate member joins the federation, it declares the subscription and publish of the cosimNetCard object class, which contains the two attributes of cardIP and cardPort (Attribute cardPate reliable timestamp) in the FOM. Then each member of the union calls the registerObjectInstance interface, which second object name parameter uses the string of "FedName: cardIP: cardPort" in which the FedName indicates the
member name, the cardIP indicates the member network IP address, and the cardPort indicates the member network port.

Each federate member judges whether the object class of the object is cosimNetHandle in the RTI callback interface of the object, and if its second parameter is a string of "FedName: cardIP: cardPort" in the parsing call parameter, then this federate member can monitor real-time data communication to another federate member by using a link tag which is created when this federate member initiates the connection using the network address and port. The link tag is a [FedName, cardIP, cardPort, linkID] quaternion which is joined the local queue (gradually forming Mesh connectivity map), and its linkID or FedName can be used as a keyword to find this quaternion. When another federate member named as FedName calls DeleteObjectInstance, the callback interface of this federate member, which first parameter uses the above "FedName: cardIP: cardPort" string, can eliminate the corresponding quaternion in the queue indexed by the FedName.

When a federate member sends real-time data, the data is packetized and sent to each linkID in the quaternion queue (which can also filter out the actual recipients to form a Mesh spanning tree according to the application). In addition to monitoring the network events from the RTI service and the interface calls from the local RTI federation side, the network port for real-time data communication is monitored, as shown in Figure 3 below. When the real-time communication data is monitored, the libRTI thread sends a Windows message to the display window, informs the display window to receive the message and updates the display.

Federate members have established a networked communication link according to the application requirements to build real-time terminal multicast queue, and a Mesh spanning tree to filter data according to meet the conditions of the members in order to reduce traffic and improve execution efficiency.

5. Constructing an experiment using the terminal multicast
Based on the virtual reality technology, interactive training includes three-dimensional projection, three-dimensional arc curtain, image virtual reality helmet, action capture, simulation workstations and network switches, using virtual reality helmet and three-dimensional arc curtain projection two immersive stereoscopic display technology.

The experiment supports multiple people collaborative work to complete a task. Multiple trainees can be different roles to log into the training scene, team work together to complete a multi-person participation in the task, as shown in Figure 4. When the trainees operate, all the federate members, including the large grid simulation program, are still moving forward in a fixed simulation step, and the propulsion strategy is both limited and controlled; both the federates and the faculty members are listening to the libRTI Threads which uses the windows message mechanism to send message of the movement and operation, and is responsible for updating the display screen in the display screen.
6. Conclusion

The introduction of virtual reality technology in distributed interactive simulation based on HLA / RTI can increase the visualization effect of simulation, but with the fidelity requirement of user experience, the realism of RTI network transmission is put forward higher requirements. It is necessary to divide the transmitted data into the virtual scene interactive data and the data supporting the simulation of time and space consistency, which can be realized with the original RTI of the six categories of services. The best method to exchange scene interactive data is the directly transferring between federate members. In this paper, CSCW's terminal multicast mechanism is introduced in the federate component libRTI of the open source CERTI to realize the direct transmission of the motion and operation data between the trainers, and the real-time demand of the scene data interaction has been meet. From the last two years for the operation of large-scale simulation training applications, it is shown that this paper has achieved satisfactory training effect on the collaborative technology used in distributed virtual reality simulation.

Figure 4. Simulation Training of Transformer Operation Based on Extended

References

[1] Zhang zhihui, Li bohu1,Chai xudong, Huang jijie and Hou baocun 2014 HP-HLA/RTI Prototype Oriented on Shared Memory Environmen. Journal of System Simulation 26L2 315-22.
[2] Xing chi, Li bohu 2016 Research on RTI Communication Mechanism on Infiniband Network Architecture ACTA ELECTRONICA SINICA 44L2 327-33.
[3] Li weiqing, Wu huizhong, Lin changnian 2006 Research on Virtual Environment of Substation Training Simulator Journal of System Simulation 18S1 123-126.
[4] Penichet V.M.R., Marin I. and Gallud J.A 2007 J.A Classification Method for CSCW Systems Electronic Notes in Theoretical Computer Science 168L8 237-47.
[5] Zhao Jianmin and Long Xiaochun 2011 A Modified Model for Flexible Workflow Access Control IEEE Computational Intelligence and Design 2011L2 279-81.
[6] Elmarzouqi N and Garcia E. ACCM 2007 a New Architecture Model for CSCW In: Proceedings of the 2007 11th International Conference on Computer Supported Cooperative Work in Design 2007 84-91.
[7] Convertino G, Billman G and Pirolli P 2008 The CACHE study: group effects in computer-supported collaborative analysis Computer Supported Cooperative Work (CSCW) 17L4 353-93.
[8] Khan SM, Sulaiman M and Tahir A M 2011 Domain-based classification of CSCW systems Research Journal of Applied Sciences 3L11 438-41.