COLLABORATIVE KNOWLEDGE BASE AND ITS APPLICATION IN ADAPTIVE MESSAGE FILTERING FOR COLLABORATIVE VIRTUAL ENVIRONMENT

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ABSTRACT

In Collaborative Virtual Environment (CVE), users need to do some collaborative work, which is highly synchronous. To achieve effective collaboration, the Level Of user behavior's simulation Accuracy (LOA) in CVE must be high. But if we adopt static high LOA, system's scalability will be greatly decreased. So scalability request must compromise with collaborative request. This paper analysis CVE system's scalability request and collaborative request, and presents a classification of collaborative work and a definition of Collaborative Knowledge Base (CKB). Based on CKB, a knowledge-based adaptive message filtering technique, which improves CVE system's scalability, is put forward.

1. INTRODUCTION

With the development of computer technology, especially computer graphics and computer network, many networked Virtual Environment (networked VE) systems come into use. There are some representative systems: NPSNET [1], which was developed by Naval Postgraduate School (NPS); DIVE [2], which was developed by Swedish Institute of Computer Science; MASSIVE [3], which was developed by Nottingham University; NICE [4], which was developed by University of Illinois.

Collaborative Virtual Environment (CVE) not only allows users to enter and share a virtual environment, like other networked VE, but also allows users to do collaborative works, which is highly synchronous and need users to work together, e.g., two remote surgeons operate on a virtual patient. These collaborative works appear in military training, collaborative design, remote teaching, and entertainment [5].

To achieve effective collaborative work, there still exist many problems to be solved, such as temporal and spatial sharing of the environment, world modeling, and avatar animation. This paper is mainly aimed at the first problem, sharing of the time and space in CVE. The research of temporal and spatial sharing of the environment could be summarized as consistency and scalability. Consistency refers to the characteristics that the system maintains one consistent state of environment throughout the simulation period. When any user changes the state of system, it must dispatch the change to all the other users. Scalability refers to the characteristics that the system could do effective consistency control even if many users enter the virtual environment. The system could keep consistency even if a large-scale population simultaneously enters the shared environment. This paper mainly aims at the scalability of CVE.

The research of scalability is a hotspot in the field of networked VE, and there are many methods to solve the scalability problem. But with the emergence of collaboration, these old methods could not meet the collaborative request. To achieve effective collaboration, the Level Of user behavior's simulation Accuracy (LOA) in CVE must be high. LOA is similar to the term Level Of Detail (LOD), which is used in virtual world's display. LOD is used to determine the virtual worlds display accuracy, and LOA is used to determine the simulation accuracy of user's behavior. In collaborative work, it is necessary for user to percept other associates' action, because his action is based on other associates' action and reaction. If the value of LOA is high, avatars, other users' representation in CVE, will have more detailed action, and user is easy to percept other users' real action. But if we adopt static high LOA, system's scalability will be greatly decreased. So scalability request must compromise with collaborative request. This paper analyses CVE system's scalability request and collaborative request, and gives a classification of collaborative work and a definition of Collaborative Knowledge Base (CKB). Based on CKB, a knowledge-based adaptive message filtering technique, which improves CVE system's scalability, is put forward.

In section 2, the DR algorithm is surveyed. In section 3, the request of collaboration is analyzed. In section 4, a classification of collaborative work and a definition of Collaborative Knowledge Base (CKB) are given and a knowledge-based adaptive message filtering technique, which is based on CKB, is introduced. Finally, section 5 will give some experimental results and some conclusions.

2. DR (DEAD RECKONING) ALGORITHM

Dead Reckoning algorithm [7] was used to filter message in client side. The principle of DR algorithm is that we postpone the state change message until a certain significant error occurs between a simulation model and a real one. If the error is under a certain value, no state change message will be delivered, as shown in Fig. 1. When no state change message arrived, other clients use the old state value and simulation model to extrapolate the new state value. In fact, this algorithm uses large amount of computation to exchange small network traffic. The certain value in DR algorithm is called threshold, and the value of threshold influences the algorithm's message filtering capacity and system's LOA.
The path extrapolation of Fig. 3 is:

$$Xt = Xt' + Vt'T \quad Yt = Yt' + Vt'T \quad Zt = Zt' + Vt'T$$

(Xt', Yt', Zt') and Vt' represent respectively the position and velocity of an entity as found in the state change message of the last state. T is an elapsed time since the last change. The above formulas are used to extrapolate the position of the entity at time t = t' + T.

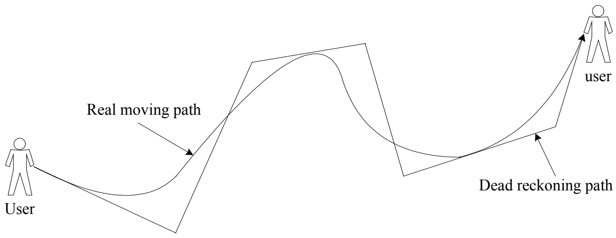

Fig. 1 DR algorithm

To decrease network traffic and increase system's LOA, many improved DR algorithms come into being. The representative improved DR algorithms are Multi-level DR algorithm (MDR) and Intelligent DR algorithm (IDR). MDR algorithm is the combination of DR algorithm and AOI method. In MDR algorithm, different entities in different AOI have different threshold value in DR algorithm. Entities that near user have a small threshold value to increase LOA and entities that far from user have a big threshold value to decrease the network traffic. IDR algorithm introduces a concept of entity's update lifetime, and entity's update lifetime refers to the time interval between entity's current update and next update. When the time interval becomes bigger, a smaller threshold value is used to increase LOA. When the time interval becomes smaller, a bigger threshold value is used to decrease network traffic.

3. REQUEST OF COLLABORATION

Because users should do collaborative work with associates in CVE, the CVE systems have more requests than networked VE systems. These requests are:

- System's message transfer delay must be small. From above analysis, we know that users' collaborative work in CVE is real time interactive processing, in other words, one user's behavior is based on other user's action and reaction, CVE system's message transfer delay must be small. If a CVE system wants to have a good collaborative performance, its transfer delay must less than 200ms [10].
- Associates' behavior simulation must be accurate. In collaborative work, it is necessary for user to percept other associates' action, because his action is based on other associates' action and reaction. If associates' behavior simulation is accurate, i.e., the value of LOA is high, avatars, other users' representation in CVE, will have more detailed action, and user is easy to percept other users' real action. In collaborative virtual environment user's behavior is based on other users' action and reaction, CVE system's user must accurately percept other users' behavior, otherwise user could not do his collaborative work. To improve CVE system's simulation accuracy, on one hand we should decrease threshold value that used in DR algorithm, on the other hand we should adopt reliable network transmission to avoid information lost in network transmission.

Because the concept of collaboration in virtual environment comes out later, few researches have done about this topic. The representative research is synchronous collaboration transport protocol (SCTP)[6]. In CVE system, an interaction between users will engender an information stream and the last information in the information stream is the most important information. Based on this characteristic, SCTP introduces the concept of interaction stream, which significantly decreases system's transmission delay and the lost of key information.

4. KNOWLEDGE-BASED ADAPTIVE MESSAGE FILTERING

From the analysis of section 2 and 3, we could see that the requests of scalability and collaboration are two interacted requests. The request of scalability needs client to do more information filtering to decrease network traffic, and the request of collaboration needs client to do less information filtering to increase system's simulation accuracy, i.e. LOA, and to achieve effective collaborative work.
In virtual environment, users need not always do collaborative work, and different collaborative work has different request of simulation accuracy, i.e. LOA. Based on this fact, we introduce a knowledge-based adaptive message filtering technology. Knowledge-based adaptive message filtering technology works in client side, and it does information filtering on different level according to different types of collaborative work. The application of

knowledge-based adaptive message filtering technology greatly increases CVE system's scalability.

4.1. Classify of collaborative work

According to the level of collaboration in collaborative work, we could classify collaborative work into four types:

- High Level Collaboration (HLC). This kind of collaborative work has a strict request of user behavior simulation accuracy, i.e. has a high LOA, and not allows a little distortion of behavior simulation.
- General Level Collaboration (GLC). This kind of collaborative work has a generic request of user behavior simulation accuracy, i.e. has a middle LOA, and allows a little distortion of behavior simulation.
- Low Level Collaboration (LLC). This kind of collaborative work has a low request of user behavior simulation accuracy, i.e. has a low LOA, and allows distortion of behavior simulation within a middle range.
- No Collaboration (NC). This kind of collaborative work has no request of user behavior simulation accuracy, i.e. has no request of LOA, and allows distortion of behavior simulation within a large range.

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4.2. Collaborative knowledge base

After defining four types of collaborative work in CVE system, the next problem is how to identify these collaborative works. Only after identifying what type of collaborative work a user is performing, could CVE system adopt suitable message filtering method to improve its scalability. Because a user in CVE system could do different types of collaborative work at different time, e.g., a virtual surgeon in virtual environment could do different collaborative work at different time, such as operation, driving, playing ball, etc. It is important for CVE system to identify the type of collaborative work that a user is doing.

In knowledge-based adaptive message filtering technique, system uses collaborative symbolic entity to identify different types of collaborative work. In real world, when human are doing collaborative work, they usually need some tools. And in virtual environment, they need tools to do collaborative work too. For example, operating need scalpel, portaging need go-cart, playing ball need ball and driving need vehicle, etc. System takes these tools that used in collaborative work as collaborative symbolic entity to identify different types of collaborative work.

System defines collaborative symbolic entity in advance. This work includes giving the name of collaborative symbolic entity, conforming the type of collaborative wok that certain collaborative symbolic entity delegates, and conforming the corresponding threshold value used in DR algorithm. Through collecting all collaborative symbolic entities, we could get Collaborative Knowledge Base (CKB), as shown in Table 1.

Table 1 Collaborative knowledge base

Collaborative symbolic entity	Type of collaborative work	Threshold value used in DR algorithm
Scalpel	HLC	0
Shuttlecock	LLC	6
Volleyball	LLC	6．5
Go-cart	GLC	3
Vehicle	NC	9

When using CKB, we must pay attention to two points. First, collaborative symbolic entities that delegate the same type of collaborative work need not use the same threshold value in DR algorithm. For example, shuttlecock and volleyball are collaborative symbolic entities, which delegate type LLC, but they use different threshold values in DR algorithm (shuttlecock use 6 and volleyball use 6.5). In certain range, system could adjust the value of threshold in DR algorithm. Second, when there are two or more collaborative symbolic entities around user, e.g. user is doing several collaborative works at the same time, system takes the collaborative symbolic entity that has a least threshold value. And system uses this collaborative symbolic entity to confirm the type of collaborative work that user is doing and to do message filtering. The purpose of this policy is to ensure system's behavior simulation accuracy, i.e. LOA.

By applying CKB in CVE system, CVE system's scalability could be greatly increased, and CVE system could do message filtering intelligently. In CVE system, user's purpose is to perform collaborative work. If system could fully abstract and utilize collaborative knowledge, many existing problems in CVE system could be solved. In addition to the above mentioned advantage, if other collaborative knowledge is added into CKB, CVE system could do intelligent consistency controlling, intelligent world rendering, etc.

4.3. Client side system architecture

After introducing four types of collaborative work and the concept of CKB in CVE system, we will present system architecture with knowledge-based adaptive message filtering technique. The client side includes six modules. They are perception of user's behavior module, perception of scene module, message filtering module, threshold value controlling module, collaborative knowledge base module and message transmission module, as shown in Fig. 2.

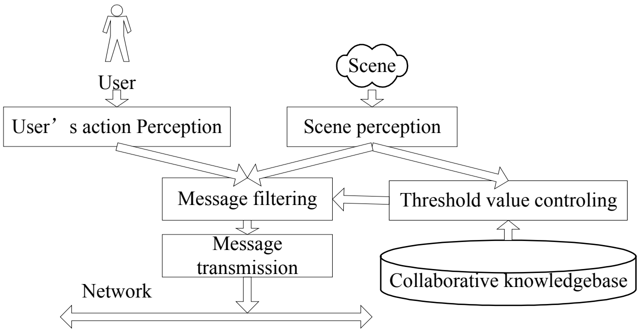

Fig. 2 System architecture in client side

In CVE system, an avatar represents a user, and user operates on virtual environment through controlling his avatar. User's behavior perception module is used to capture the behavior that user is putting on avatar, because system should transmit these state change messages to other users. Scene perception module is used to capture the scenic changes that are caused by user's behavior, e.g., user's behavior of moving scalpel or playing ball. Threshold value controlling module is used to determine the threshold value used in DR algorithm, according to collaborative symbolic entities in scene and CKB. In the next paragraph, the flow chart of threshold value controlling module will be given. Collaborative knowledge base module is used to store and manage CVE system's CKB. At present, only different collaborative symbolic entities and their collaborative work types and threshold values used in DR algorithm are stored in CKB. Message filtering module is used to filter the message transferred from perception of user's behavior module and perception of scene module by DR algorithm, according to the threshold value provided by threshold value controlling module. Message transmission module is used to packet messages and transfers these packets.

Threshold value controlling module is the key to the knowledge-based adaptive message filtering technology. The Threshold value controlling algorithm used in this module is an application-dependent procedure and it should be designed according to the application's request.

5. CONCLUSIONS

To show the feasibility of the knowledge-based adaptive message filtering technology, we develop an experimental system using JDK and Java3D. In the experimental system's testing, it shows good message filtering performance and could meet LOA request of different types of collaborative work. Comparing to former client side message filtering technology, this technology has following advantages:

- When collaborative work has a high requirement of behavior simulation accuracy, i.e. LOA, this technology could ensure the system's collaboration performance.
- When collaborative work has a low requirement of behavior simulation accuracy, i.e. LOA, this technology could let lots of messages be filtered and ensure system's scalability.
- When user is shifting between different types of collaborative work, the system could automatically adjust threshold value used in DR algorithm. This adjustment is based on the type of collaborative work that the user is performing. This technology could significantly decrease CVE system's network traffic and increase system's scalability, and this technology could guarantee system's behavior simulation accuracy, i.e. collaboration performance, too.

With the development of CVE systems, there are more and more people doing their collaborative work in virtual environment, and we have the confidence that CVE system will become more realistic and collaboration between people will be more effective.

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