Awareness Scheduling and Algorithm Implementation for Collaborative Virtual Environment[1]

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Abstract. The limitation of network resource reduces the awareness capability of CVE system, which becomes the main bottleneck for applications in Internet. In this paper, we study the relationship between the awareness capability of system and network parameters, such as latency, jitter, and data loss rate; also, according to the features and preferences of user awareness, a network-status-based solution is proposed for self-adaptable awareness scheduling. Moreover, the scheduling algorithm is implemented and verified by a prototype system, results from which indicate that awareness scheduling is useful for decreasing the loss of the awareness capability of system in a limited or unstable network.

1 Introduction

Awareness is an important concept in Computer Supported Cooperative Work (CSCW). It is always defined as understanding what happens in the environment. Awareness was defined in distributed work group that it provides a view of one another in the daily work environments [1]. In the real world, awareness is the first step to understand the surrounding environment, and the beginning of all activities.

Collaborative Virtual Environment (CVE) makes use of Virtual Reality technology, which offers reality and immersion to collaborative users, and improves the awareness capability of system. Internet broadens the area of CVE applications. However, the limitation of network resource reduces the awareness capability of Virtual Environment (VE), and becomes the primary bottleneck for Internet applications. There are many methods to solve this problem, all of which focus on improving the system performance by decreasing transmission cost, such as LOD, Dead Reckoning[2][3], scheduling based on visual scope and priority [4], etc. However, the common problem is that the decrease of transmission cost cannot completely equal the improvement of the awareness capability. So we introduce a solution named *Awareness Scheduling*, which schedules awareness objects in VE according to network status and user preference.

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In the next section, we will introduce the concept of awareness scheduling, and then we will elaborate awareness scheduling in the following steps. First, the evidence of scheduling is analyzed. Then the awareness model is defined. Thirdly, the scheduling algorithm is implemented, which is experimented and verified in the fourth section. Finally, the work of this paper is summarized, and the future work is described.

2 Awareness Scheduling in CVE

2.1 The Features of User Awareness

There are mainly three awareness objects in CVE: scene environment, virtual object, and others' social activity. So, user's awareness effect, which is equal to the awareness capability of system, is the sum of all awareness objects of the three types. For example, in a virtual meeting system, the user's awareness effect includes the awareness of surrounding environment, meeting content and other participators, etc.

However, the contribution of each awareness object doesn't equal. To different users, CVE has the characteristics of individual configuration and Area of Interest (AOI). Users may be interested in different awareness objects with different expressing precision and priority definition. For example, in virtual meeting, some users only want the awareness information of avatar and sound, others may want the video. Furthermore, users may have different AOI in different period of time. Take the virtual meeting above for example; users may be only interested in their talking partners when communicating, but more interested in the subject and other speakers during the meeting.

2.2 Influences of Network Status to Awareness Capability

Network status can be described by several parameters, such as latency, data loss rate and jitter. Consequently, we can study these parameters to analyze the influences of network status to awareness capability. In CVE, the increase of latency will weaken the awareness capability, e.g., the lag of real-time action and voice. It is indicated by research that jitter influences much more to awareness capability than latency, e.g., there is no significant difference in overall performance between networks having latencies of 200 milliseconds without jitter and 10 milliseconds with jitter [5]. Data loss rate indicates the current congestion level of network, which will cause the data to be discrete and incomplete, and influence the awareness capability.

2.3 Requirements of Media Form to Network Parameters

Different media form has different requirement to the three network parameters. For example, stream media allows a specific level of data loss rate, but is sensitive to jitter. As objects in VE are concerned, the data must be transferred properly and the latency must be reduced as much as possible. While user interactive data, which calls for a strong real-time processing ability, is especially sensitive to latency. It is indicated in the DIVE system that the interactive data package must be received in 100 milliseconds; otherwise, there will be a serious lag of awareness [6].

Consequently, awareness objects in CVE contribute differently to users, and call for different network performance. Different media form also requires different network performance. In a limited or unstable network, we can adjust the awareness objects based on contributions, media forms, and user preference to adapt the network and make user's awareness effect the highest.

3 Awareness Scheduling and Algorithm Implementation

3.1 Evidences of Awareness Scheduling

According to the analysis above, we get three evidences of awareness scheduling: features and preferences of user awareness, network status, and media forms. They affect the awareness scheduling differently, and must be completely concerned in the scheduling algorithm.

3.2 Awareness Model

Based on the features of user awareness, awareness model is defined to be composed of awareness object, awareness priority, awareness level, awareness QoS and awareness correlation [7]. They are explained as follows:

Awareness Object: It is a complete object to be identified, operated and controlled by users in CVE.
Awareness Priority: It indicates user preference of an awareness object, and the rate that it contributes to user's awareness effect. It's determined by user preference.
Awareness Level: Define different levels for an awareness object using a quantitative approach. It's quantitated in three hierarchies: awareness, identification, and comprehension. Awareness is the lowest level, which means user can be conscious of the object's existence, but can't identify its concrete attribute. In the hierarchy of identification, user can identify the object's attribute, but can't operate it. On the highest level, comprehension, user can not only identify the object, but operate it.
Awareness QoS: It describes the network service quality required by awareness media on each awareness level. Different kind of media at the same level may require different network service quality. When the described QoS parameters can't be satisfied, the system will lower its corresponding awareness level.
Awareness Correlation: According to the feature of human being's cognition, there is correlation in contributions of different awareness object, which depends on its intrinsic attribute, such as similarity, and user awareness configuration. There are three kinds of correlation: positive correlated, non-correlative, and negative correlated. Positive correlated indicates that one object enhances the awareness capability of the other, while negative correlated means a negative effect. Non-correlative means no relevance in awareness capability between two objects.

3.3 Denotation of the Awareness Capability of System

Before the definition of awareness capability is given, we denote several elements in awareness model as follows:

Awareness Priority P_i: P_i is the awareness priority of awareness object i. For each P_i, it satisfies,

I. $0 < P_i < 1$, and

II. $\sum_{i=1}^{n} P_i = 1$

Awareness Capability W_i: W_i is the awareness capability of an object at awareness level L. Suppose that an object's W_i is 1 at the highest level, then the values on other levels will be in the range of 0 and 1. We can denote W_i as a function of L, which is $W_i = F_i(L)$. Function F_i depends on the attributes of awareness object, which may be different from each other.

Awareness Correlation C_{ij}: C_{ij} is awareness correlation coefficient of awareness objects i and j, which satisfies,

I. $C_{ii} \equiv 1$

II. $0 < C_{ij} < 1$, when i, j are positive correlated

III. $C_{ij} = 0$, when i, j is non-correlative

IV. $-1 < C_{ij} < 0$, when i, j are negative correlated.

According to the contents above, for an awareness object i in CVE, its singular awareness capability is $P_i * W_i$. Take awareness correlation into account, its awareness capability will be $A_i = \sum_{j=1}^{n} C_{ij} * P_i * W_i$. So, for a system containing n objects, its awareness capability A is expressed by the following formula,

$$A = \sum_{i=1}^{n} A_i = \sum_{i,j=1}^{n} C_{ij} * P_i * W_i \quad (1)$$

Consequently, scheduling for awareness objects is transformed to the procedure of searching the maximum value of A.

3.4 Awareness Scheduling Algorithm

Suppose a scheduling event occurs because of resource fluctuation or change of user preference, or because that the user's demand can't be satisfied, which means certain awareness capability must be lost. As mentioned above, P_i and C_{ij} depend on the user awareness preference and inherent attributes of awareness object, while W_i is the function of awareness level. So when the scheduling event occurs, there is a possible awareness capability loss AL_i for each awareness object, which is,

$$AL_i = ((\sum_{j=1}^{n} C_{ij}) * P_i * (F_i(L) - F_i(L-1))) \tag{2}$$

The calculation of A is valid only under the condition that awareness QoS is guaranteed, so we have to find the awareness objects K_1, K_2, …, K_m which will be scheduled to make $\sum_{i=1}^{m} AL_{ki}$ minimum and the awareness QoS of each object is satisfied. However, for each awareness object i, its QoS satisfaction is interactive. So the key to the problem is to find the reason that the awareness capability decreases, according to which we can adjust the awareness level of corresponding object.

(1) The Reason That Awareness Capability Decreases

We analyze the relationship between the three network parameters that influence awareness QoS and the parameters that describe the network status, which are,

I. Latency has a compact relationship with bandwidth and utilization.
II. Jitter is independent of bandwidth when the network load is low. But the correlative factor can be 0.95 when network overloads [8].
III. Data package is lost for three reasons. First of all, active loss, e.g., data loss is used to guarantee the best effect in jitter compensation algorithm. Secondly, network overloads, e.g., there will be a 50% data loss when an application that calls for 10Mbps network is applied on a 5Mbps network. Thirdly, there will be a 0.5% data loss when network is fully loaded.

It's concluded from the analysis above that data traffic of each kind of awareness objects is an important factor of influence to VE. Therefore, decreasing appropriate data traffic will be an effective method to guarantee the awareness QoS to be satisfied.

(2) How to Decrease Data Traffic

Suppose that the data traffic to be decreased is V. We sort all the awareness objects from low to high according to loss of awareness capability, as shown in Figure 1.

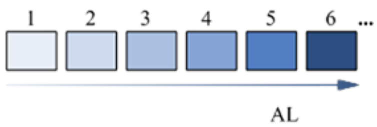

Fig. 1. Incremental series of AL

According to the QoS parameters of an awareness object, the data traffic V_i can be calculated while the awareness level of the object is lowered by 1. Then we will find a descendent series of awareness objects K_1, K_2, …, K_m, which can satisfy:

I. The decreasing data traffic produced by lowering the awareness level of the objects K_1, K_2, …, K_m is larger than V, that is, $\sum_{i=1}^{m} V_{Ki} > V$.

II. In all the series $K_1, K_2, \ldots, K_m$, which satisfy $\sum_{i=1}^{m} V_{Ki} > V$, it makes the total awareness capability loss minimum, that is, $\sum_{i=1}^{m} AL_{ki}$ is minimum.

It is a typical knapsack problem, which can be solved by dynamic programming [9].

(3) Algorithm Description

According to the analysis above, the algorithm is described as follows.

Step1. Calculate the data traffic, network traffic, and the data traffic ΔV that needed to be decreased, according to the requirement of QoS.

Step2. Examine the status of each awareness object, and calculate the awareness capability loss AL of each awareness object when its awareness level is lowered by 1, and the network traffic V it saves.

Step3. Find the awareness object Obj, whose V_{Obj} is bigger than ΔV, and AL_{Obj} is the smallest.

Step4. Use dynamic programming to find the awareness objects list ObjList which satisfies the two conditions in Step3, and its V is smaller than ΔV.

Step5. Compare AL_{Obj} with $sum(AL_{ObjList(i)})$, the smaller one is the result object or objects list.

In Step 1, current network traffic can be obtained by network inspection, and data traffic can be calculated from awareness QoS [7] [10] [11] of each object in CVE.

The algorithm describes the scheduling when QoS of awareness objects can't be satisfied. When CVE detects that the network performance is sufficient for improving awareness level; correspondingly, the awareness object (list), which can mostly improve the awareness capability from the network resource available, will be found. The procedure is similar to the algorithm above. Therefore, the algorithm is self-adaptable.

4 Experiment and Verification

We've designed and developed an experimental system to support the technology of awareness scheduling above, using V-NET [12] as a prototype.

4.1 System Framework

The system consists of 3 layers: user layer, awareness management layer, and network layer.

(1) User Layer

User layer is made up of two parts. One is the user interface, which is the input and output of the system; the other is user awareness configuration, including user's AOI parameters, awareness priority of awareness objects, etc.

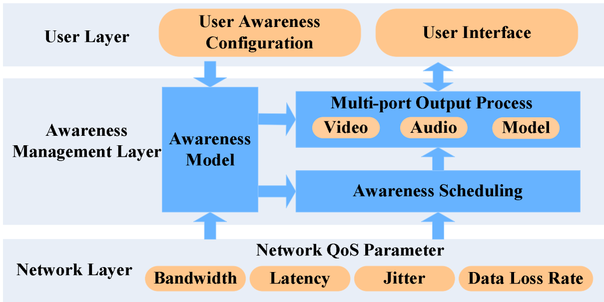

Fig. 2. System framework of experimental system

(2) Awareness Management Layer

This layer is the center of the whole system. It obtains configuration parameters from user layer, and current data of network status from network layer, which are used as the input of awareness algorithm. After calculating, scheduling algorithm will choose the media form and the model with corresponding precision to process and output.

(3) Network Layer

It's one of the data resources of awareness management layer; it is mainly responsible for collecting the data that reflects current network status.

4.2 Experimental System

We've designed a network simulator to describe the network status of client. It simulates the network status through four parameters, which are bandwidth, latency, jitter, and data loss rate. The scheduling algorithm gets the network parameters from it, including the data traffic and network traffic that satisfies awareness QoS. The system is based on VRML, Java, and EAI.

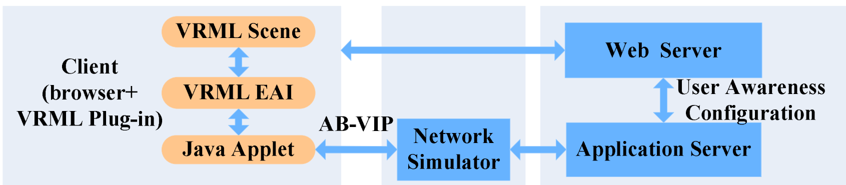

Fig. 3. Architecture of client, server and the communication between them

Web server offers the user login interface, VE of meeting, and avatar. Client and Application Server communicate through AB-VIP, which is implemented by modifying the VIP [12]. The actual network is replaced by network simulator to simulate the environment of Internet. User can configure his or her preference on objects in VE, which is the ejected window shown in Figure 4. The scheduling algorithm above is used to simultaneously execute the tasks in client and server, which are designed in the scheduling framework [10].

Fig. 4. System interface

4.3 Result

We use the calculation result of awareness capability to describe user's awareness effect. When every awareness object is on its highest awareness level, awareness capability is 1, which is used as a relative value to calculate the awareness capability of system in different bandwidth. We get the following awareness effect distributing figure in the case of 100 users, each with network traffic of 1.2K bytes.

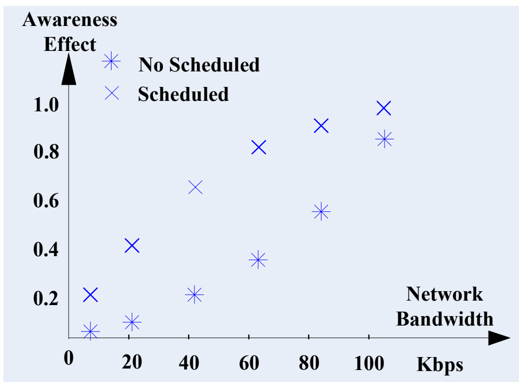

Fig. 5. Distribution of awareness effect

Study data and the figure above, we can draw the following conclusions:

(1) In a bad or unstable network, awareness effect can be maintained in a small range by using awareness scheduling, which improves the immersion of system.
(2) When network status becomes worse, user awareness effect decreases inevitably, but awareness scheduling can slow the decrease. However, when the bandwidth decreases below a critical point, the effect of awareness scheduling decreases rapidly, which means the scheduling has lost its effect.

5 Conclusions and Future Work

Restricted by network resource, CVE can't fully exert its advantages of reality and naturalness. To solve this problem, we analyze the relationship between awareness capability of system and network parameters such as latency, jitter and data loss rate, then advance a method of awareness scheduling based on network status and user preference, and we've got some achievement. Nevertheless, there are still many problems to be solved. For example, we need to study the transfer technology among different kinds of awareness information, as well as the technology of consistency in time and space, to satisfy the equal transfer between awareness elements in an environment of limited resource. We will also study the network traffic prediction model, and the influence to awareness parameters in complex network. With the problems above solved, the conflict between awareness capability and resource utilization will be further ameliorated, and it will promote the application of CVE in Internet.

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