Generalized Interest Management in Virtual Environments

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ABSTRACT
We present an interest management technique that organizes the shared state of a virtual environment into domains and sub-domains. To specify users' interests, we have partially adopted the general aura-nimbus model. It has been generalized beyond its original spatial use to allow users to express their interests explicitly without relying on their spatial characteristics only.

Categories and Subject Descriptors
I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism – *Virtual reality;* C.2.4 [**Computer-Communication Networks**]: Distributed systems – *Distributed applications;* Local and Wide-Area Networks – *Internet*

General Terms
Algorithms, Design, Security.

Keywords
Interest management, shared state partitioning.

1. INTRODUCTION
In a typical networked virtual environment (net-VE) users do not need to know about every other user's activities. Filtering irrelevant messages is usually referred to as *interest management*. Its main goal is to minimize network traffic and to reduce the burden on clients.

Interest management is nothing other than a disruption of the perfect case, where every net-VE participant maintains an identical copy of the state. In this paper we present an interest management technique that organizes the shared state into *domains* and *sub-domains*. It enables clients to express their interest in particular sub-domains so that they maintain and synchronize only those portions of the shared state that are of particular interest for them.

2. PREVIOUS WORK
In our approach, we partially adopt the spatial model of interaction [2], which uses notions of *aura* and *nimbus* to express interests and impacts of clients. We further abstract the model to not depend on the spatial metric, thus allowing interaction between participants to occur regardless of their spatial properties.

In net-VE systems the scope of information exchange among users is very broad and should not be constrained only by spatial regions. Users can form logical workgroups and interaction within a workgroup can be shared only by workgroup members – either for efficiency or security reasons. For example, while workgroup members who are located in separate regions do not need positional information about other members they cannot see, they should still be able to communicate with them. Alternatively, users who are located in the same region at the same time, but belonging to different workgroups, might be limited in the way they can interact. This technique is called functional filtering [3]. Our approach tries to combine advantages of both techniques. Key ideas are being implemented as part of the General Variables (GV) library and verified in our testbed net-VE system for social interaction called e-Agora.

2.1 General Variables Concept
The GV concept [4] was designed to formalize storing and distributing updates in a typical net-VE system.

If a user performs an interaction in the world the client sets a particular GV to some value (byte stream). This value is then sent to a server, which updates its GVs database and forwards the value to other connected clients. They parse the value and perform the original action locally. If a new client (*late join*) connects to the system, the server sends it the content of the GVs database so that the client can update its state promptly.

2.2 e-Agora
e-Agora [1] is our testbed net-VE system aimed at social interaction and culture content dissemination. Visitors connected via the Internet can see each other by the help of avatars and communicate by chat and gestures. The virtual environment is a model of an existing culture centre in the city of Prague. The system has been built on the top of the GV concept and VRML technology.

3. DOMAINS AND SUB-DOMAINS
To allow users to express their interest in only some part of the shared state, we propose to partition the shared state into *domains* and *sub-domains* (Figure 1a). The domains represent categories of areas of interest (logical groups, regions, navigation, chat or game playing). The sub-domains represent concrete areas (particular group, room, chat theme or specific game). Any state variable can belong to any number of domains – its *domain set* is specified upon its creation and it defines the scope of the variable.

When the state variable update is being sent (a user performs some action in the VE), the actual sub-domain values (*sub-domain set*) have to be associated with the update, one sub-domain value for every domain in the variable domain set. To construct the sub-domain set, we utilize *aura* (Figure 1b). The aura represents an individual set of areas of interest, which are impacted by the client. The aura is specified as a set of sub-domains. These sub-domains, which domains match with the

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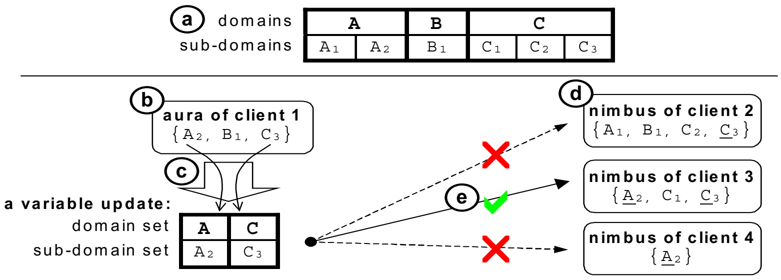

a) sample domains and sub-domains
b) source client's aura
c) filling the variable sub-domain set according to aura
d) nimbi of potential receiving clients
e) update propagation to final recipient – client 2. The other clients' nimbi do not contain all sub-domains from the update's sub-domain set. Common sub-domains are underlined in clients' nimbi.

Figure 1. Process of creating, filtering and receiving the variable update.

variable domains, are put in the variable update sub-domain set (Figure 1c).

To express the client's interest in a set of areas, we utilize *nimbus* (Figure 1d). Nimbus is a counterpart of the aura and is also specified as a set of sub-domains. To determine whether a client is interested in a particular update, we check if every sub-domain in the variable update sub-domain set is contained in the nimbus. If so, the update is propagated to the client (Figure 1e). In other words, we perform restricted intersection of the aura and the nimbus for domains contained in the variable domain set. If the intersection contains a sub-domain for every domain, the update propagation occurs.

4. DOMAINS IN E-AGORA

This section explains how our approach could be applied to a future version of e-Agora net-VE, which is currently being developed.

First, we have to define domains by finding possible categories of area of interest. In e-Agora, users can (C)hat, (N)avigate in the VE, (P)lay desk games or (E)dit objects in the environment. The VE is divided into several (R)ooms. Users are divided into logical (G)roups that operate independently. These categories represent possible domains, each containing several sub-domains. For example (R)ooms stands for a domain containing several sub-domains that represent the particular rooms (bar-R_1, hall-R_2, toilet-R_3). Now we can partition the shared state by assigning state variables to one or more domains – construct the variables' domain sets. For e-Agora we propose following sets: {C, G} for chat, {N, G, R} for navigation, {E, G, R} for editing, {E, R} for cross-group editing and {P, G} for cross-room playing.

The combination of domains restricts the scope of the variable. Since the chat variables does not contain the domain R, the communication among users is limited only to participants of the same group and it is not limited in space. Navigation variables describing positions and orientations of the users are a different case. A user has to express interest in a particular combination of the group and room to receive updates. The e-Agora also enables two types of editing in the VE. First we have independent editing for every group, where each modification occurs only in the group it has originated from. It can be used for group related projects. Secondly, cross-group editing occurs in every group. An example is installation of an exhibition that should be visible to all users. Playing desk games is also not related to particular room, so users can iconize the desk game, move to another room and continue playing the game.

When a user enters the VE, her client expresses interest with the help of the nimbus. If she is interested only in chat, her nimbus will contain only particular chat theme or themes and the group to which she belongs: e.g. $\{C_1, G_2\}$. If she wants to see the other users too, her client extends the nimbus and specifies a particular room along with the navigation interest itself: $\{C_1, G_1, N_1, R_2\}$. If she wants to see the users in adjacent rooms too, her client extends the nimbus again by adding these rooms: $\{C_1, G_1, N_1, R_2, R_3, R_1\}$. And finally, if she wants to join or watch some desk game, her client extends the nimbus by the particular desk game: $\{C_1, G_1, N_1, R_2, R_3, R_1, P_2\}$. The aura is being composed in the same manner. However, the aura usually contains only one sub-domain for each domain; for example the user is usually presented in one room only.

Whenever a client changes its nimbus, it receives all changes of the appropriate shared state that have been made. The client can provide a timestamp of the last update it has received to obtain only recent changes of the state. Concerning security issues, every change of the aura and nimbus can be subject to security checking to restrict clients to access only particular parts of the shared state.

5. CONCLUSION

We have identified the problem of interest management in the context of the net-VE shared state. We argue that interest management actually limits the net-VE participants to maintain only specific parts of the global net-VE shared state. We have proposed a method that subdivides the shared state into domains and sub-domains. The Aura-nimbus model has been adopted for expressing clients' impacts and interests. We demonstrated an application of our approach on e-Agora, a net-VE system aimed at social interaction.

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