

Research Article

Perception-Based Filtering for MMOGs

Souad El Merhebi, Jean-Christophe Hoelt, Patrice Torquet, and Jean-Pierre Jessel

VORTEX Group, Institut de Recherche en Informatique de Toulouse, Paul Sabatier University, 31062 Toulouse, France

Correspondence should be addressed to Souad El Merhebi, merhebi@irit.fr

Received 30 September 2007; Revised 13 January 2008; Accepted 8 April 2008

Recommended by Kok Wai Wong

Online games have exploded in the last few years. These games face several problems linked to scalability and interactivity. In fact, online games should provide a quick feedback of users' interactions as well as a coherent view of the shared world. However, the search for enhanced scalability dramatically increases message exchange. Such an increase consumes processing power and bandwidth, and thus limits interactivity, consistency, and scalability. To reduce the rate of message exchange, distributed virtual environment systems use filtering techniques such as interest management that filters messages according to users' interests in the world. These interests are influenced by perceptual facts which we study in this paper in order to build upon them a perception-based filtering technique. This technique satisfies users' needs by precisely providing an exact filtering which is more efficient than other techniques.

Copyright © 2008 Souad El Merhebi et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. INTRODUCTION

Online game players interact within a shared virtual world through their avatars. Players' interactions change the state of their avatars and may affect the state of the world. To insure coherency, all players should observe the same state of the shared world at the same moment. Therefore, the activity of a player must be communicated to the other players. This must be done as quickly as possible to provide an interactive game in which players have a quick feedback of their interactions.

On the other hand, online games, especially massively multiplayer online games (MMOGs), need to be more and more scalable. However, increasing the number of participants tends to dramatically increase the number of update messages. A higher amount of message exchange requires higher bandwidth and more processing power, which slows down the system and makes it less interactive "lagging" [1]. The system should therefore be adapted to these limited resources. This can be done by minimizing exchanged messages and the number of their recipients.

Distributed virtual environments (DVEs) systems take advantage of the fact that participants neither perceive nor are interested in the whole virtual world. This is due to many reasons: world's design, distances that separate avatars, limitation of avatars' awareness, and so forth. Sometimes, developers themselves create these limitations to enhance the

scalability of the system (shards, fog, etc.). Limitations of awareness define the interests of players within the world. This provides an interesting basis to design message filtering whose concept is to deliver messages only to concerned participants, this is called interest management.

The perception of an avatar within its world expresses or contributes to expressing its interest. Perception-based filtering [2] defines the perceptual interests of avatars in an exact way. This paper completes the study of perception-based filtering by including a more general perception model and providing deeper mathematical analysis backed up with the results of an experimental evaluation.

In Section 2, we present a brief overview of related work. Section 3 describes the relation between awareness and perception. Section 4 describes perception-based filtering. In Section 5, we present the translation of perception rules into existing interest management techniques. Section 6 presents the experimental and analytical evaluation of perception-based filtering. Finally, Section 7 presents conclusions and outlines future work.

2. RELATED WORK

Interest management techniques have been implemented within military DVE systems as well as in games. They use the division of space or the definition of individual interests of avatars, or a combination of the two approaches.

NPSNET [3] divides the environment into hexagonal cells and specifies for each entity an area of interest (AOI), which is a circle centered on the entity. An entity is only aware of entities within the hexagons that overlap its AOI.

MASSIVE implements the spatial model of interaction [4] which assigns an aura to each object for each medium (graphics, audio, etc.). Spatial model's filtering is achieved in two stages. The first detects auras' collision of couples of objects. This entails a possibility of interaction and leads to the second stages which consists, in the negotiations, of levels of awareness between users. The level of awareness of entity *A* toward entity *B* is a function of *A*'s focus and *B*'s nimbus, the focus being the observer's allocation of attention and the nimbus the observed's manifestation or observability. The negotiations of awareness levels decide the *existence* of awareness on each side. If there is awareness, its level can influence the attribution of resources (e.g., bandwidth, audio quality, etc.). Whenever a change occurs, the couple has to negotiate again to know whether a change in awareness took place. For performance and development cost reasons, this model is often used in a simplified way which only uses auras to determine awareness of avatars, even if this entails the exclusive establishment of symmetrical relations.

Effect management [5] is a variation of the spatial model of interaction which preserves the attractive feature of asymmetric awareness, while offering the possibility of not defining foci and nimbi functions if there are no resource accommodations. Effect management determines the existence of awareness on the two sides distinctly in the first stage. The second stage (i.e., awareness level computation) will only be dedicated to the determination of the *nonnull* awareness level through foci and nimbi negotiations if needed. To achieve that, the first stage associates with each entity a viewing zone which reflects the ability to perceive and an effect zone which reflects the ability to be perceived instead of combining the two abilities within the aura. When the viewing zone of an entity *A* overlaps the effect zone of an entity *B*, *A* becomes aware of *B*.

HLA [6, 7] uses interest management through a runtime infrastructure (RTI) service: the data distribution management (DDM). This service first allows the expression of entities' interest and availability by defining subscription and publication zones. Then, it computes intersections between zones and deliver updates according to those computations (i.e., an update is only sent to the entities whose subscription zones intersect with its publication zone). DDM uses a multidimensional coordinate system in which entities define their interests and availability. This system can use a fixed or hierarchical grid.

Other DVE systems and online games use division of space without the individual definition of entities' interests into zones. Some of them also associate to each division or share a server in order to enhance scalability. Such systems are SPLINE [8], RING [9], Ultima Online, Neverwinter Nights, Silkroad Online, World of Warcraft, and so forth.

Our study focuses on the definition of individual interests of avatars because this approach provides a more exact filtering than division of space. As we have seen, many interest management techniques define their users' interests

in individual zones because they are simple, natural and not expensive. However, these systems define the extents of their zones in an empirical way. This leads to imprecise filtering which makes avatars receive more or fewer messages than they actually need. In fact, if an avatar does not receive all the messages that interest it, the player's experience will be less realistic and interactive. Otherwise, if avatars receive messages that do not interest them, the system and the network will be overloaded with unnecessary messages. Thus, in both cases the empirical definition of zone extents will harm the simulation. For these reasons, it is very important to have a mechanism that determines the interests of users in a precise way. Our previous study of perception-based filtering [2] defined the limits of avatars' perception and presented a translation of these limits into zones in other interest management techniques. In this paper, we will complete this study by presenting a more general perception model and by providing a comparative analysis backed up with experimental results between the perception-based filtering and the other interest management techniques.

3. RELATION BETWEEN AWARENESS AND PERCEPTION

The perceptibility of an avatar (its ability to be perceived, its manifestation) depends on its importance in the world. This importance may be related to the avatar's situation (an aircraft is easily perceived in a clear sky) or its function (a speaker in a stadium is seen and heard by all the audience). Most importantly, an avatar is noticed due to its physical manifestation: its size.

On the other hand, not all avatars have the same capacity of awareness because of their structure, function or behavior. An avatar can simulate a short-sighted person, another represents a person carrying binoculars. We can also have a well-positioned entity or a fast entity. These entities have different degrees of perception.

Therefore, an avatar's awareness of another depends on the perception of the observer, the perceptibility of the observed and the distance that separates the couple. This awareness may only depend on these factors in case of the absence of others. This relationship was expressed in some interest management techniques such as area of interest management, spatial model of interaction, and effect management through the use of zones.

4. PERCEPTION-BASED FILTERING

Computer graphics' developers use many algorithms to perform visibility tests. In the following, we will study these algorithms to see if they may specify convenient message filtering parameters.

Computer graphics determines that an object is not visible due to the following widely used properties.

- (i) P1 is outside of camera's view volume.
- (ii) P2 is hidden by other objects.
- (iii) P3 covers less than one pixel on the screen.

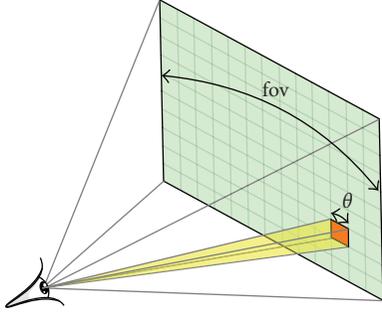


FIGURE 1: Angle of view of a virtual camera.

P1 cannot define an efficient filtering technique for DVEs because when a player turns his head, he may quickly visualize a lot of new avatars. Therefore, P1 does not define stable filtering parameters that prevent an avatar from frequent and thus expensive changes of interests.

P2 may be interesting because it can eliminate an important amount of message exchange. Many techniques, based on this property, have been used in computer graphics. These techniques can be used for message filtering for DVEs. For example, it is possible to use occlusion queries on recent GPUs [10] or precomputed potentially visible sets [11] (as used in Quake(tm) [12] and RING [9], e.g.). However, the implementation of these techniques is difficult and they require complex computations when they are done dynamically (especially on a client/server architecture because the server performs filtering for many entities during each simulation frame).

P3 offers a simpler method: knowing player A's screen resolution and the 3D-engine camera parameters, we can easily determine the projection of avatar B's bounding sphere on the screen. If the size of the projected sphere is less than a certain threshold (which may be set to the size of one pixel, e.g.), A will not see B. This will be the basis of our perception-based filtering.

4.1. Maximal distance of perception

Let us take the standard approach of a virtual camera using a projection plane as it is defined in OpenGL and Direct3D. The camera is defined by its angle of view (or field of view—fov), which is the angular extent of the virtual scene that is rendered (see Figure 1). This defines a viewing volume (a pyramid), which is then divided into smaller volumes, one for each pixel. Given this, we can determine the angle of view covered by a pixel for a specific player from the virtual camera's field of view (fov) and the number of pixels covered by the user's viewport (SSize). The whole screen covers 100% of the field of view, therefore a single pixel covers approximately an average angle θ (The camera model induces a distortion for the pixels that are far from the center of the screen. We will consider this distortion negligible in our study.):

$$\theta = \frac{\text{fov}}{\text{SSize}}. \quad (1)$$

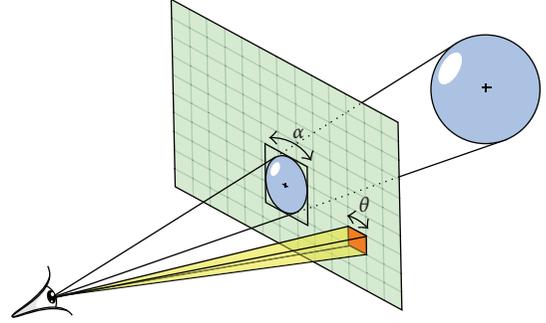


FIGURE 2: Angular extents of a pixel and a sphere.

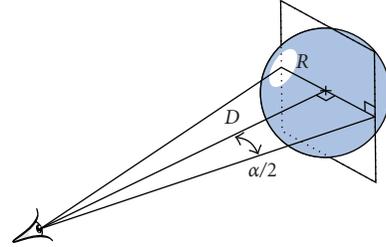


FIGURE 3: Angular extent of a 3D object.

On the other hand, we can compute the angular extent α of a 3D object projection on the screen (Figure 2). To compute this extent, we can see in Figure 3 that the relationship between the angle α (view angle covered by the object), the “opposite” side R (the bounding sphere radius), and the “adjacent” side D (distance between object and camera) is

$$\tan\left(\frac{\alpha}{2}\right) = \frac{R}{D}. \quad (2)$$

By using our filtering criteria, P3 allows an object to be seen when the size of its projection is superior to one or several pixels. The minimal number of perceived pixels depends on the viewing capacity of the user. A user with an enhanced capacity of view can see an object if its projection covers one pixel, while a short-sighted user will need a projection superior to several pixels to be able to see a projected object.

When the size of the projected sphere is bigger than a pixel this is exactly the same as having the angular extent “ α ” bigger than the angle covered by one pixel “ θ ” (Figure 2). For a short-sighted user, this maximal angle will be multiplied by the minimal number of pixels seen by the user “ n ”. Knowing that α and $n \cdot \theta$ are always smaller than π , we have

$$\begin{aligned} \alpha \geq n \cdot \theta &\Leftrightarrow \tan\left(\frac{\alpha}{2}\right) \geq \tan\left(n \cdot \frac{\theta}{2}\right) \\ &\Leftrightarrow \frac{R}{D} \geq \tan\left(n \cdot \frac{\theta}{2}\right) \\ &\Leftrightarrow D \leq \frac{R}{\tan(n \cdot \theta/2)}. \end{aligned} \quad (3)$$

This inequality shows that an observer can see an object if the distance that separates them is less or equal to “ $R/\tan(n\cdot\theta/2)$.” This gives the maximal distance of perception under which the user sees the other avatar;

$$\begin{aligned} D_{\max} &= \frac{R}{\tan(n\cdot\theta/2)} \\ &= R \cdot V, \quad \text{where } V = \frac{1}{\tan(n\cdot\theta/2)}. \end{aligned} \quad (4)$$

This maximal distance depends on the player’s viewing capacity V and on the observed avatar’s size R .

The number of visible avatars is directly related to the player’s viewing capacity. However, it is possible that at a certain moment during the game, the system or a user becomes no longer able to handle more message transfers. To prevent this, we allow it to artificially reduce the values of perception distance by using the filtering coefficient “FC” that varies between 0 and 1:

$$D_{\max} = R \cdot V \cdot FC. \quad (5)$$

4.2. Filtering mechanism

To be able to use perception-based filtering, a server (in client/server architectures) or clients (in peer-to-peer architectures) compute the maximal distance of perception that the observing avatar has of the observed avatar (a simple multiplication). Then, they compare this maximal distance of perception to the distance that separates the two avatars to deduce if the perception takes place or not.

5. DETERMINING RADIUSSES OF INTEREST ZONES

As we have seen in Section 2, many interest management techniques use zones to determine avatars’ interests and manifestations. Until now, these techniques have determined the radiusses of their zones empirically. In this section, we propose mechanisms that determine these radiusses based on our perception rules. This translation has two goals: providing a mechanism to determine the size of zones for these used filtering techniques and establishing a fair ground to compare the perception-based filtering with the existing interest management techniques.

The condition that the zones should strictly fulfil to express perception is that whenever an avatar sees another with perception-based filtering, it should be able to see it with the parallel interest management techniques (area of interest management, spatial model of interaction or effect management, etc.). If this entails a reception of unnecessary information, this can be tolerated. But not receiving important update messages cannot be tolerated.

In Figure 4, we can see the translation of perception rules into various interest management techniques. The computation of these radiusses varies according to the techniques, but it always depends on the perception and perceptibility of all the avatars of the environment. In the following, we analyze these dependencies and their impact on filtering.

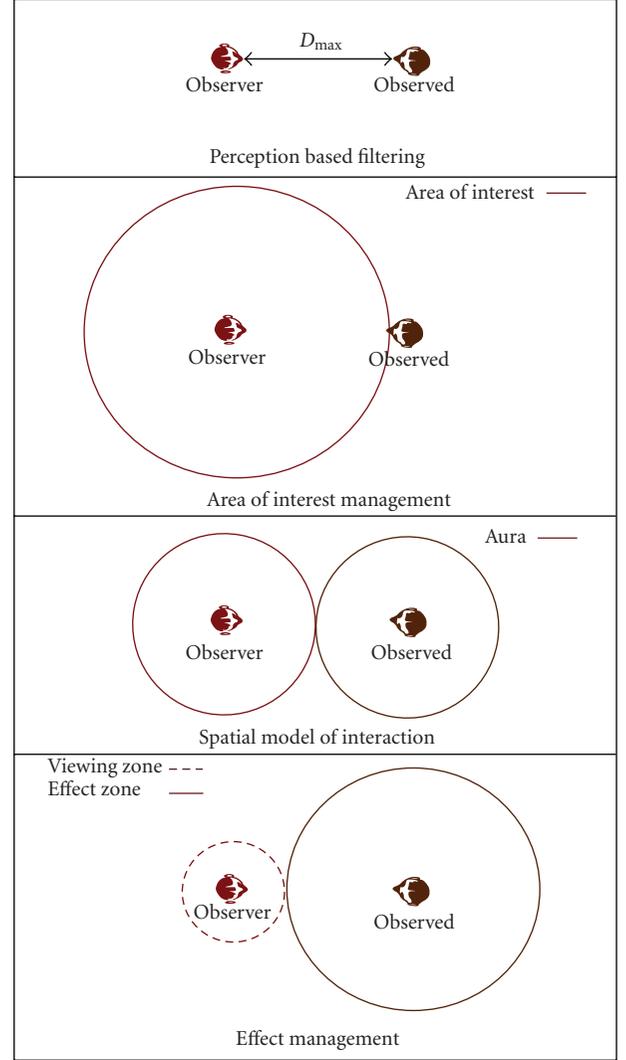


FIGURE 4: Translation of perception rules in various interest management techniques.

5.1. Area of interest management

The area of interest management allows an avatar to see the avatars that are within its area of interest (AOI). To have a fair translation, whenever an avatar sees another with perception-based filtering, it should see it with area of interest management. Therefore, if the distance between two avatars is smaller than D_{\max} , the AOI of the viewing avatar should cover the other avatar (see Figure 5). Consequently, the radius of the AOI should be greater than or equal to all the D_{\max} . To optimize filtering, we choose the largest D_{\max} that the avatar has as its AOI radius.

S being the set of games’ avatars:

$$AOI(A) = \max \{D_{\max}(A, n), \forall n \in S\}. \quad (6)$$

This may entail excessive information reception because if we have an important avatar, all the avatars will enlarge their AOIs to be able to see it when it is distant. This will make

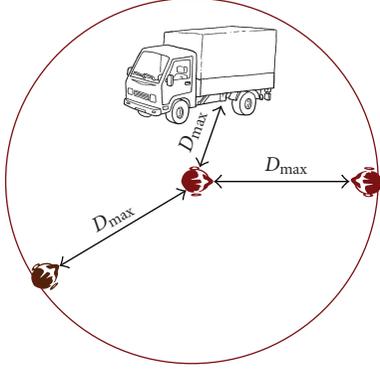


FIGURE 5: Determining the AOI radius.

the avatars receive information of small and distant avatars that they are not supposed to see.

5.2. Spatial model of interaction

The spatial model of interaction allows two avatars to see each other when their auras collide. The sizes of the auras will be defined following the rule **R**.

“A sees B with perception-based filtering” means that the distance between A and B is less than or equal to the corresponding D_{\max} :

$$D(A, B) \leq D_{\max}(A, B). \quad (7)$$

And “A sees B with the spatial model of interaction” means that the auras of A and B collide:

$$D(A, B) \leq \text{Aura}(A) + \text{Aura}(B), \quad (8)$$

where $\text{Aura}(N)$ is the radius of N’s aura.

A condition that makes **R** possible is

$$\mathbf{C}: \text{Aura}(A) + \text{Aura}(B) \geq D_{\max}(A, B) \quad (9)$$

because

$$\begin{aligned} D(A, B) &\leq D_{\max}(A, B), \\ D_{\max}(A, B) &\leq \text{Aura}(A) + \text{Aura}(B) \implies D(A, B) \\ &\leq \text{Aura}(A) + \text{Aura}(B). \end{aligned} \quad (10)$$

So condition **C** allows the satisfaction of rule **R**. Therefore, S being the set of the game’s avatars, the general rule will be

$$\forall a \in S, \forall b \in S, \quad \text{Aura}(a) + \text{Aura}(b) \geq D_{\max}(a, b). \quad (11)$$

This rule gives a set of constraints which define a system of inequalities. For example, if we take a game with three avatar types: a person (P), an eagle-eyed person (EE), and a truck (T), the following constraints will be raised:

$$2 * \text{Aura}(P) \geq D_{\max}(P, P), \quad (12)$$

(to enable two persons to see each other when they should),

$$\text{Aura}(P) + \text{Aura}(EE) \geq D_{\max}(P, EE) \quad (13)$$

(to enable a person to see an eagle-eyed person),

$$\begin{aligned} \text{Aura}(P) + \text{Aura}(T) &\geq D_{\max}(P, T), \\ \text{Aura}(EE) + \text{Aura}(P) &\geq D_{\max}(EE, P), \\ 2 * \text{Aura}(EE) &\geq D_{\max}(EE, EE), \\ \text{Aura}(EE) + \text{Aura}(T) &\geq D_{\max}(EE, T), \end{aligned} \quad (14)$$

$$\begin{aligned} \text{Aura}(T) + \text{Aura}(P) &\geq D_{\max}(T, P), \\ \text{Aura}(T) + \text{Aura}(EE) &\geq D_{\max}(T, EE), \\ 2 * \text{Aura}(T) &\geq D_{\max}(T, T). \end{aligned}$$

These constraints define a system of linear inequalities which has an infinity of solutions. Our goal is to find the optimal solution that minimizes the number of possible interactions between avatars. This number is proportional to the possibility of auras’ collisions, which makes it proportional to the total area covered by all avatars’ auras:

$$AA = \sum_{n \in S} \pi \text{Aura}(n)^2. \quad (15)$$

Such a system can be solved in many ways. We used Newton’s method for the solution of systems of equalities and inequalities [13], parameterized to minimize the value of AA .

5.3. Effect management

Effect management offers better precision because for each avatar we distinguish the ability to see (perception) from the ability of being seen (perceptibility), this gives more precise constraints. A similar demonstration to that of the spatial model of interaction gives the following translation condition:

$$D(A, B) \leq V(A) + E(B), \quad (16)$$

where $V(A)$ is the radius of an avatar A’s viewing zone and $E(B)$ is the radius of an avatar’s B effect zone.

So, S being the set of the game’s avatars, the system takes this form:

$$\forall a \in S, \forall b \in S, \quad E(a) + V(b) \geq D_{\max}(a, b). \quad (17)$$

If we take our previous example, we will have the following system of inequalities:

$$V(P) + E(P) \geq D_{\max}(P, P), \quad (18)$$

(to enable persons to see each other)

$$V(P) + E(EE) \geq D_{\max}(P, EE), \quad (19)$$

(to enable a person to see an eagle-eyed person)

$$\begin{aligned}
V(P) + E(T) &\geq D_{\max}(P, T), \\
V(E E) + E(P) &\geq D_{\max}(E E, P), \\
V(E E) + E(E E) &\geq D_{\max}(E E, E E), \\
V(E E) + E(T) &\geq D_{\max}(E E, T), \\
V(T) + E(P) &\geq_{\max}(T, P), \\
V(T) + E(E E) &\geq D_{\max}(T, E E), \\
V(T) + E(T) &\geq D_{\max}(T, T).
\end{aligned} \tag{20}$$

The system can be solved by minimizing the area covered by the effect and viewing zones:

$$AEV = \sum_{n \in S} \pi C(n)^2 + \pi E(n)^2. \tag{21}$$

6. EXPERIMENTAL RESULTS

To implement perception-based filtering, we used Architecture for Systems of Simulation and Training in Teleoperation (ASSET) [14], a prototyping system supporting the design and evaluation of new teleoperation systems by using virtual reality components. In our context, ASSET is used in simulation mode only thus becoming a generic client/server-based DVE system.

We compared the performance of perception-based filtering with those of area of interest management and spatial model of interaction in its simple version and effect management. The level of realism is constant with the four techniques, since it is fixed by the perception rules while the communication load varies following the filtering technique and this is what interests us.

6.1. Experimental environment

We used for our experiments 100 nodes of a cluster of Grid'5000 [15], which is a grid of thousands of CPUs distributed at 9 sites France wide. Nodes have Rocks Linux 3.3.0 as operating systems and are connected by a Gigabit Ethernet network. The nodes are *IBM eServer 325* shipped with AMD Opteron 246 CPUs (2.0 GHz/1 MB/400 MHz), 2 GB memory, 2x Gigabit Ethernet (1 in use) and Myrinet-2000 (M3F-PCIXF-2) network cards.

An experiment is a two-minute simulation with a simulation step of 200 milliseconds. We carried out the experiments varying the number of clients. We repeated the experiments several times and averaged the resulting values. During an experiment, the server collects various experimental data such as the number of exchanged messages and the server's load.

The server was always allocated a dedicated node. However, since the number of clients in a single simulation got up to 160 (and we only have 100 nodes available), we eventually had to run two clients on the same node.

6.2. Simulation parameters

The virtual environment is a 20000×20000 square. The behavior of avatars is autonomous following a random acceleration with a privileged direction. An avatar can be a normal person, an eagle-eyed person (with good visual ability) or a truck. The person and the driver of the truck have a limited viewing capacity, while the eagle-eyed person has an enhanced viewing capacity. Furthermore, the truck has a larger size, thus it has a stronger chance of being seen than the others.

6.2.1. Perception-based filtering

For perception-based filtering, we consider that the field of view is equal to 120 degrees and the screen is 1024 pixels large. This gives us the angle covered by one pixel,

$$\begin{aligned}
\theta &= \frac{\text{fov}}{Nb \text{ Pixels } X} \\
&= \frac{120}{1024} \\
&= 0.117.
\end{aligned} \tag{22}$$

We consider that the eagle-eyed person is able to see the details on the screen up to one pixel ($n = 1$). His viewing capacity is of

$$\begin{aligned}
V_{\text{eagle}} &= \frac{1}{\tan\left(n_{\text{eagle}} \cdot \frac{\theta}{2}\right)} \\
&= \frac{1}{\tan\left(1 \cdot \frac{0.117}{2}\right)} \\
&= \frac{1}{\tan(0.058)} \\
&= 977.8.
\end{aligned} \tag{23}$$

To obtain the maximal distance of perception that the avatar has of a person, we multiply the radius of the person with the visual capacity of the avatar:

$$\begin{aligned}
D_{\max}(\text{eagle, person}) &= R_{\text{person}} \cdot V_{\text{eagle}} \\
&= 1.022 \cdot 977.8 \\
&= 1000.
\end{aligned} \tag{24}$$

On the other hand, the maximal distance of perception that an eagle-eyed person has of a truck depends on the truck's bounding sphere radius:

$$\begin{aligned}
D_{\max}(\text{eagle, truck}) &= R_{\text{truck}} \cdot V_{\text{eagle}} \\
&= 2.045 \cdot 977.8 \\
&= 2000.
\end{aligned} \tag{25}$$

The avatars with a normal viewing capacity (the person and the driver of the truck) will see less clearly on the screen.

TABLE 1

D_{\max}	Person	Truck	Eagle-eyed
Person (P)	500	1000	500
Truck (T)	500	1000	500
Eagle-eyed (EE)	1000	2000	1000

TABLE 2

Avatar	Person	Truck	Eagle-eyed
AOI	1000	1000	2000

TABLE 3

Avatar	Person	Truck	Eagle-eyed
Aura	250	1000	1000

TABLE 4

Avatar	Person	Truck	Eagle-eyed
Viewing zone	250	250	1000
Effect zone	250	1000	250

We will consider that their minimal threshold of perception is of two pixels ($n = 2$). Thus, we have

$$\begin{aligned}
 V_{\text{person}} &= \frac{1}{\tan} \left(n_{\text{person}} \cdot \frac{\theta}{2} \right) \\
 &= \frac{1}{\tan} \left(2 \cdot \frac{0.117}{2} \right) \\
 &= \frac{1}{\tan} (0.117) \\
 &= 488.9.
 \end{aligned} \tag{26}$$

This influences all the maximal distances of perception of the person.

Table 1 lists the maximal distances of perception of our environment. We can see for example that the maximal distance of perception that a person has of a truck is 1000.

6.2.2. Area of interest management

By using the rules of translation defined above, we defined the radiuses of the areas of interest for our avatars in Table 2.

6.2.3. Spatial model of interaction

The system of inequalities related to the spatial model of interaction was solved using a solver which gave the results listed in Table 3.

6.2.4. Effect management

Table 4 shows the optimal solution of the corresponding system of inequalities.

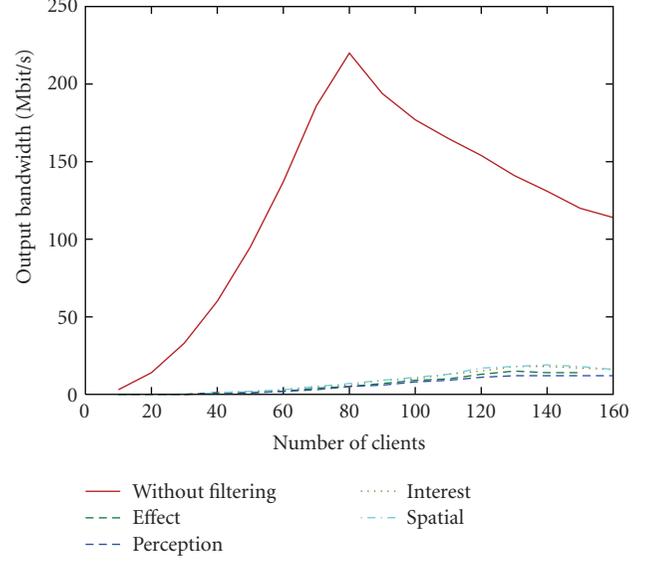


FIGURE 6: Network bandwidth with and without filtering.

6.3. Results

6.3.1. The impact of filtering

Figure 6 shows the rate of messages sent by the server with and without filtering. We notice that all the filtering techniques succeeded in reducing the rate of outgoing messages. This pushes further the bottleneck on the server that is due to the cost of sending messages when there is no filtering used. However, filtering techniques postpone the bottleneck but do not eliminate it. The bottleneck is related to the load of filtering that is equivalent in all the filtering techniques (Figure 7).

We should note that we use a Gigabit network. If the network had a narrower bandwidth, the bottleneck without filtering would take place a lot sooner because of the network load and not the server load.

6.3.2. Evaluation of perception-based filtering

Figure 8 compares the rate of messages sent by the server with the four filtering techniques. We can notice that the perception-based technique presents the lowest rate of sent messages. This exact filtering performed by our technique allows the server to use less upload bandwidth and makes users receive fewer messages. This makes the application less expensive and more interactive.

6.3.3. Analysis

We have seen that perception-based filtering achieves better results than the other filtering techniques. This is due to the fact that perception-based filtering performs an exact filtering and delivers to each user only data that he is able to perceive while others do not.

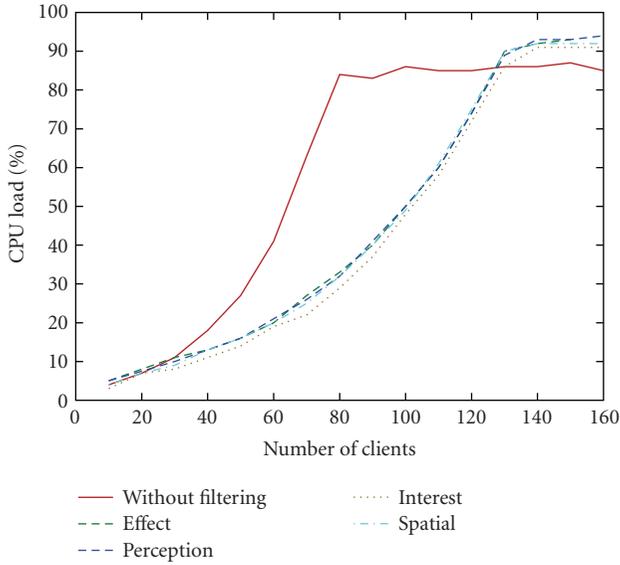


FIGURE 7: Server’s load with and without filtering.

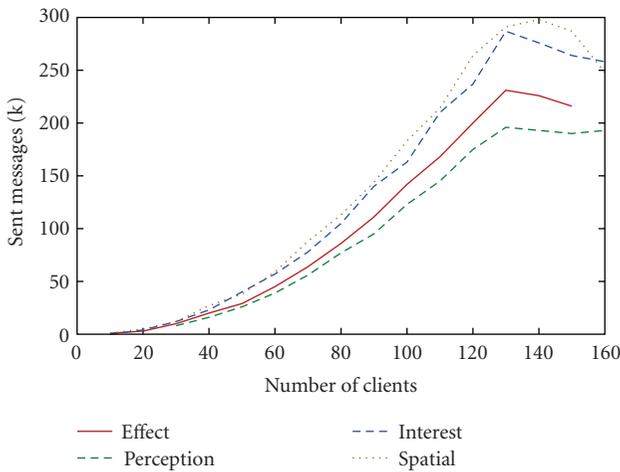


FIGURE 8: Sent messages.

(i) The area of interest management does not allow avatars to express their manifestations. For these reasons, the AOI of an avatar depends on all the existing avatars. Therefore, if we have an important avatar that is seen from a long distance, the AOIs of all the avatars should be large enough to cover this avatar when it is distant. Thus, these AOIs will cover small and distant avatars that should not be seen.

(ii) The spatial model of interaction combines the ability to see and the ability to be seen within the aura. This prevents avatars from establishing asymmetrical relations. Therefore, an important avatar which is seen by everyone will be forced to see everyone.

(iii) Effect management does not suffer from the shortcomings of the previous techniques. That is why it offers a better rate of filtering than both of them. However, it still has an excessive rate of message exchange due to the sizes of effect

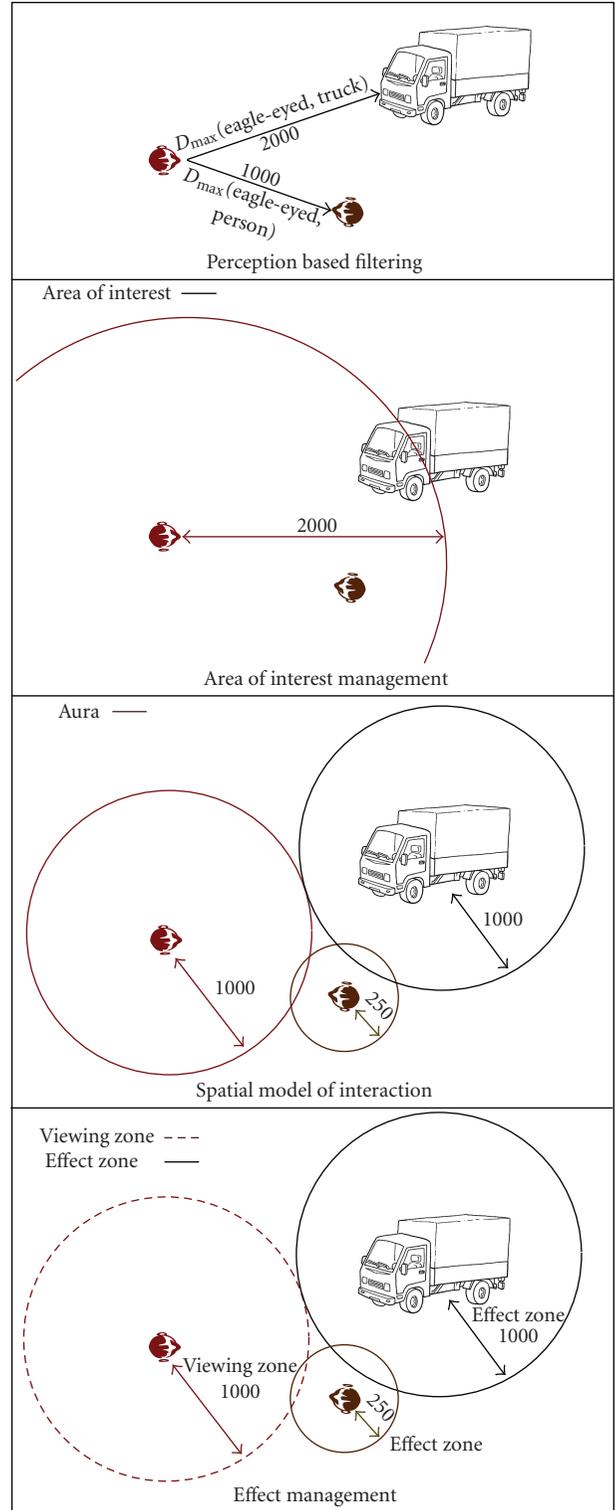


FIGURE 9: D_{max} translation into various interest management techniques.

and viewing zones which depend on each other because of the system of inequalities.

Figure 9 gives a concrete example of the inexact filtering.

Let us consider the scenario of an eagle-eyed person who is standing at a distance of 2000 away from a truck and of

1100 from a normal person. We will study the perception of the eagle-eyed toward the two other avatars.

With perception rules, our observer can see the truck because they are at a distance (2000) which is equal to the observer's maximal distance of perception of the truck. However, the distance that separates him from the other person (1100) is superior to the corresponding maximal distance of perception (1000). Therefore, the eagle-eyed person receives the update of the truck but not that of the other person.

With area of interest management, the observer's AOI covers the truck and the person. So the observer will receive the update of the person, while he is not supposed to see him.

With the spatial model of interaction, the aura of the observer overlaps the auras of the two other avatars. Thus, he receives the messages of the other two avatars.

With effect management, the viewing zone of the observer overlaps the effect zones of both the truck and the person. So the observer also receives unnecessary updates.

This concrete comparison further details the causes of the advantage of perception-based filtering over the other interest management techniques.

7. CONCLUSIONS AND FUTURE WORK

We have presented the perception-based filtering technique. This technique will help developers determine their avatars' perceptual interests in a precise way. We have also presented a translation of perception rules into interest management techniques which define the interests of players by using zones. We have then compared the performance of perception-based filtering with other techniques and we found that our technique further reduces the amount of exchanged messages. We have also described the reasons why our technique offers such advantages.

Perception-based filtering presents an additional advantage related to the dynamic change of interests. In fact, perception-based filtering allows avatars to change their abilities to perceive or be perceived without having to change a lot of simulation parameters. Furthermore, any change of ability of one avatar with the other techniques will induce a new system of inequalities that should be solved to give a new set of filtering parameters.

However, perception-based filtering only expresses perceptual factors while the other techniques allow to express other characteristics in addition to perception (function, behaviour, etc.). This is why we intend to extend our research to the auditive and functional domains.

ACKNOWLEDGMENTS

This work was supported in part by the French Government through the NatSIM ANR Project (Contract ANR 05-MMSA-0004-01). Grateful acknowledgment for proofreading and correcting our article goes to Anne Beauvallet, Senior Lecturer at Toulouse II University (English Studies Department).

REFERENCES

- [1] D. Terdiman, "World of warcraft battles server problems," <http://articles.techrepublic.com.com/2100-1087911-6063990.html>.
- [2] S. Elmerhebi, J.-C. Hoelt, P. Torguet, and J.-P. Jessel, "Perception based messages filtering for massively multiplayer online games," in *Proceedings of the 3rd International Conference on Games Research and Development (CyberGames '07)*, Manchester, UK, September 2007.
- [3] M. R. Macedonia, M. J. Zyda, D. R. Pratt, D. P. Brutzman, and P. T. Barham, "Exploiting reality with multicast groups: a network architecture for large-scale virtual environments," in *Proceedings of the IEEE Virtual Reality Annual International Symposium (VRAIS '95)*, pp. 2–10, Los Alamitos, Calif, USA, March 1995.
- [4] S. Benford and L. Fahlén, "A spatial model of interaction in large virtual environments," in *Proceedings of the 3rd European Conference on Computer-Supported Cooperative Work (ECSCW '93)*, pp. 109–124, Milano, Italy, September 1993.
- [5] S. Elmerhebi, P. Torguet, and J.-P. Jessel, "Realism and communication evaluation of effect management in distributed virtual environments," in *Proceedings of the 12th Eurographics Symposium on Virtual Environments (EGVE '06)*, Lisbon, Portugal, May 2006.
- [6] A. Boukerche, N. J. McGraw, C. Dzermajko, and K. Lu, "Grid-filtered region-based data distribution management in large-scale distributed simulation systems," in *Proceedings of the 38th Annual Symposium on Simulation (ANSS '05)*, pp. 259–266, San Diego, Calif, USA, April 2005.
- [7] J. Calvin and R. Weatherly, "An introduction to the high level architecture (HLA) runtime infrastructure (RTI)," in *Proceedings of the 14th Workshop on the Standards for the Interoperability of Defence Simulations*, pp. 705–715, Orlando, Fla, USA, March 1996.
- [8] R. C. Waters, D. B. Anderson, J. W. Barrus, et al., "Diamond park and spline: social virtual reality with 3D animation, spoken interaction, and runtime extendability," *Presence*, vol. 6, no. 4, pp. 461–481, 1997.
- [9] T. A. Funkhouser, "Ring: a client-server system for multi user virtual environments," in *Proceedings of the Symposium on Interactive 3D Graphics (SI3D '95)*, pp. 85–92, ACM Press, Monterey, Calif, USA, April 1995.
- [10] D. Bartz, M. Meißner, and T. Hüttner, "Extending graphics hardware for occlusion queries in opengl," in *Proceedings of the ACM SIGGRAPH/Eurographics Workshop on Graphics Hardware*, pp. 97–104, ACM Press, Lisbon, Portuga, August-September 1998.
- [11] J. M. Airey, J. H. Rohlf, and F. P. Brooks Jr., "Towards image realism with interactive update rates in complex virtual building environments," in *Proceedings of the Symposium on Interactive 3D Graphics (SI3D '90)*, pp. 41–50, ACM Press, Snowbird, Utah, USA, March 1990.
- [12] M. Abrash, "Inside quake: visible surface determination," in *Dr. Dobb's Sourcebook*, pp. 41–45, January-February 1996.
- [13] B. N. Pshenichnyi, "Newton's method for the solution of systems of equalities and inequalities," *Mathematical Notes*, vol. 8, no. 5, pp. 827–830, 1970.
- [14] N. Rodriguez, J.-P. Jessel, and P. Torguet, "A virtual reality tool for teleoperation research," *Virtual Reality*, vol. 6, no. 2, pp. 57–62, 2002.
- [15] F. Cappello, F. Desprez, M. Dayde, et al., "A large scale, reconfigurable, controlable and monitorable grid platform," in *Proceedings of the 6th IEEE/ACM International Workshop on Grid Computing (Grid '05)*, Seattle, Wash USA, November 2005.



Hindawi

Submit your manuscripts at
<http://www.hindawi.com>

