# LOCALIZATION IN AN INTERACTIVE SYSTEM

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Abstract: The localization of the nearest parts of an object to a device is usually solved by means of a proximity measurement of each one of the features that form this object to the device. In order to perform this efficiently, hierarchical decompositions of the space or of the object are used, so that the features of objects are classified into several types of cells, usually rectangular. In this paper we propose a solution based on the classification of a set of points located on the device in a spatial decomposition named tetra-tree. Using this type of spatial decomposition gives us several qualitative properties that allow us a more realistic and intuitive visual interaction. In order to show these properties we have compared an interaction system based on tetra-trees to one based on octrees.

## 1 INTRODUCTION

In several virtual reality systems (Burdea and Coiffet, 2003) it is usual for the user to move a device through the scene, so that the user tries to interact with the different objects that form the virtual world. In order to do this precisely, the system must provide the user with feedback in the form of visual information (Sherman and Craig, 2003). This usually consists of such parts of the object that are interacting or are going to interact. This information could consist of the parts nearest to the device, so that the system gives information to the user about the interactive object features, even before touching them. In this case the interaction does not produce undesired effects, such as collision response (deformation, etc.) without previous knowledge of the area of interest.

In order to solve this problem, image-based techniques could be used (Schneider and Klein, 2007), but these tend to be less precise. In addition, interaction possibilities are limited due to the type of feedback obtained.

In the case of object-based techniques, it is habitual to use a proximity measurement from the device to the objects, aided by a spatial decomposition or by a bounding volume hierarchy (Ericson, 2005), in order to classify the triangles of the object and thereby reduce the number of features to consider. Grids (Samet, 1990) and octrees (Ayala et. al, 1985) are usually used for this aim, as well as AABB-Trees (van den Bergen, 2004), OBB-Trees (Gottschalk et. al, 1996) and Sphere-Trees (Hubbard, 1996), among others.

Using these types of decompositions and bounding volume hierarchies, although they are appropriate when the device is near the object, do not give suitable information when the device is at a greater distance. In addition they present problems of amplitude and continuity in relation to the triangles displayed when the device moves.

Due to the aforementioned discussion, we will use a spatial decomposition based on tetra-cones, called tetra-tree (Jimenez et. al, 2006). This data structure is constructed for each object of the scene in pre-processing time. Simultaneously, the triangles of the objects are classified in the tetra-cones that from the tetra-tree of each object.

In interaction time, a set of selected and significant points from the device are classified in the tetra-trees of the objects, allowing us in this way to display the triangles classified in the tetra-cones in which these points are located. This system will allow us to perform some operations requested by the user, i.e. to change the amplitude (triangles to display) by modifying the depth in the tetra-tree.

In addition this system provides us with a smooth transition of the displayed triangles when the device moves, in order to display (or not) the nearest triangles. All these properties allow us to obtain a more intuitive system and with better qualitative properties with regard to other systems.

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This paper is organized in the following way: In the next section the use of the interaction system is described. After that, a study of some qualitative properties is carried out, compared with the use of a octree. Afterwards, the time obtained by the system is studied for different types of objects. Finally, the main contributions of this method and the future work to be undertaken are summarized.

## 2 INTERACTION SYSTEM

The virtual environment we are dealing with is composed of objects modelled by means of triangle meshes. The device can be a hand or a pointing device (Figure 1). In these cases, several points have been distributed strategically by the device, so that they will allow us to determine the triangles of the objects that are in relative proximity to the device.

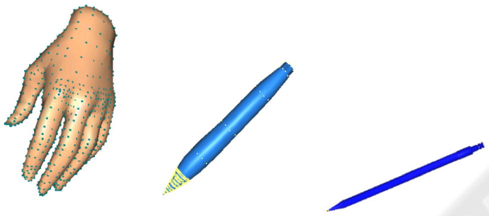


Figure 1: Devices used and control points.

Points have been placed mainly in parts of the device in which presumably the first contact in case of collision will take place. We have named these control points. For example, in the hand device control points are necessary on the endpoint of the fingers, on the joints and on the palm. In the pointing device these are necessary on the part where presumably the interaction will take place, as well as points uniformly distributed by the device. In the case of the pencil, only one control point has been used on its end.

In this system we will consider two possible situations in which we wish to obtain the triangles related to the interaction., drawing the triangles referred to in each case:

**Expected triangles**: Triangles of the object in relative proximity to the device in movement, without collision with the object (Figure 2.a).

**Collision triangles**: Triangles of the object that the device interacts with (Figure 2.b). In this case it is necessary to call the collision detection module in case a suitable response is needed.

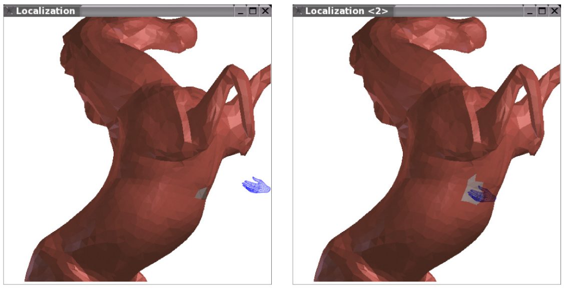


Figure 2: a) Expected triangles for interaction. b) Collision triangles.

The collision detection module first checks the collision of the control points with the object. In order to do this it verifies the inclusion of these points in each one of the triangles classified in the tetra-cone in which the control point is included, using the inclusion algorithm developed by (Feito et. al, 1997), and optimized for this case, considering the temporal and geometric coherence. Only if none of the control points are inside the object is an intersection test between triangles of the object and the device required.

This system takes advantage of the temporal and geometric coherence of the environment when the device moves through the scene, first verifying the inclusion of the control points in the tetra-cones in which they were located in the previous frame, in order not to classify these points through the different levels of the tetra-tree. Thanks to the coherence, most of the time the control points are in the same tetra-cone as in the previous frame.

## 3 PROPERTIES OF THE INTERACTIVE SYSTEM

The use of tetra-trees (Jimenez et. al, 2006) provides a set of advantages with regard to other types of spatial decompositions based on rectangular cells, like octrees and grids, or bounding volume hierarchies, like AABB-Trees and OBB-Trees. These advantages are given mainly by an interactive visualization of the triangles that take part or are close to taking part in an interaction or manipulation of the objects, this visualization being more intuitive and offering a better sensation to the user with regard to other types of decompositions.

## 3.1 Obtaining the Triangles Related to the Interaction

The use of tetra-trees allows us to obtain the triangles related to an interaction, independently of the distance of the device from the object. When the distance increases, the number of expected triangles diminishes, because the set of tetra-cones in which the control points are is smaller (Figure 3). However, the closer the device approaches, the more related the triangles are to the future interaction.

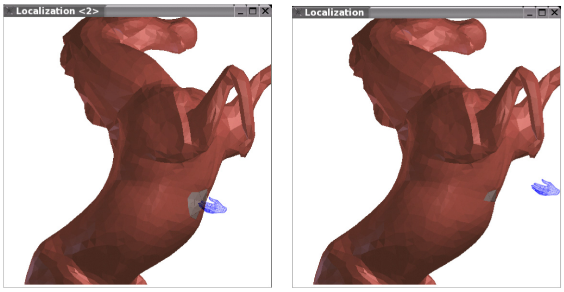


Figure 3: When the distance increases, the number of expected triangles diminishes.

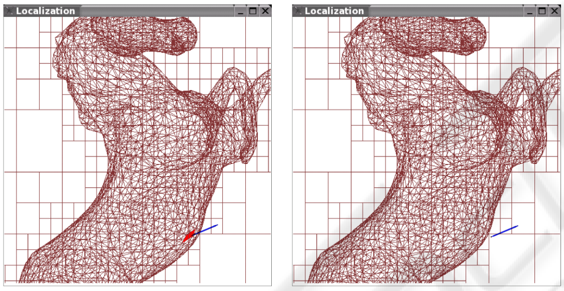


Figure 4: In an octree there are situations in which we do not obtain a set of triangles related to the interaction.

Nevertheless, in an octree there are cases in which the control points are not classified (because they are outside the bounding box) or are classified in empty cells (without triangles, Figure 4), the reason why this classification does not obtain a satisfactory set of triangles related to the interaction. This set has worse distribution in an octree, because the cells fits deficiently to the geometry of the object, presenting worse visual appearance.

## 3.2 Smooth Transition between Cells

When the device moves a change in the set of cells in which this object has been classified takes place. In order to obtain a more agreeable visual sensation a smooth transition is necessary between the triangles classified in both sets of cells, that is to say that the set of triangles shown between two frames has certain overlapping triangles, and that they contain a similar number of triangles.

When using tetra-trees the transition between cells (tetra-cones) is smooth, and discontinuity in the set of triangles between consecutive frames is not noticed (Figure 5). However, when using rectangular cells as in the case of octrees, we noticed an abrupt transition in the set of triangles between two consecutive frames (Figure 6), either because of the difference in the size of the cells, or because the cell is empty (it does not contain triangles).

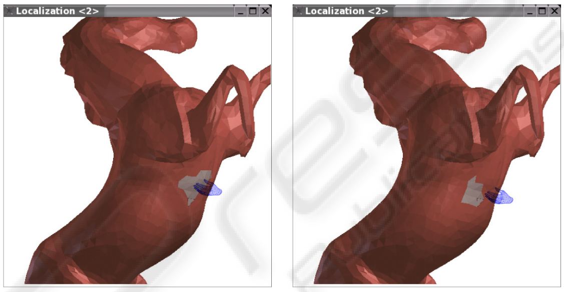


Figure 5: Smooth transition between cells in a tetra-tree.

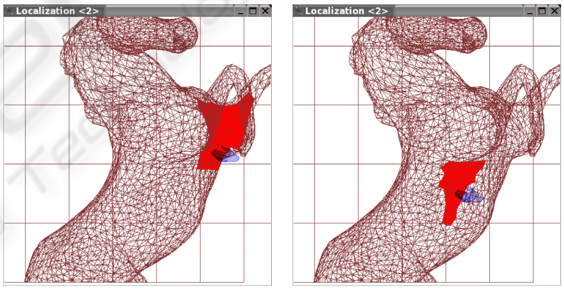


Figure 6: Transition between cells in an octree.

## 3.3 Smooth Transition between Levels

In any given moment, the user may be interested in modifying the level of detail for the interaction, and displaying a greater or lesser number of triangles. In order to do this it is necessary to increase or diminish the level reached in the tree.

A tetra-tree has a greater set of levels than an octree for an equal number of space subdivisions; therefore it provides a smoother transition between detail levels. On the other hand, in an octree this change in the level of detail is more abrupt, and due to the fact that the cells' form is worse adapted to the geometry of the object, the set of triangles obtained may be quite far from the device.

## 4 TIMES STUDY

The system was implemented in C++ using gcc and OpenGL for visualization. We used an Intel Pentium IV-1.6 GHz processor with 1 MB in a Linux O.S..

We measured the number of frames per second in the worst case (when collision with the objects takes place) obtained by the interaction system for each one of the objects of Figure 7 and the devices of Figure 1. In this study we have included the time consumed in obtaining the related triangles and the collision detection time. The time needed for visualization has not been included.

In this system the user moves both, the device and objects freely throughout the scene. In Figure 8 we can see these times providing a real time interaction system.

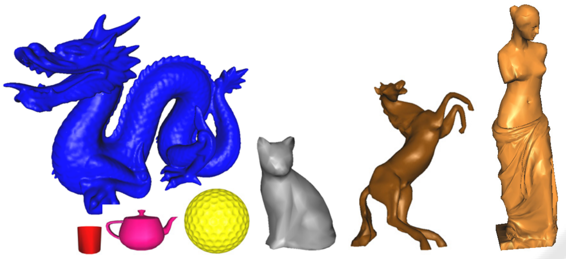
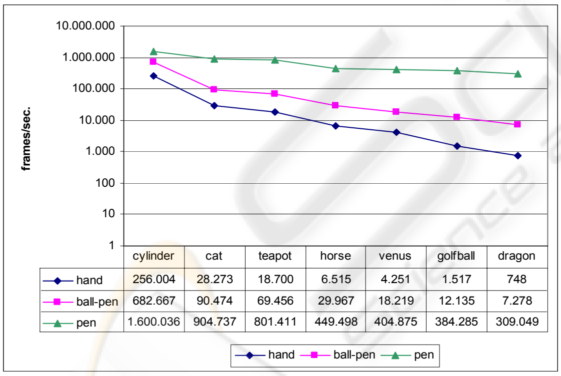


Figure 7: Objects used (f=faces): cylinder (60 f), cat (760 f), teapot (993 f), horse (7,172 f), venus (11,241 f), golf-ball (16,205 f), dragon (201,031 f).



| | cylinder | cat | teapot | horse | venus | golfball | dragon |
|---|---|---|---|---|---|---|---|
| hand | 256.004 | 28.273 | 18.700 | 6.515 | 4.251 | 1.517 | 748 |
| ball-pen | 682.667 | 90.474 | 69.456 | 29.967 | 18.219 | 12.135 | 7.278 |
| pen | 1.600.036 | 904.737 | 801.411 | 449.498 | 404.875 | 384.285 | 309.049 |

Figure 8: Interaction times (frames/sec. in the worst case, with logarithmic scale).

## 5 CONCLUSIONS

In this paper we have used a data structure for space decomposition, especially appropriate for the location of the parts of an object for interaction. This data structure presents several advantages with regard to other space decompositions and hierarchies of bounding volumes based on rectangular cells, mainly regarding the obtaining of the related triangles, the accurate level of detail, and with a better visual appearance and comfort in the interaction.

The system obtained is able to perform an object interaction in real time, including collision detection with devices, by using certain control points on the device in order to obtain the triangles related to the interaction.

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