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Tetra-trees properties in graphic interaction

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ABSTRACT

The localization of the components of an object near to a device before obtaining the real interaction is usually determined by means of a proximity measurement to the device of the object's features. In order to do this efficiently, hierarchical decompositions are used, so that the features of the 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 situated on the device in a little-known spatial decomposition named tetra-tree. Using this type of spatial decomposition gives us several quantitative and qualitative properties that allow us a more realistic and intuitive visual interaction, as well as the possibility of selecting inaccessible components. These features could be used in virtual sculpting or accessibility tasks.

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 [1] it is typical 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 the scope of this paper we refer to a device as a real or virtual object (e.g. a pen or a haptic device) used as a tool for the interaction with objects modeled by means of triangle meshes. In order to do this interaction precisely, the system must provide to the user with feed-back in the form of visual information [2]. This information may consist of the parts of the object that are going to interact or are interacting with the device, being able to select inaccessible components; so that the system gives information to the user about the object features, even before touching them. In this situation the interaction does not produce undesired effects, such as a collision response (deformation, etc.) without prior knowledge of the area of interest.

The aim of this work is to show the properties of a little-known object decomposition named tetra-tree [3,4] in the interaction between a device and an object. This interaction concerns to interference and proximity queries with better quantitative and qualitative properties regarding traditional decompositions. The quality of the visual interaction is defined and improved by means of the techniques proposed in this paper. Construction and interaction times studies are included in order to show the improvement achieved in relation to octrees for different models (including large models) with a moderate penalty in the storage cost.

This paper is organized in the following way: next sections show the background, the motivation and main contributions. It follows with the spatial decomposition used. Then the use of the interaction system is described. After that, a study of some quantitative and qualitative properties is carried out, compared with the use of an octree for the same aim. Afterwards, the time obtained by the system is studied for different types of objects. Finally, the conclusions and the future work to be undertaken are summarized.

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2. Background

In order to perform the tasks outlined in the previous section, image-based techniques could be used [5,6], but these tend to be less accurate. In addition, interaction possibilities are limited due to the type of feed-back obtained.

In the case of object-based techniques, it is typical to use a proximity measurement from the device to the objects, aided by a spatial decomposition or by a bounding volume hierarchy [7] in order to classify the triangles of the object and thereby reduce the number of features to deal with. Grids [8] and octrees [9] are usually used for this aim, as well as AABB-Trees [10], OBB-Trees [11] and Sphere-Trees [12,13], among others.

There are several works related to proximity queries on rigid objects [14] or deformable objects [15]. Others works use the programmable GPU for this aim [16,17].

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. For the selection of far or inaccessible components auxiliary ray-triangle [18,19] and ray-box intersection algorithms are necessary. In addition these types of decomposition present problems of amplitude and continuity in relation to the triangles displayed when the device moves.

In such systems it is possible to establish a proximity measurement, but this becomes ineffective if we use the previous decompositions, for the reason that this measurement is limited to the scope of a cell or bounding volume, that is usually too small to be useful and to display the suitable triangles of the object.

Due to the aforementioned problems, we propose the use of a spatial decomposition based on tetra-cones, called tetra-tree [3,4]. A tetra-cone is defined as a spatial region of the space similar to a cone but limited by three planes, each one identified by means of three vertices of a tetrahedron. A tetra-tree is composed by a set of tetra-cones which cover the whole space and which can be recursively decomposed in sub-tetra-cones. This data structure can be constructed for each object of the scene in pre-processing time. The triangles of each object are classified recursively in the tetra-cones of their tetra-tree. In interaction time, a set of selected and significant points from the device are classified in the tetra-trees of the objects, allowing in this way to display the triangles classified in the tetra-cones in which these points are located. This system will allow to perform a significant number of operations requested by the user, for example to change the number of triangles to display by modifying the depth in the tetra-tree, or to select inaccessible components in a certain direction.

In addition this system provides a smooth transition of the displayed triangles when the device moves, as well as helps to establish a measurement of the proximity of the device to the object, in order to display the triangles which are going to interact with. All these properties allow to obtain a more intuitive system and with better qualitative properties with regard to other systems.

3. Motivation and main contributions

Visual feed-back is needed in several applications for a more realistic and intuitive interaction. In some situations, accessibility to certain elements of the model is not possible [20], due to the collision of the device with the geometric model and the forces obtained, as could occur with the use of haptic devices. In this situation an accessory method for selecting inaccessible components, like the application of ray-triangle or ray-box intersection algorithms (as "pick" operations), is needed because the spatial decomposition does not facilitate the selection of these parts of the model. In this case, the system will offer some components for selecting one without touching any of them. We look for a direct method in which the spatial decomposition helps to the user in the selection of inaccessible components without the needed of using additional algorithms like the ray-triangle or the ray-box intersection tests.

Similarly, in Virtual Sculpting [21–23] it is useful to know the parts of the mesh which are going to be interacted before the interaction, e.g. before the deformation or material substraction, obtaining better precision and not being necessary to "undo" operations. Other applications, like virtual surgery, place demands on information about the elements which are going to be interacted. For example, in arthroscopic surgery it is helpful to know the part of the anatomy to be cut or drilled before performing the operation. In this type of applications the use of aided techniques facilitates and improves the surgeon training, obtaining in this form better abilities for the user.

We define quality of interaction as the set of techniques which facilitates the interaction, obtaining a more intuitive feed-back to the user, in the form of sensations around the interaction (previous to, during and post-interaction). With this type of interaction we obtain systems which improve the training abilities of users, or systems which improve the times and precision for obtaining certain results, it not being necessary to constantly perform "undo" operations due to the precision in the interaction.

Quality interaction includes visual feed-back previous to the interaction, with the triangles which are going to be interacted, or the triangles which are located in a determined direction from the device. When spatial decompositions are used to this aim, it is desirable to have some properties like a smooth transition between adjacent cells or between different levels. Other desirable properties include the possibility of accessing to parts of the model which are at a fixed or variable distance from the device, including inaccessible components which can be selected or dragged. In this paper we propose a method which satisfies these properties, combined with a spatial decomposition which obtains the triangles related to the interaction in interactive rates.

The main contributions of this paper include:

- The use of a little-known spatial decomposition suitable for the localization of the parts of an object in interactive rates which improves the construction and interaction times with regard to octrees.