CONSIDERATIONS ON THE UTILIZATION OF VIRTUAL REALITY IN COMPUTER-AIDED DESIGN OF TECHNOLOGICAL DEVICES

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INTRODUCTION

The graphics used in virtual reality allows for image generation via calculus, starting from the models of three-dimensional objects that make up the scene. Two performance requirements of graphics are vital in virtual reality systems: image realism and their real-time generation. These requirements involve both software aspects, related to the selection of the most adequate image generation algorithms, and hardware aspects, related to the achievement of highly-efficient equipment, that should ensure realism and speed of virtual-reality image generation. Multiprocessor graphic stations and graphic accelerators that implement in the hardware the algorithms of image generation are basic equipment in virtual reality, and the technological breakthroughs enabled their utilization in a huge number of virtual-reality applications, accessible now to various user categories [5], [6], [8].

Virtual reality is just one of the computer graphic applications, beside ones like: achievement of user interfaces developed in numerous utility programs and programming environments, computer-aided design (CAD), interactive graphic presentations, scientific data visualization, multimedia technology etc. [2], [3], [4], [5].

In the field of virtual-reality graphics, technological breakthroughs are especially dynamic: there appear permanently more and more efficient equipment, at ever lower prices; numerous libraries, languages and toolkits appear that propose various modalities of graphic application approaches [1], [3], [5], [7], [9], [11], [12], [13], [14].

1. GRAPHIC DATABASES

Graphic databases are the representation on memory-support (folders) of object and visual scene models and contain all the information needed to render the scenes [1], [3], [5], [7], [9].

The common databases used for storing, updating and retrieving information based on a certain criterion, are based on various data models, like, for instance, the hierarchical model, the network model, the relational model, the object-orientation model. At present, most database systems are relational systems that ensure the efficiency and the reliability of stored information updating and retrieval [5].

In the case of graphical databases, the main criterion of selection of a data model is that of ensuring the efficient rendering of the visual scene within the real-time applications. Due to the graph-representation of the virtual scene in most image generators, the graphic databases are, in most cases, organized in a hierarchical model that uses the representation of entity relations by explicit functional links, such as father-son. The hierarchical model of graphic databases is the most adequate for how their data are used [1], [3], [5], [7].

There is a large number of formats of representing graphical database, more or less complete from the standpoint of the information to build the virtual scene graph. The proliferation of the databases makes difficult the portability of graphic-application programs, which should foresee interpretation possibilities for as many formats as possible [1], [5], [8].

In any image generator, the model of the scene has a well-defined structure that depends on the application purpose, and the important data of various database formats are converted to the internal format of the scene. A type of database format consists in a certain manner of description of component entities of the database and of the relations among them. The most celebrated of graphic database formats are presented in Table 1 [1], [3], [4], [5], [8], [10], [11], [12], [14].

Table 1.

Name	Description
3ds	3Dstudio binary format, AutoDesk company
dxf	ASCII AutoCad Format, AutoDesk company
obj	ASCII Format, Wavefront Technologies company
phd	Polyhedron-description format, Silicon Graphics company
iv	ASCII Open Inventor Format, Silicon Graphics company
dwb	Binary/ASCII Format, Corypheus company
flt14	Open Flight Binary Format, Multigen company

The *3ds* and *dxf* formats are export formats of general-se design systems 3Dstudio and AutoCad from AutoDesk company. They were not conceived especially for graphic database design, so that they cannot have but a limited utilization; they can be used for designing individual three-dimensional objects, which are then incorporated into scenes described by more complete formats.

obj format is a simple format that can describe three-dimensional objects represented by poligon systems. Wavefront Technologies brought on the market a number of *obj* models, that became well known enough. A large library of models produced by Viewpoint library (over 3500 three-dimensional models) are available in *dxf, obj, flt* formats.

dwb and *flt* formats are special formats of graphic database description, developed together with database generation models of Corypheus and Multigen companies. These formats contain complete pieces of information regarding objects, their location and grouping, materials, lights, out of which the scene graph can be created in the image generation.

iv format (Open Inventor), developed by Silicon Graphics, is a superset of the modeling language VRML 1.0 (Virtual Reality Modeling Language) which in 1997 became standard under the name of VRML 97. VRML 97 enables the creation of virtual scenes and their accessing via Internet. A virtual scene in VRML language is a graphic database format resembling other database formats. The name of VRML language comes from the fact that VRML contain defined syntactic and semantic rules that allow for the check of the used construction correctness.

2. CREATION AND RENDERING OF VIRTUAL SCENES

A virtual scene is composed of a three-dimensional object model collection, specified by their form and position, by aspect (color, matter etc.) and by behavior (motion in space interaction). Various other names are used with the same meaning: virtual world, virtual environment. The hierarchical building of the scene allows for its organization and display. The hierarchical scene is composed of knots connected by directed arches. A knot in the scene describes a certain entity: a three-dimensional object, a three-dimensioning object grouping, a geometrical transformation, a texture etc. A scene graph arch introduces descendants of a knot that inherit some of the father knot attributes (fig.1) [5], [8].
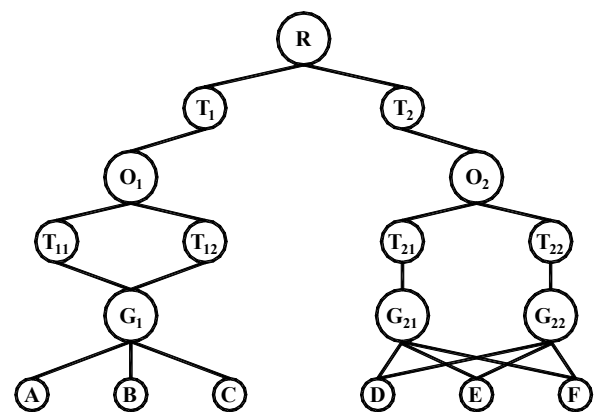

Figure 1. The graph of a virtual scene represented by a knot hierarchy

The hierarchical building of the scene allows for the reutilization of objects and geometrical transformations. A complex object is composed of grouping several simpler objects, of which some repeat themselves, in different instance positions. Thus, a knot can have more than one parent. The graph knots are of several types, the most important being: the description knots of

geometrical forms of three-dimensional objects, the transformation knots and the grouping knots. The knots of geometrical description contain elementary object models, represented poligonally, parametrically or by the mathematical equation in a local system of reference (modeling). The transformation knots position a son knot in relation to a parent knot. The grouping knots form objects made up of several descending knots.

In fig.1, knots A, B, C, D, E, F represent three-dimensional objects NordG1 grouping several simpler objects, forming a compound object that, at its turn, is instanced twice, in defined positions by means of transformation knots T_1 and T_2, obtaining an O_1 object etc. Knot R is a grouping knot and represents the root of the scene graph.

The scene graph describes the hierarchical relations between the knots. The attributes of an object described by a knot can be inherited from the parent knot, can be modified or redefined in a son knot. The virtual scene is defined in a universal reference system, in which the observation point is placed and oriented in each frame of the generated image. Leaf-knots objects of are represented in a local reference system. A transformation knot contains a transformation matrix M that defines the position and the orientation of son-knot reference system in the reference system of the parent-knot. The transformation by applying matrix M to son-knot points transforms them from the parent knot reference system.

The image of a virtual scene represented by an oriented acyclical graph is displayed by means of depth first search of the graph, which begins at the graph root knot and searches all graph paths up to each leaf-knot. In this way, a knot can be searched several times through different browsing paths. For example, when browsing the graph from fig. 1, the knot A is searched twice, once through the path $RT_1O_1T_{11}G_1A$ and once trough the path $RT_1O_1T_{12}A$. The same happens with B and C knots.

When the objects and the scene are hierarchically represented, a three-dimensional object is instanced (placed in the universal reference system) by applying a sequence of instancing transformations, and namely all transformations from root transformation knots up to the leave-knot through one graph browsing paths. The combination of graph depth first search and the concatenation of matrixes calculated during search by means of

saving them in transformation stacks and restoring when necessary.

3. CREATION OF A SCENE GRAPH

In modern implementations, object-oriented programming is frequently used to represent a virtual scene, which enables the creation of an efficient program easy to use and service [2], [5], [8].

The modeling of virtual scenes is an off-line process, through which is created the collection of object models that compose the virtual scene. The modeling process of objects is computer assisted, by means different design systems that put at the designer's disposal model creation functions that start from different input data.

For virtual reality applications we may use both, automatic design systems of general usage, such as, for instance, Autocad or 3Dstudio, and special design systems devised for the virtual scene creation, called databases generation systems (DBGS-Database Generation Systems). This kind of systems, such as Multigen, Corypheus, Sense8 and many others, offer numerous modeling possibilities of three-dimensional objects. The results of modeling operation are the object models or the model collections that compose the virtual scene. These are stored as *graphic databases*, composed of one or several files.

The display of virtual scenes is a process that takes place in interactive time, most often in real time, during different virtual reality experiments, in graphic systems called *Image Generators-ID* [5], [8]. In Image Generators virtual object and scene models are recreated, using the graphic database files as input data. In order to display efficiently the image, the virtual scene is hierarchically organized, on several hierarchy levels, what allows the rapid selection of objects, the inheritance of geometric transformations of objects etc. This hierarchical organization is implemented through an oriented acyclic graph, called *scene graph*. The graph knots contain object models or display information (object position, materials, lights etc.)

4. TYPICAL APPLICATIONS OF VIRTUAL REALITY IN COMPUTER ASSISTED DESIGN OF TECHNOLOGICAL DEVICES

One of CAD main advantages is its capacity of visualizing an object before it is created, but virtual reality allows us to get one step closer, by inspecting it in real time, by means of an adequate display. Although, this facility cannot be arbitrarily linked to a CAD process. It must be an integrated feature. It will take time, but it is very probable that virtual visualization and quality control will become a standard characteristic of future CAD systems.

Among the typical applications of virtual reality in the design of technological devices we should mention:

- visualization of some technical concepts;
- staff instructing;
- evaluation of certain ergonomic aspects;
- visualization of virtual prototypes;
- exploration of service strategies
- simulation of building-blocks interaction;
- effort analysis;
- product development management; production process simulation;
- concurrent engineering
- simulation of the dynamic of connected structures;

5. VIRTUAL PROTOTYPES

No one can deny the importance of the virtual environment created by CAD systems (fig.2). But this environment has now extended, through virtual reality, in all directions - due, mainly, to the way it increases the value of the product in all stages of its life cycle. The universality introduced by this design methodology accepts design in cooperation and offers to anybody a high understanding of 3D structures
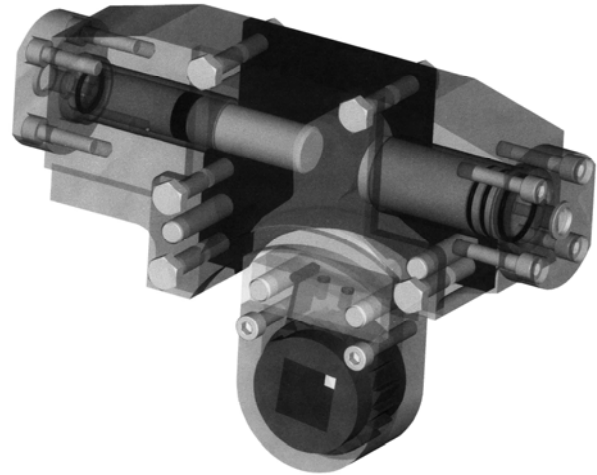

Figure 2. . 1 Virtual prototypes of hydraulic torque wrench

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