IMMERSIVE 3D OBJECT MODELLING IN ICOME

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ABSTRACT

ICOME (Immersive Collaborative 3D Object Modelling Environment) is a Virtual Environment for 3D geometric object modelling using an immersive interaction paradigm. The modelling system has been realised with collaborative design in mind. In this paper we concentrate on the user interfacing for the modelling features. In this context, special attention is given to the direct manipulation functionality supporting free-form deformation. The various tools for the interactive modelling of 3D geometrical objects are described and illustrated.

Keywords: Immersive Modelling, Collaborative Work, Virtual Reality, Networking, User Interfacing

INTRODUCTION

For several years research groups are investigating techniques to provide designers with efficient modelling systems for the creation of 3D geometrical objects. Part of the research efforts addresses intuitive user interfacing to facilitate the modelling process [Sachs91, Butte92, Liang94, Green96, Deeri96]. A particularly interesting approach is to introduce immersion in a modelling system. Examples of immersive modelling systems are 3DM [Butte92], CHIMP [Mine96a, Mine96b] and IM-Designer [Conin97a, Conin97b]. It must be emphasised that ICOME is used to create 3D geometrical objects from scratch. We believe (based on intuition and experiments with IM-Designer) that immersing the designer in the design space facilitates a number of modelling tasks.

On the other hand, working in an immersive virtual environment has its drawbacks. It is hard for designers to precisely control the input device for accurate work in three dimensions. An immersive viewing device may not be available for all designers, or it may inhibit communication with nearby colleagues. Therefore the user interaction with ICOME is designed to be useful in an immersive as well as a non-immersive setting.

Besides similar interaction in an immersive and a non-immersive setting, support for collaborative work is a central theme in the ICOME research project. Although computer support for collaborative work in a design context is emerging, we are currently not aware of computer supported collaborative 3D object design. Existing computer support deals with communication issues regarding collaboration (e.g. synchronous or asynchronous communication by means of sound fragments, videoconferencing or transfer of design pictures and ephemeral information) or with composition of objects (e.g. architectural design of the interior of a house, placement of furniture) rather than creating new objects. It is a challenge to let designers synchronously collaborate within the ICOME environment.

Support for collaborative work in an object modelling system to be used in an immersive as well as a non-immersive context, possibly at the same time, opens new perspectives and leaves us with a number of research issues to be investigated.

In this paper we concentrate on the user interfacing for the modelling features whereas the architecture of the system is described in [Rayma99]. The next section describes related research work. An overview of the ICOME system architecture is given. User interfacing issues concerning the various modelling tools are described and illustrated. Finally some conclusions and future work are given.

RELATED WORK

The immersive modelling concept of ICOME has mainly been inspired by the following research projects concerning immersive modelling.

IM-Designer is a previous research project in our laboratory at the EDM (Expertise Centre for Digital Media) [Conin97a]. The main research objectives of IM-Designer are to investigate immersion in the context of 3D geometric object modelling, and to design an intuitive user interface for the modelling tasks. Therefore the concept of a hybrid 2D/3D user interface has been developed, in which 2D and 3D interaction is combined. IM-Designer makes use of a BOOM (Binocular Omni-Orientational Monitor) for stereoscopic immersive viewing and of a Pinch Glove with 3D tracking as an interaction device. IM-Designer concentrates on user interaction for immersive creation and manipulation of 3D objects from scratch, whereas CHIMP (Chapel Hill Immersive Modelling Program) [Mine96a] is intended for object composition and placement during later design phases. The building blocks for CHIMP are existing object models such as a piano, a chair… The user can position the objects and change their size. CHIMP investigates interaction techniques using a head-mounted display for immersive viewing and two bats for 3D interaction.

The collaborative work in ICOME is supported by means of a distributed system architecture. The general requirements of future large-scale distributed virtual reality systems are identified and a number of well-known VR systems are described in [Snowd96]. The identification was based on existing VR systems and more general distributed systems platforms. The authors of [Taylo95] suggest that the problems faced by designers of distributed virtual reality applications are very similar to those faced by designers of distributed systems in general.

A fast display rate is needed in order to have a sense of presence in a virtual environment. This places stringent constraints on the system, especially in a distributed system like ICOME. The influence of the update rate on the sense of presence in a virtual environment has been investigated in [Barfi95].

SYSTEM OVERVIEW

The distributed system architecture is based on a client/server structure. The server stores all information concerning the virtual world being modelled, and is responsible for the synchronisation of the clients. Therefore the server addresses collaboration issues such as floor control, and inhibits several designers to modify an object at the same time.

It has been pointed out above that immersive as well as non-immersive interaction is supported by ICOME. This has been realised through the use of different client types, possibly at the same time.

Clients for the Silicon Graphics Irix operating system can make use of immersive or non-immersive interaction. Immersive viewing is supported by the BOOM (Binocular Omni-Orientational Monitor) or a head-mounted display. Interaction in the immersive context is done with a Pinch Glove (glove with contact pads) on which a 3D tracker is mounted. The BOOM can be considered as an input device for navigation parameters by moving the viewing head and using the handles. In the non-immersive context a 3D mouse or spaceball is the interaction device.

PC-clients for Windows NT provide a non-immersive setting with a regular display and a 3D mouse or spaceball as the interaction device.

More details concerning the system architecture can be found in [Rayma99].

USER INTERFACING

The interaction paradigm has been inspired on the hybrid 2D/3D interaction in our previous research project IM-Designer [Conin97a]. The general idea is that 2D and 3D interaction are combined, and each of them is used in the situations it is suited for. Our conclusion is that 2D interaction is favourable for interfacing elements such as menus and dialog boxes. So 2D interfacing elements are used in the user interfaces of the ICOME clients too. Furthermore, 3D interaction is intuitive for a selection of object modelling tasks such as object positioning. resizing,... Direct manipulation is the dominant interaction style for 2D as well as for 3D interaction.

FUNCTIONALITY

Navigation

Navigation through the environment is used to move the viewpoint on the object being modelled. This provides the designer with different views on the same object in order to get insight in the object geometry. It also enables the designer to reach remote objects before they can be manipulated.

The interaction scenarios to navigate in ICOME are based upon the input devices being used at the clients. If a BOOM is used in the immersive setting as viewing device, it is an input device for navigation parameters too (by moving the viewing head and by using the handles). In other system configurations (such as PC clients or non-immersive Irix clients) the navigation is done with the 3D-mouse (or spaceball). The keyboard can be used on all clients for navigation as an alternative to the 3D input devices.

A representation of a virtual hand is shown. This virtual hand can be navigated through the environment by means of the 3D input device (3D mouse, spaceball or Pinch Glove with 3D tracker). It is obvious that interaction by means of the BOOM or the Pinch Glove is the most intuitive way to steer the virtual hand.

Because accurate 3D interaction is difficult, constraints can be defined for the virtual hand movement. Translation along the X, Y or Z direction can be ignored, or rotation round the X, Y or Z axis can be ignored. Constrained movement of the virtual hand can also be realised by means of snapping to a grid. Standard as well as user defined grids can be used. These are depicted in fig. 1.

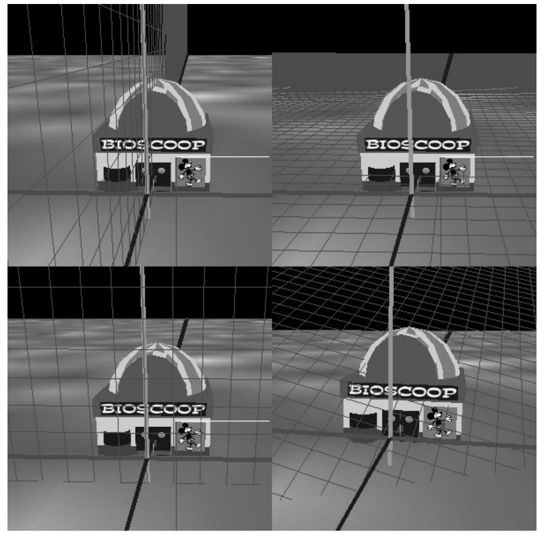

Fig. 1 Grids

Object selection

Object selection is a typical example of 3D interaction. The virtual hand plays the role of a cursor, and moves according to the 3D input device. Objects are selected based on collisions between the virtual hand and an object (fig. 2). As feedback for the user, selected objects are shown in wireframe representation. Within selected objects, individual triangles or vertices can be selected in the same way. Texture co-ordinates are stored for each triangle-vertex pair.

Fig. 2 Object Selection

Object positioning

Selected objects can be moved and their orientation can be determined with the virtual hand as an intermediary tool. The user determines the position and orientation of the virtual hand by means of the 3D input device. The selected object follows the translations and rotations relative to its current position and orientation. This approach differs from object positioning in several existing systems, where the selected object adopts the position and orientation of the cursor. We believe that our approach to object positioning affords fine-tuning and that it's more natural for the user to interact with the system in this way.

The server ensures that feedback about the object positioning is sent to all clients immediately, while the interaction is still going on. An audio tool for communication between users will be added, and can be helpful to comment on the currently displayed situation.

Object positioning exploits the object hierarchy by positioning child objects together with their parents.

Object manipulations

Object creation

A particular category of object manipulation functions consists of object creation.

Primitives

A first possibility is to create an object from a set of predefined 2D/3D primitives such as triangle, square, circle, pyramid, cube, sphere... The user defines the initial size of a primitive and depending on the primitive, additional information such as the number of vertices has to be provided. The object's size can be readjusted with a scenario similar to the one described for object positioning.

Extrude

In addition to using primitive objects, new 3D objects can be created based on an existing 2D object by means of the extrude functionality. The extrude tool applies a series of rotations, scalings and translations on a 2D object in order to create a 3D object. A cone can be extruded by rotations from a triangle, or by translations and scaling of a circle. A torus is extruded from a circle by repeatedly applying translations and rotations on a circle.

Another useful tool is 3D extrude, which manipulates 3D objects. For instance to create stairs. The object is created in five major steps. (1) create a square with a wood texture, (2) extrude the square to create a step of the stairs, (3) select the single step, select the rotation point, and move a copy of the step to the correct position, (4) positioning of the second step, and repeat this positioning as many times as desired, and (5) end the 3D extrude function (fig. 3).

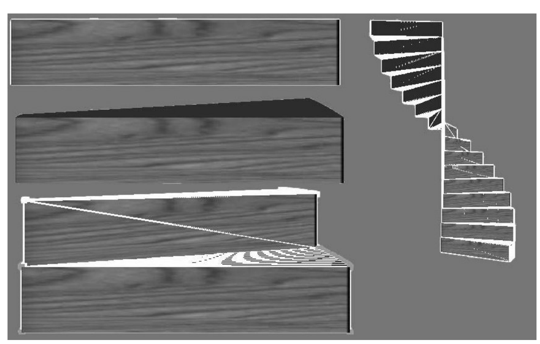

Fig. 3 3D Extrude

Object manipulation

Basic manipulation, Copy and delete

Basic object manipulation is done by positioning individual vertices as shown in fig. 4. The object hierarchy implies that all triangles and edges that contain this vertex are changed accordingly.

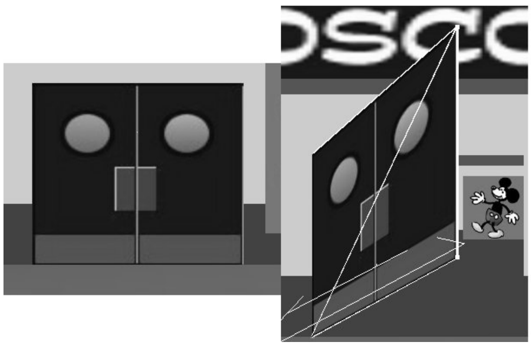

Fig. 4 Dragging

An object can be copied either as a new object or as a child object of an existing object.

Obviously, the user is able to remove superfluous objects.

Free form deformation

It is possible to deform a mesh of triangles by dragging a series of reference points. In order to deform such a mesh, a bounding box is created around the object that has be deformed. This box defines a co-ordinate system. Every vertex has three co-ordinates in this system. In every direction a series of reference planes is defined, so that on the outside of the surrounding box a series of reference points is defined. The user is then able to drag these reference points in the 3D world. By applying a Bernstein polynomial ([Seder86]) on the co-ordinates of the vertices and of the reference points, the vertices' new co-ordinates can be calculated. In the fig. 5 a square is first extruded to a triangle mesh, forming a cube. This cube is then deformed using a free-form deformation.

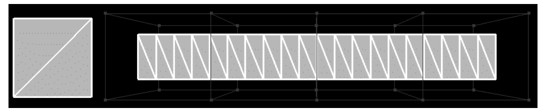

Fig. 3a Original Square + Extrude

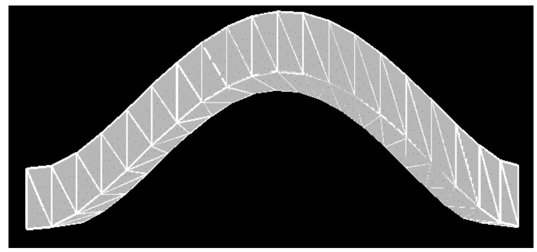

Fig. 5b Free-Form Deformation

MATERIALS

Finally, some changes can be made on a material. A material can be selected using a list or by clicking in a triangle that uses the material.

The material's properties that can be changed include its colour. Various other material properties, such as the ambient colour, the diffuse colour and the shininess can be changed.

Materials that are not used by an object can be removed. When a user wants to remove a material, the client will check if it is not in use. In order to avoid a malicious client to corrupt the system, the server will also perform this check.

CONCLUSIONS AND FUTURE WORK

The ICOME collaborative modelling system is presented in this paper. Collaboration issues are realised by means of a client/server architecture. We've pointed out how similar interaction techniques can be used on immersive and non-immersive clients. A hybrid 2D/3D user interface has been designed, based on earlier research projects in this context. The focus in this paper has been on a description of the interaction for the modelling features.

Future work will extend the modelling features of ICOME (e.g. tools on 3D surfaces, interactive placement of textures,...) and will investigate force feedback in a modelling context.

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