CONSTRUCTION VISUALIZATION AND MANIPULATION OF STATIC (3D) AND DYNAMIC (4D) EARTH MODELS USING THE VIRTUAL REALITY TOOLS

I.L. RITSEMA and B.H.M. GERRITSEN
TNO Institute of Applied Geoscience, PO Box 6012, 2600 JA Delft, The Netherlands

Introduction

Building of 3D velocity models is one of the activities in the total chain of exploration and production business processes aimed at understanding the geology of the earth. In the exploration phase the focus is directed to a regional geological model for prospect appraisal and in the production phase to a reservoir geological model needed in production optimisation. The geological models are derived from seismic data via the velocity depth models on regional (macro) and reservoir scales. These models are normally static (3 dimensional) while seismic data only reflect a momentane snapshot in the geological or production evolution. The shape and velocity of the geological objects in the models need to be geologically acceptable putting constraints on the results of the seismic inversion process.

This paper describes how virtual reality tools (software environments) can provide to the geoscientific users new functionality to create, visualise and manipulate static (3 dimensional) and dynamic (4 dimensional) worlds.

The main reason to use virtual reality tools is that they work better with dynamic (4 dimensional) models then current 3D modelling software's. Dynamic earth models are for example needed to contain the inversion results of repeated seismic surveys. More importantly, it enables the application of dynamic geological constraints on the shape and properties of geological objects in a more natural way.

Firstly, static and dynamic models and their differences will be discussed. Secondly, the virtual reality concepts, tools and TNO's experiences applying them to geoscientific modelling will be presented.

Static (3D) models

Models of static 3D tangible objects (such as the earth or man-made products) define their geometry, topology and properties (Ref. POSC and STEP). The topology part describes how the objects are built up from e.g. volumes, surfaces, lines and points or sampled regular grids (connectivity). The geometry defines the location (co-ordinates) of the topological elements in space. The property part describes which properties (e.g. velocities) are attached to these topological elements and what their values are.

Various topological and geometrical representations are used by current software tools:

- boundary representations, using finite element, regular grid and functional representations for the geometry of surfaces surrounding the geological regions
- 3D finite element meshes or 3D finite difference grids crossing all geological regions

The properties of these models are respectively contained in:

- irregularly spaced property sets and property functions for the different geological regions
- grid cell properties

3D model building and visualisation software's are based on one of these representations but contain conversion utilities to the other representation. Each approach described has advantages and disadvantages, determined by performance storage and algorithmic requirements. Examples of 3D modelling software's are (Gocad, Stratamodel, Earth Vision, Lynx, etc.). There are two major drawbacks of the current software's:

- creation of models from geological primitives is poorly supported
- dynamic behaviour is mostly absent
- the user interface is two dimensional (screens)

Virtual Reality tools seem to have solved these drawbacks. After a discussion on dynamic model requirements, virtual reality concept and tools and their application to a velocity model.

Dynamic models

If earth models are not constant in time (time dependent), dynamic behaviour has to be attached to parts of the model. For example to be able to visualise and analyse flow simulation or repeated seismic inversion output, flow and structural deformation processes have to be incorporated. In this case the actual geometry and topology of the geological objects in models must be time dependent. To take into account geological constraints behaviour such as sedimentation also changes the connectivity in time. Currently used dynamic models, often represented by a repetition of static topology with time dependent geometry and properties, are not the solution.

Figure 1 Static Velocity Macro model (Gocad)

We define three possible areas of extension of static model data structures to include time dependence in a better way,

- time dependent properties,
- time dependent geometry,
- time dependent topology.

For example in production output reservoir properties (and indirectly seismic velocities) can change every new time step. Thus the geometry and topology are fixed in time, but the properties may change.

We require time dependent geometries if the shape of the objects present in the subsurface model change, but their connectivity does not. Thus layers which are compacted or folded can be modelled with time dependent geometry. If changes occur in the connectivity of topological elements, which describe a modelled object, then the previous two extensions will not suffice. For example by erosion or fractures, layers become connected with other layers than before. Now topological elements may appear or disappear. Corresponding topological relations will have to vanish or be established to secure continuity of the objects in time. To include time dependency, the topological dimension has to be extended.

Virtual Reality concepts and tools

Virtual reality tools are based on a model of reality whose representation is available in the computer and can be experienced directly and interactively (Schmitt, 1992). The computerised information surrounds the geologist or geophysicist who finds himself inside the data space. The data space can be the **past** based on measured data or simulation of the past and the **future** based on design and simulation of the future.

Figure 1 Dynamic (time dependent geometry) surface (Gocad)

Virtual Reality Environments include aspects of reality which communicate with different human senses. Specific user interface tools are needed to experience these sensations, such as:

- head-mounted display devices, enabling stereo graphic visualisation
- ear-phones, enabling stereo sound sensation
- data gloves, enabling to feel

To travel in space and to manipulate objects the position of head, hands need to be tracked. This is done by:

- head-mounted tracking devices, tracking of head (eye- and ear-pair) and eye pupil movements
- tracking hand movements and manipulating objects
- steering devices (spaceball, mouse) to travel in the model space

The virtual worlds created can be:

- static, this means the objects are not changing over time
- dynamic, the model contains moving, changing objects

In addition different levels of information can exist separating global information from details. This is position and scale dependent.

Functionality of Virtual Reality tools

The process to build, visualise, manipulate and exchange virtual reality worlds differ from techniques common in exploration and production applications.

Creation

Typically, objects from a library are (re)used in a scene to create virtual reality environments, e.g. families of trees, houses in a terrain scene.

Tools are available to create these libraries, and the composition of models. The definition of dynamic behaviour is attached to (groups of) objects. The behaviour can include rotation, translation and deformation (mostly based on displacement vectors not based on simulation of physical laws).

Visualisation

Visualisation in virtual reality is actually experiencing sensations, such as seeing, feeling and hearing. This is achieved by using the sensation devices described above. The most important are the head mounted display devices creating the sensation to be immersed in the model space.

Manipulation

Manipulation can be done as in 3D modelling software (on 2D screens), but new 3D approaches are feasible. Examples are translating, rotating, resizing, deforming and sculpturing objects by hand movements using a data glove.

Application of Virtual Reality tools to geoscientific models

The Virtual Reality software's are being used in Flight simulation and training, Architecture design and simulation and Medical Sciences. Virtual reality tools developed at TNO in these areas have been applied to investigate the possibilities for visualisation and manipulation of 3D velocity models.

Experiments are being carried out to bring 3D models constructed using Gocad into the TNO build virtual reality environment.

Various important issues have arisen:

- data exchange
- model primitives
- usefulness of virtual reality functions

They will be shortly discussed while work is still in progress.

Data exchange

Typically data exchange requirements are input to virtual reality tools:

- derived from measured data, i.e. requiring input from interpretation systems or 3D modelling software.
- derived from a statistical family of objects requiring the input from spatial object libraries
- from and to the models are interacting with simulation codes determining the dynamic behaviour instead of storing it.

Data Exchange requirements need to be solved in a using flexible techniques described in Floris and Ritsema, 1993. For static models and objects the GEOMOD software is used.

Primitives

A need for more geological primitives or statistical primitive families is becoming very important. Available data in this area (such as in the Geological Analogue database developed by TNO, Technical University of Delft and the Danish Geological Survey) are very useful in this area.

Virtual Reality functions

The evaluation has not been finished and will continue especially in the area of dynamic objects. However, some conclusions can be drawn that the sensation of immersion is very useful, especially combined with sculptural type of manipulation techniques. In addition especially the dynamic models are extremely useful in training and understanding geology and geological model building processes.

Conclusions

Virtual Reality tools are under development for various industry branches. The experience gained indicates that also the petroleum industry will benefit from these tools, while they:

- support model building using geological primitives
- dynamic behaviour is included
- they provide a new user interface

Experience also learns that before becoming productive, practical problems have to be solved, such as:

- data exchange
- availability of geological primitives
- customisation to useful functionality
- performance problems.

References

- Floris, F.J. and Ritsema, I.L., Spatio-temporal (dynamic) subsurface models, Proc. EAEG '93, Stavanger
- Mallet, J.L., Gocad report, version 8.0, 1993, Ecole National Supérieure de Nancy.
- Ritsema, I., S. Pen, Th. Kemme, Logical object model and derived exchange format for 3D subsurface model data, Proc. EAEG '91, Florence
- Schmitt, G.N., Virtual Reality in Architecture, 1993, in Virtual Worlds and Multimedia.
- Thalmann, N.M. and Thalmann, D., Virtual Worlds and Multimedia, 1993, Wiley and Sons Ltd.