VIRTUAL REALITY FRAMEWORK FOR SURFACE RECONSTRUCTION

Dietmar P. F. Möller
Chair Computer Engineering
& McLeod Institute of Simulation Sciences, German Chapter at University of Hamburg
Email: dietmar.moeller@informatik.uni-hamburg.de
University of Hamburg, Department Computer Science
Vogt-Kölln-Str. 30, D-22527 Hamburg, Germany

Abstract. We briefly introduce the methodology of virtual reality as a framework for surface reconstruction based on morphing. Henceforth the scope of our work should give a deeper insight into complex research work showing the power of deformable models, as part of morphing, in a virtual reality framework in the spacious areas of the geological application domains. Based on that facts we will give a case study examples of virtual reality application in the field of applied geotechnology. Currently we are working on other applications of morphing in geology.

1. Virtual Reality applied to geology

Applying the virtual reality methodology to the geological domain could be stated as combining distributed virtual environments, in order to support collaboration among team members working with space distance, developing plans and procedures, doing measurements and data processing in geological procedures, research projects, geo-technology oriented support systems development and evaluation etc. in order to attempt to manage new investigations and organizations in a collaboratively manner, as it is needed in global as well as international project development.

One of the most interesting new paradigms in virtual reality methodology in this domain is that three dimensional representations are not only the lonely possibility of a setting.

Many virtual applications in geology, if not already now, will in future make use of specific graphics. The virtual domain will be visualized in space, which means in terms of three dimensions, and time. People in charge with virtual reality in the geological domain are able to interact with space and time, e.g. like walking through the water and wastewater underground infrastructure for inspection of safety and security at the walls intima, or interacting with other geological disciplines for consultancy through a graphical user interface in the manner of computer supported cooperative work, as well as designing the plastic view of sustainable interventions in underground infrastructure. The interweaving of functionality, distribution, efficiency, and openness aspects is very noticeable in computer graphics. The virtual space is graphically visualized flamboyance and for the most part the people in charge with the virtual space application domain should see the same image.

Therefore, for virtual reality applications, a three-dimensional, multi-user virtual reality tool for the geological application domain as been developed, consisting of the following main components:

- space ball and cyber gloves for tactile interaction in virtual space
- head mounted devices for visual interaction in virtual space
- 3-dimensional geometric body creation and motion methodology for ”virtual space feeling” capability
- 3-dimensional visual interactive system for definition, manipulation, animation and performance analysis of geological geometric bodies
- object oriented data base for efficient data management in virtual reality applications
- hardware for the power of computing in space and time
- objects organization into inheritance hierarchies for virtual reality system transparency

When geological objects are created, they inherit the properties and verbs of their ancestors. Additional verbs and properties as well as specializations of inherited components may be defined to give the new object its unique behavior and appearance.

Based on that assumptions a virtual reality simulator for the geological application domain has been build up.

Proceedings 18th European Simulation Multiconference
Graham Horton (c) SCS Europe, 2004
ISBN 3-936150-35-4 (book) / ISBN 3-936150-36-2 (CD)

2. Morphing as basis for Visualization in Geology

The presentation of process states is of importance, which has to be realized time dependent, bringing together real scenarios as well as virtual scenarios of the geological project under realization as real research project, in order to find out e.g. optimal geometries, based on Non Uniform Rational B-Splines (NURBS).

This special kind of B-Spline representation is based on a grid of defining points $P_{i,j}$, which is approximated through bi-cubic parameterized analytical functions.

$$P_{i,j} = \begin{Bmatrix} p_{1,1} & p_{1,2} & \cdots & p_{1,n} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m,1} & p_{m,2} & \cdots & p_{m,n} \end{Bmatrix}, p_{i,j} = (x, y, z)$$

$$S(u,v) = \frac{\sum_{i=0}^{n}\sum_{j=0}^{m} N_{i,p}(u)N_{j,q}(v)w_{i,j}P_{i,j}}{\sum_{i=0}^{n}\sum_{j=0}^{m} N_{i,p}(u)N_{j,q}(v)w_{i,j}}$$

$$0 \le u,v \le 1$$

This method allows to calculate the resulting surface or curve points by varying two (surface) or one (curve) parameter values u and v of the interval [0,1], respectively, and evaluating the corresponding B-Spline basis function $N_{i,p}$.

$$N_{i,0}(u) = \begin{Bmatrix} 1 & \text{if } u_i \le u \le u_{i+1} \\ 0 & \text{otherwise} \end{Bmatrix},$$

$$N_{i,p}(u) = \frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1}(u) + \frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(u)$$

$$U = \{u_o, \ldots, u_m\}, u_i \le u_{i+1},$$

$$V \text{ analogous}$$

As the parameter values u and v can be chosen continuous, the resulting object is mathematically defined in any point, thus showing no irregularities or breaks.

There are several parameters that adjust the approximation of the given points and thus changing the look of the geological object under test (description), hence, if needed, interpolation of all points can be achieved.

First of all, the polynomial order describes the curvature of the resulting surface or curve, giving the mathematical function a higher level of flexibility. Second, the defining points can be weighted according to their dominance in respect to the other control points. A higher weighted point influences the direction of the surface or curve more than a lower weighted. Further more, knot vectors U and V define the local or global influence of control points, so that every calculated point is defined by smaller or greater arrays of points, resulting in local or global deformations, respectively.

NURBS are easy to use, as modeling and especially modifying is achieved by means of control point movement, letting the user adjust the object by simply pulling or pushing the control points (Figure 1).

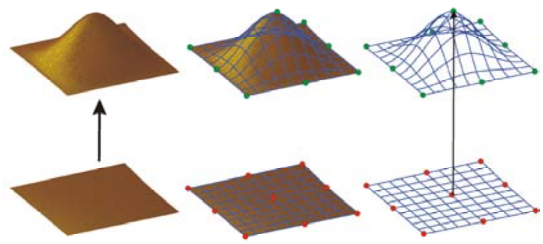

Fig. 1 Modeling and modification of a NURBS surface

Based on these concepts a methodology to interpolate a given set of points, for example the results of scanned data of application domain surface measurements, has been developed. Huge sets of scattered data points of a geological object are used to generate the resulting object, outgoing from the very simple geometric object of a cylinder.

Using multiple levels of surface morphing, this multi level B-Spline Approximaton (MBA) adjusts a predefined surface, i.e. a flat square or a cylinder. Constraints like the curvature or direction at special points can be given and are evaluated within the algorithm.

Based on OpenGL, a quasi standard for three dimensional modeling and visualization, we are able to create geometric medical bodies of every shape and size and move them in real time.

3. Deformable Models in Geological Surface Reconstruction

Mathematically geometric (geological) subjects can be interpreted as embedded contour within an image plane

$$(x,y) \in \Re^2$$

of a virtual reality framework concept. The contour itself can be assumed as

$$\exists (s) = (x(s), y(s))^T$$

where x and y are the coordinate functions and $s \in [0,1]$ the parametric domain. The shape of a contour subject to an image I (x,y) can be described [McInerney et al., 1999] by the functional

$$\Im (\exists) = E (\exists) + \Gamma (\exists)$$

The functional given above can be interpreted as representation of the energy of the geological contour. Hence the final shape of this geological contour corresponds to a minimum of energy. Due to that the first term of the functional given above can be introduced as internal deformation energy

$$\Xi (\exists) = {}_0\int^1 \Lambda_1 (s) \left| \delta\exists/\delta s \right|^2 + \Lambda (s) \left| \delta\exists^2/\delta s^2 \right|^2 \delta s.$$

This equation describes the deformation of a stretchy, and flexible geological contour, with $\Lambda_1(s)$ as tension of the geological contour and Λ_2 (s) as rigidity.

In accordance with the calculus of variations, the geological contour $\exists$ (s) , which minimizes the energy $\Im (\exists)$ must satisfy the Euler-Lagrange equation [McInerney et al., 1999]

$$- \delta/\delta s (w_{1*} \delta\exists/\delta s) + \delta^2/\delta s^2 (w_{2*} \delta^2\exists/\delta s^2) + \nabla P(\exists(s,t))=0$$

The vector partial differential equation, introduced above, describe the balance of internal and external forces when the geological contour rests at equilibrium. Therefore the first two represent the internal stretching and bending forces respectively, while the third term represents the external forces that couple the contour to the image data.

4. Conclusions

The potential of virtual reality is huge. We only scratched the surface of this important area due to the geological application domain. The potential of morphing contains an incredible number of solutions to different problem depending domains.

5. References

1. Crilly, A.J., Earnshaw, R.A. and Jones, H., Applications of Fractals and Chaos. Springer Verlag, Berlin, 1993.
2. Encarnacao, J.L., Peitgen, H.-O., Saka, G. and Englert, G., Fractal Geometry and Computer Graphics, Springer Verlag, Berlin, 1991.
3. Gilfillan, L. and Harbison, K., Using distributed virtual environments (DVE) for collaborative program planning and management: Problems and potential. In: Proc. VWSIM´98 (Eds.: Landauer, C. and Bellman, K.L.), SCS Publishers, San Diego, 1998, 39-46
4. Möller, D.P.F., Virtual Reality: Simulation Synergy in Laboratories and Outer Space Domains. In: Simualtion: Past, Present and Future (Eds.: Zobel, R. and Möller, D.P.F.), Vol. II, SCS Publishers, Delft, 1998, 64-66
5. Schneider, M., Spatial Data Types for Database Systems. Springer Verlag, Berlin, 1997.
6. Singh, A., Goldgof, D. and Terzopoulos, D., Deformable Models in Medical Image Analysis, IEEE Press, Los Alamitos, USA, 1998.
7. Straßer, W. and Seidel, H.-P., Theory and Practice of Geometric Modeling, Springer Verlag, Berlin, 1989.
8. Yachik, T.R., Synthetic Scene Quality Assessment Metrics Development Considerations. In: Proc. VWSIM´98 (Eds.: Landauer, C. and Bellman, K.L.), SCS Publishers, San Diego, 1

.