About interactive modeling system with the help of implicit function

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Abstract

In this paper the interactive modeling system with the help of implicit function is presented. The main tolls of such system are considered; some of the tools are already implemented in the system other of one it is supposed to develop.

Keywords: *computer graphics, interactive modeling, interactive tools, implicit function, implicit surface, poligonization, mesh optimization.*

1. INTRODUCTION

With evolution of hardware the technique of modeling with the help of implicit functions is used with increasing activity ([1], [2], [3], [4]). Today there are the graphic systems, which provide the user by various tools of modeling; among them there are with the implicit surfaces. The implicit modeling is applied for creating objects of organic nature [2], objects with arbitrary topologically type and for their animation.

2. IMPLICIT SURFACE

The implicit surface is mathematically defined in space as the set of points $p = (x, y, z)$, satisfying the equation $f(p) = 0$.

In the work, implicit surface S is represented as an isosurface of level T in scalar field $F(p)$.

$$S = \{ p \,|\, F(p) - T = 0 \}$$

Thus, the operations such as: sum, union, residual, intersection of implicit surfaces, are reduced to operations with the functions, which assign implicit surfaces. For instance, the sym of implicit surfaces U and V

$$U = \{ p \in R^3 \mid u(p) - T = 0 \}$$

$$V = \{ p \in R^3 \mid v(p) - T = 0 \}$$

is the implicit surface W

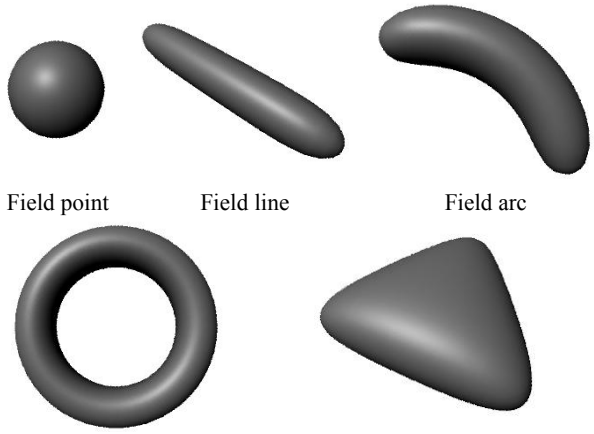
$$W = U + V = \{ p \in R^3 \mid (v(p) + u(p)) - T = 0 \}.$$

As the primitives in the system, the convolution surfaces are used. The convolution surface is the implicit surface based on field function *f(p)*, obtained as space convolution of two scalar functions *g(p)* and *h(p)*. Geometrical function *g(p)* gives a spatial distribution potentials-radiates, *h(p)* is a kernel of convolution which specifies damping of the potential produced by a radiant.

$$f(p) = g(p) \circ h(p) = \int_{R^3} g(r) \cdot h(p - r)\, dr$$

The kernel of convolution *h(p)* should be represented by the function which value sharply decreases depending on distance. In the work, the function of Cauchy is used.

In the system, the following geometric primitives are implemented: point, line, arc, circle, triangle (fig. 1). Usage of such functions was offered in A. Sherstyuk's thesis [2].



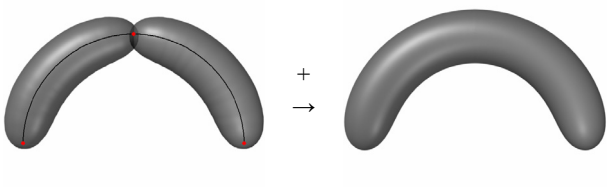
Field point Field line Field arc

Field circle Field triangle

Figure 1

Advantages of such representation of implicit functions are following:

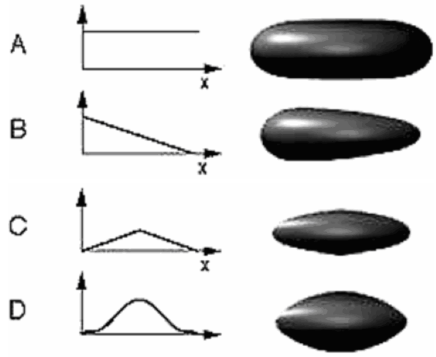
1. The primitives introduce features of skeletal modeling into process of creating complex implicit surfaces.
2. It is easy to receive smooth concatenations in the complex object (fig. 2).



Two primitives of field arc Complex field

Figure 2

Besides the operations of sum, union, residual, intersection of implicit surfaces mentioned above there are the tools for affine transformations in the modeling system. As the non-affine transformations the operation of profiling of implicit surfaces is used. Profiling is the deformation of field with the help of multiplication of implicit function by another scalar function. This scalar function changes the field value and isosurface trace these changes and change its profile [2], [3] (fig 3).



Profiling of field line

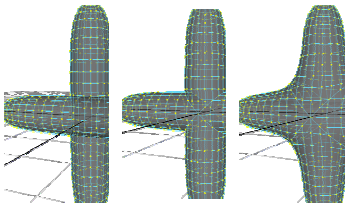
Figure 3

3. POLIGONIZATION OF IMPLICIT SURFACES

Approximating of an implicit surface is applied for visualization of an implicit surface in the system with the help of a polygonal mesh. At interactive modeling the polygonal mesh is necessary, for example, for shading, texturing and other operations. Interactiveness superimposes the serious requirements on velocity of poligonization algorithms.

The following algorithms of poligonization of implicit surfaces are known: algorithms of a space division, algorithms of fitting of a surface through the points, algorithms of restoring of a surface (tracking), etc. [4], [1].

In the system the fast method of build-up of grids of complex implicit surfaces on the basis of grids of primitives is used. Knowing geometry of a primitive, the mesh for it is fast created with the help of appropriate parametric approximation. The idea of a method is following: at build-up of a grid of changed implicit surface is maximally fully to use the grids available on the previous step (fig. 4).



The grids of two fields line

The grid obtained as union of grids of primitives as polygonal surfaces

Grid of complex field

Figure 4

The method of normalization is applied for obtaining the optimal grids of implicit surfaces. The method of normalization is a method of moving of a grid of a single orb on the implicit surface. The polygonal grid on single orb may be fast obtained by using parametrically approximation of the sphere. Further the vertices of the grid are being transferred on the implicit surface, at this time the task of searching of a point on an implicit surface with a known gradient value is being solved

The projection of the orb onto ovaloids (surface of the positive curvature) is unambiguously. For the ovaloid, the task of construction of a polygon grid, is easily being solved. The arbitrary surface may contain areas of the positive and negative curvature; therefore the projection of an orb onto such surface is ambiguously. Usage of original algorithm allows to construct the polygon grid and for such surfaces.

For optimization of grids interactive tools are offered. After the indicating of the area in which it is necessary to improve a polygon grid, the appropriate methods of optimization of grids are applied. In some areas the method of normalization for getting an optimum grid is used, in others areas the method of marching triangles is applied [1] and etc.

4. APPROXIMATION OF IMPLICIT SURFACES BY SPLINES

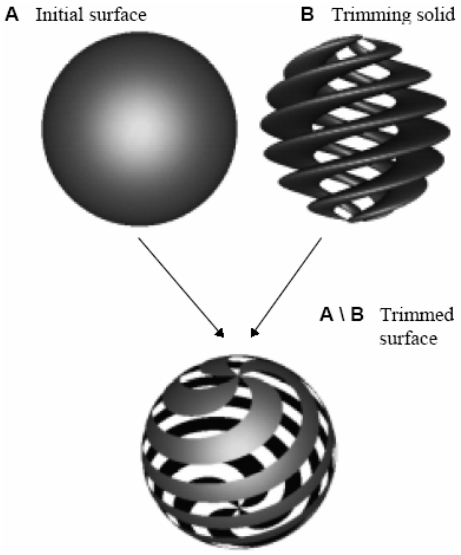
In the system it is supposed to implement algorithms of bi-cubic approximation of implicit surfaces, i.e. representing of implicit surfaces as surfaces joined out of the pieces of bi-cubic splines.

5. TOPOLOGICAL TYPE OF IMPLICIT SURFACES

During animation of implicit surfaces the topological type of a surface is frequently modified, therefore it is necessary to keep track of these modifications and to change topology of polygon grids. Algorithms designed in B. Stander's thesis [5] for implicit surfaces constructed on the basis of metaballs are being extended to the surfaces constructed on the basis of primitives.

6. EXCISION OF HOLES ON IMPLICIT SURFACES

For obtaining an implicit surface with boundary firstly the initial implicit surface (fig. 5) in which the hole will be cut is being created. Secondly, the cut surface along which contour to make the excision is being created. Further the surfaces are superposed and the area outside or inside cut surface is indicated. As a result the piece of a initial surface with the hole is gained.



Excision of holes on implicit surfaces

Figure 5

Such approach was considered in the work A. Pasko [6].

In the system it is supposed to create the tool of interactive excision of the arbitrary hole on an implicit surface. The boundary of such hole is being constructed directly on an implicit surface.

7. USING OF IMPLICIT SURFACES IN MODERN SYSTEM OF INTERACTIVE MODELING

The modern systems of 3D modeling and computer graphics, such as Maya 6.0, 3DStudioMax do not incorporate full-fledged tools for modeling with the help of implicit surfaces. They provides the designer with other tools of modeling, such as polygon surfaces, NURBS curves and surfaces, subdivision surfaces

Implicit surfaces are the alternate tool of modeling of smooth 3D surfaces and they coupled with other surfaces should be given to the designer as a part of the system. Thus there should be a possibility of making of the objects from various surfaces. For this purpose in the system it is supposed to develop tools of splicing of implicit surfaces with polygonal and NURBS surfaces and tools of conversion of implicit surfaces in polygonal and NURBS surfaces and back.

The modeling system with the help of implicit functions is being implemented as a plug-in for Maya 6.0. Plug-in is created in MicrisoftVisualStudio.NET 2003 on C++ with usage of class library Maya API (Application programmer interface).

8. REFERENCES

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