

VR における直観的な操作性を重視した自由形状モデリングの研究

Free-Form Modeling Based on Human's Intuitive Operation

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Abstract : It is not easy for beginners to manipulate virtual objects in conjunction with advanced “real-life” modeling applications made by CG. In this paper, we propose novel freeform modeling software controlled by a haptic interface. We intend to show human's intuitive operation that natural manipulation in real life using our freeform modeling tool. Finally, we show characteristic of our freeform modeling software.

1. Introduction

It's a main issue to make objects created easily, simply and fast in a modeling tool. The good design tool for modeling system should allow users to create basic model and to edit it in detail. So, many 3D design tools, such as CAD and VR program, have been developed. For beginners, it will take them much time to draw 3D objects using ordinary modeling tools till they finally grasp those complicated skills. For users who use 2D input device such as general mouse and joystick, it is a little difficult to manipulate modeling tool intuitively. Furthermore, it also takes much time for users who have been used current modeling tools to draw a curved surface. But human beings have been learned necessary skills to make shape naturally in usual life.

In this paper, we want to make intuitive modeling tool which allows beginners to design 3D objects in short time, to manipulate intuitively and to make curved surface easily.

2. Related Work

To improve designing performance, facilities and accuracy, various design methods and many systems have been developed.

By drawing the picture on the plane with already determined rule, the modeling method can make 3 D model automatically. These systems have intuitive manipulation about creating specialized form. But because users manufacture target object using 2D input device such as general mouse or joystick in this system, it is inconvenient to design area where 3D manipulation is needed. Furthermore, drawing skill which expresses 3D

objects with 2D picture is needed, but it is difficult for them who don't have this skill.

To get hold of stereo shapes more easily, the system that uses the display such as HMD and CAVE was also proposed. But this system is to gather each fundamental object such as a sphere, a cube, and a cone, so there was restricted characteristics to make available shapes, and it was insufficient to model the complex curve shape like human body or animals.

The skin algorithm made by Lee Markosian and Jonathan M.Cohen[4], it is the method of making the overall frame of a subject and applying the skin on the frame. Since design method is easy and intuitive, and this method uses Loop subdivision algorithm for multiresolution editing, user can make a model with smooth curved surface intuitively. However, users should make a frame of target model before using this method, and it is difficult to design local surface with the details and the sharp feature.

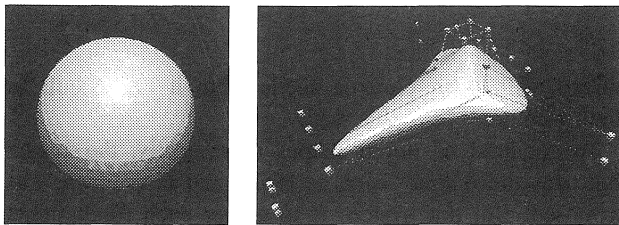
Recently, a modeling tool called FreeFormTM was developed by Sensable technologies Incorporated [5][6]. This system provides modeling method like “Cray Work” with force feedback. However, since this FreeForm modeling system uses an internal volumetric representation such as “Voxell”, and use simple edit probe, it is difficult to manufacture the local surface with the details and the sharp feature. Furthermore, it takes conversion time from internal volumetric structure to polygonal surface. Our proposed 3D modeling tool is similar to FreeformTM with viewpoint of a digital modeling tool. But in our tool, since a polygonal is used as a data structure instead of “Voxell”, it doesn't need conversion time. And our modeling tool adapted method of “weight control”, users can make complex and sharp object fast and easily. Still more owing to use FFD[7], users can change size and shape of object fast and easily without affecting shape of local area.

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3. Global Shape Design

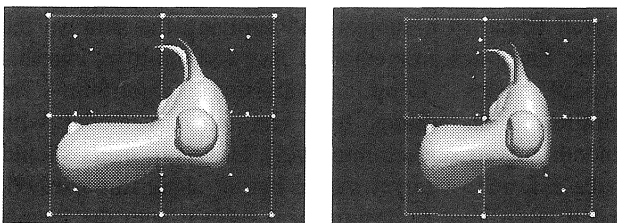
Users design a model after selecting primitive. Human being performs global deformation which generates a form overall when manufacturing a certain object, before performing fine work. However, it is not easy to make a smooth object from a primitive that is composed of a few polygons. Since processing speed will fall gradually with the increasing of the number of the polygons, it is hard to keep processing speed if users start to design a primitive composed of many polygons. In this research, one of the modification algorithms, FFD[7], was applied and it satisfies the following conditions.

- 3-dof intuitive manipulation
- Possibility of overall deformation
- Curved surface deformation with a few polygons



(1) Primitive (2) After Deformation
Fig.1 Primitive deformation

(1) of Fig 1. is primitive with 1280 polygons and (2) is the result after deformation using FFD.



(1) Before deformation (2) After of deformation
Fig.2 Designed object deformation

So we use FFD algorithm in deformation processing, and Fig.2 shows that overall deformation is possible, without having big influence on a local surface which have been made already.

4. Local Surface Design

We can expect that if we only use reappearing to create shapes in real world, users do modeling what they intend to model in computer. The following is requirement to do intuitive modeling in the computer,

- That modeling tool has to input 6-dof manipulation in 3 dimensional space.
- That modeling tool has to create free form include curved surface.
- That modeling tool has to allow local reform about from
- That-modeling tool has to specify deformed place.

So, in this paper, we provide local surface design method

that is suitable for the above necessary conditions. There are some characteristics in our modeling method,

- The operator can specify various reformative place
- The operator can control a degree of reforming by weight value.
- The above two points are displayed clearly by color changed.
- The operator can manipulate the reformative place with 6-dof.
- The operator can smooth rough surface.

4.1 The method of Area Selection

Our tool provides two methods of selecting area to deform. The first method used a shadow which arises on target object surface when light is projected on target object. For selecting the space area, the second method is to select space area by the circumscribed area to deform, which is the overlap part of target object and primitive such as a ball, a cube, etc.

4.1.1 A selection method by illumination

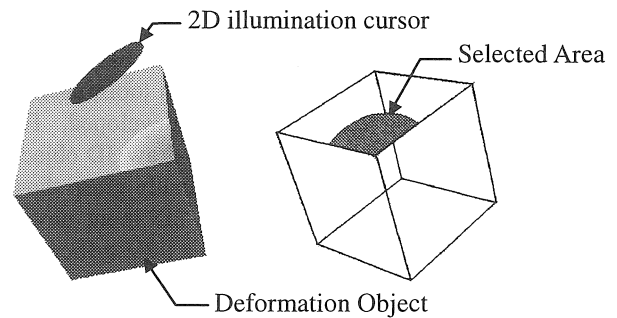


Fig.3 Surface Area Selection by illumination

This way is based on characteristic of the illumination. That is to say, we consider selected area by illumination as a target area. The selected vertices have weight α , which is related to distance from area center to them. Users can select only a surface area to deform by this method.

4.1.2 A method of space area selection

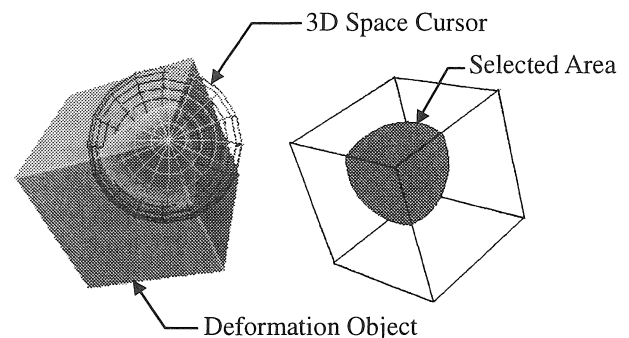


Fig.4 Space Area Selection by 3D Space Cursor

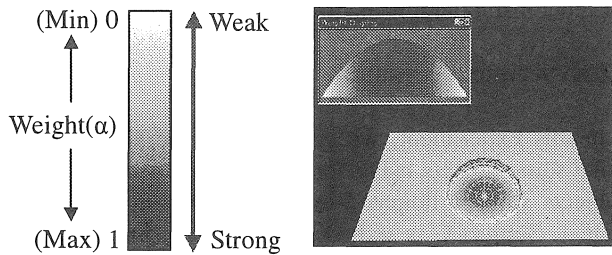
It is the method of choosing all area that affected by 3-dimensional object cursor, such as a ball and a cube, on a target object, Fig3. Shows how to select space area with

touching it. When the user performs area selection, to perceive depth direction in 2 dimensional display, so we used force feedback [8][9].

As weight is given to each vertex, the depth direction problem was solved by always placing a origin point on the surface of a subject. The selected vertices have weight α , which is related to distance from datum point mentioned above. Fig.4 shows area selection using sphere cursor.

4.1.3 Weight Expression

We visualize weight α in the selected area that the color according to the value of weight is changed.



(1) Color expression (2) Current distribution in 2D

Fig.5 Weight Expression

The color of both ends is distinguishable as shown in Fig.5. But it is very difficult to judge by the change of color simply for the color of close parts in bar is so similar. So in our system, the present weight distribution is expressed in 2D. And the case where a selection area is transformed by the weight distribution such as Fig.6, the function to expect and express a result is adopted and the repetition working time by the deformation result different from an intention were reduced.

4.2 Deformation of selected area

In this mode, depending on the distribution of weigh degree that is set in the area selection mode, we deform the target subject using input device with multi-dof.

4.2.1 Translation Deformation

The deformation of translation is reflected by translation the component of input device. The distance movement in each vertex becomes distance which weight degree multiples by translating the component of the input device.

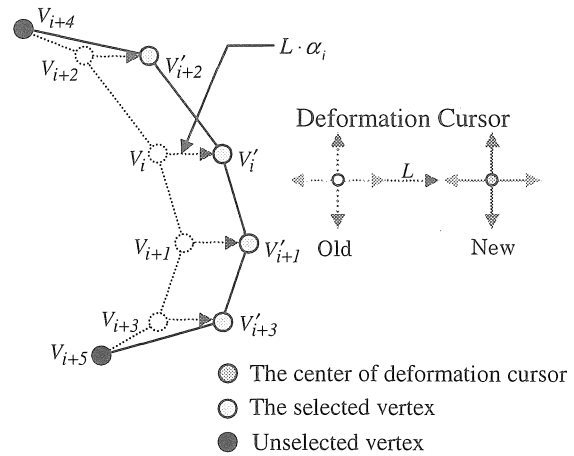
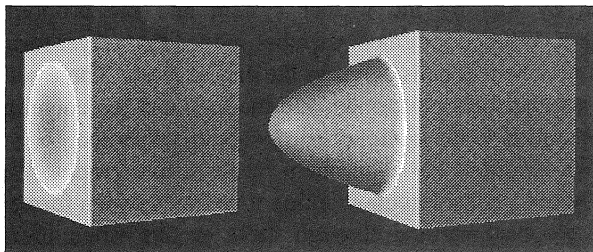


Fig.6 Translation Deformation

4.2.2 Rotation Deformation

The deformation of rotation is reformation that rotation component of input device is reflected. Each vertex rotates a degree that rotation component of input device multiplies by weight degree about center of deformation console.

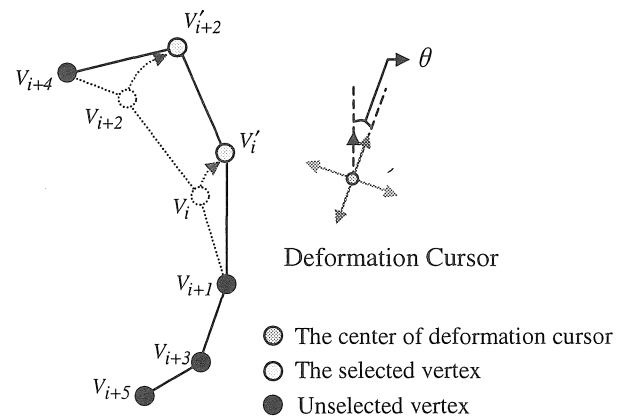
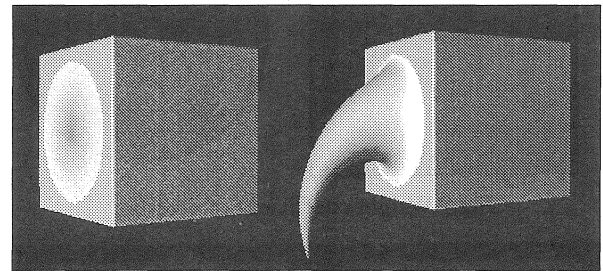
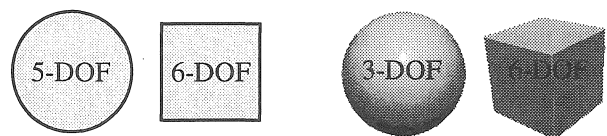
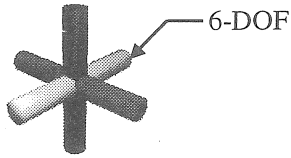


Fig.7 Rotation Deformation

4.2.3 Cursor type



(1) Surface Selection Cursor (2) Space Selection Cursor



(3) Deformation Cursor

Fig.8 Cursor type

As shown in Fig.8, Our system supports 5 type cursors have different DOF respectively.

4.2.3 Weight coefficient

We prepare 3 weight coefficients to make basic curved surface like following

$$\begin{aligned} \alpha &= (r - d) \times k \\ \alpha &= (r^2 - d^2) \times k \\ \alpha &= (r - d)^2 \times k \end{aligned} \quad k : \text{user input coefficient} \quad (1)$$

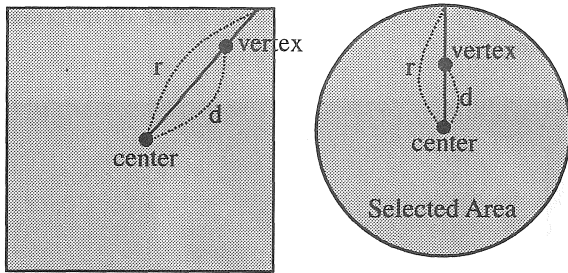


Fig.9 Weight coefficient of a vertex

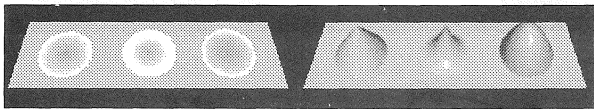


Fig.10 Deformation by each weight coefficient

Figure.10 show the result of deformation, each vertex is moved by a weight coefficient that multiplied by weight α

4.2.4 Deformation by partial cut of weight

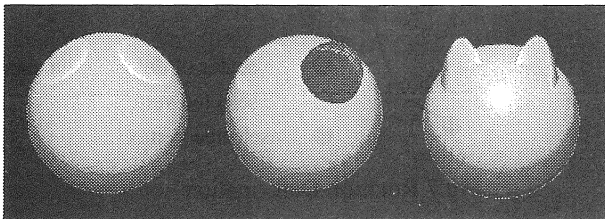


Fig.11 Deformation by partial cut of weight

Users have to select area to deform, and have to make various shaped 3-dimentional objects in former tools. But it takes much time to be skilled. So we suggest deformation method by partial cut of weight.

4.3 Subdivision of deformation area

After users deformed the surface of polygonal mesh

want to deform the deformed surface one more time, that surface will be break, because the area of polygon is changed, even though the number of polygon is same. So subdivision of polygonal mesh is need. In this research, in order to reduce computational processing time, we applied method that only deform select deform area

5. Experiment

5.1 Experiment system

Our system use dual Pentium CPU (550Mhz), 390Mbyte system memory, and Geforce2 GTS as a graphic board. As an input device, we choose PHANToM™ which was made by sensible Technologies. PHANToM™ has 6-dof for input manipulation and 3-dof for force display.

5.2 Experiment condition

In this experiment, we compare the working time to make some objects using former way and proposed way. Subjects who participated in this experiment are 3, like table 1. Subject C is skilled at former way but subject A and B is beginner. We choose LightWave3D as a former way tool [10].

Table 1. List of Subjects

Subject	Experience of Light wave 3D
A	No
B	No
C	Yes

5.3 Modeling Experiment 1

As shown in Fig. 12, we chose the simple model with the curved surface as a target model of experiment 1.

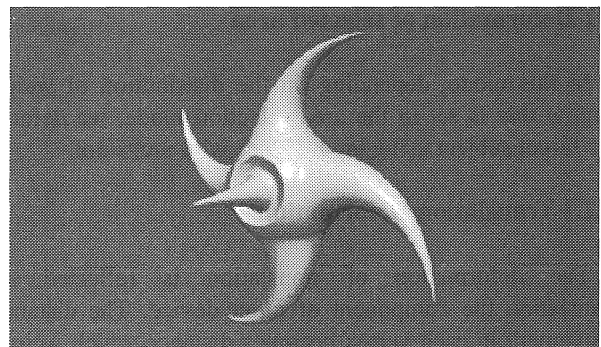
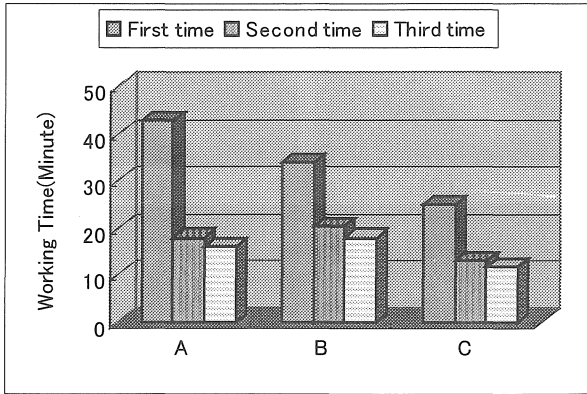


Fig.12 Target model of Experiment 1

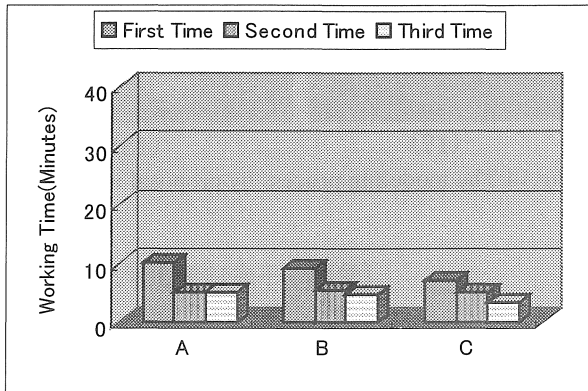
A subject performs the subject that designs the same form by this by the former system and the proposal system. When a judgment member judged that target form was re ached, it considered as the end of work. Three sets per a subject are performed, and the time and the contents of operation to the completion of work are recorded.

-We recorded the experiment result in two graphs. We can know a considerable working time lag between former and proposal method through these graphs when users

manufactured target object. Graph 1 and 2 expresses that a subject performed 3 times There also was also a considerable working time lag between first time and second time when users designed target model by former method, But There wasn't time lag like former method



Graph.1 Working time of Recursive work by Former



Graph.2 Working time of Recursive work by Proposal

5.4 Modeling Experiment 2

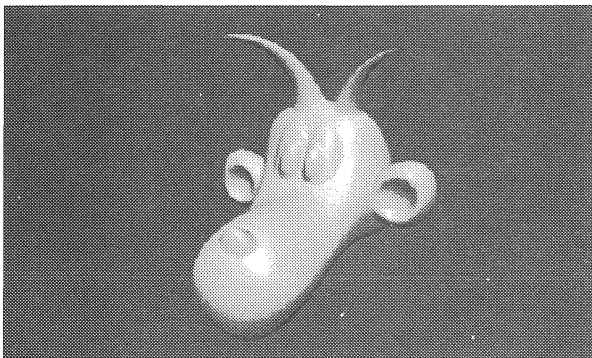
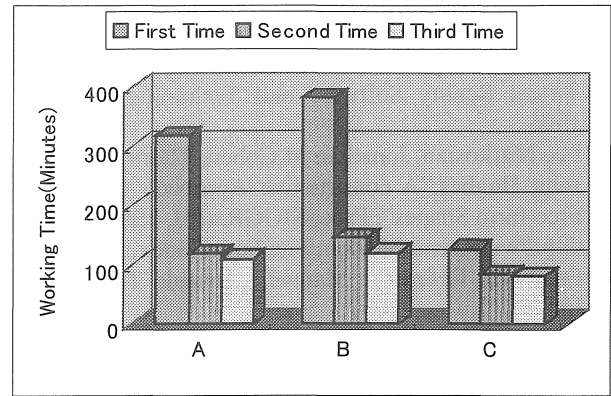


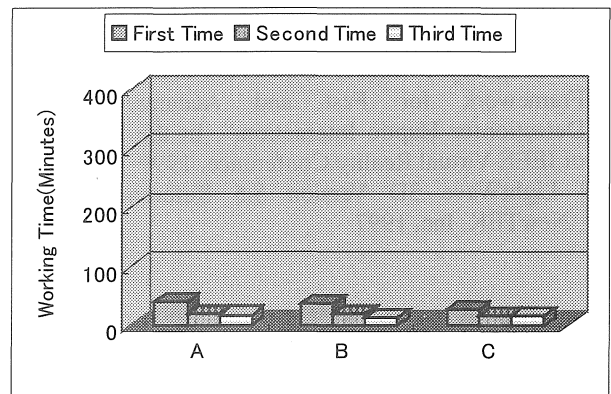
Fig.13 Target model of Experiment 2

In this experiment, as shown in Fig.13, we chose the complex model more than target model of Experiment 1 as a target model of experiment 2. The experiment method is the same as that of experiment 2.

Since the target model of experiment 2 had many curved surfaces than the subject of experiment 1, long working hours were needed. These graphs are also saying the result that is similar to the result of experiment 1.



Graph.3 Working time of Recursive work by Former



Graph.4 Working time of Recursive work by Proposal

5. Consideration

Through graphs of experiment result, we can know that working time of proposed system is almost same. But working time of LightWave3D is irregular. That means our proposed system is based on human's natural skilled, so subjects manipulate our tool intuitively.

6. Conclusion

In this research, to design 3 dimensional free-form modeling environments as an intuitive shape-creative method in the real world, we proposed deformation method that global shape design using FFD and deformation value to the deformation target. To perceive depth direction more easily, we used the haptic device. Throughout experiments, we can know that suggested method is not only more intuitive but also efficient way that former on in our system using multi DOF device. For the future work, we will develop fast trace algorithm to keep speed regularly and will research the method that linear work can be worked intuitively.

Reference

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Appendix.

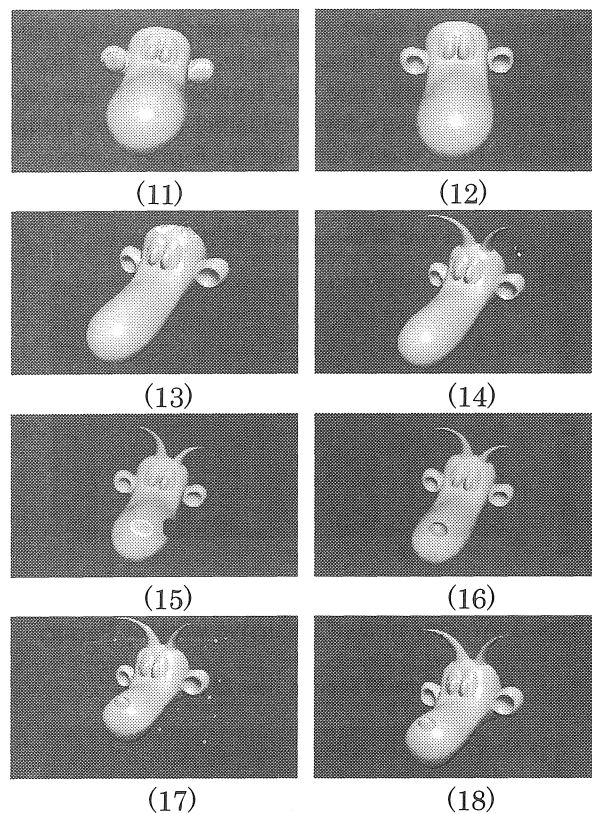
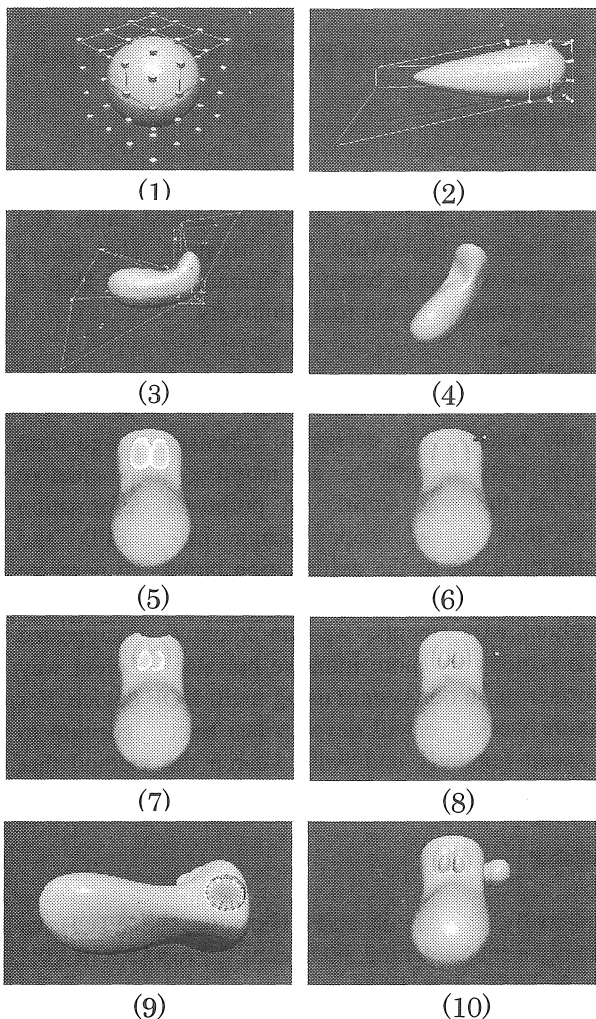


Fig.14 The modeling process by proposal method

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