Interaction with Autonomous Free-form Surface

Hiroo Iwata and Hiroaki Yano

Institute of Engineering Mechanics, University of Tsukuba
Tsukuba, 305 JAPAN
Tel: +81-298-53-5362
FAX: +81-298-53-5207
Email: iwata@kz.tsukuba.ac.jp

abstract: This paper describes about a method for interaction with autonomous surface in virtual environment. The method is intended to be applied to industrial design. We have developed a software tool for programmers of virtual environment called VECS (Virtual Environment Construction System). VECS manages attributes of virtual objects and physical law. The system enables the user to direct manipulation of autonomous free-form surface. Time, congenital characteristics, and acquired characteristics are interactively controlled by the user. This interaction enables combination of autonomous shape and intentional shape. The free-form surface has surface tension which enables restoration to the original shape. The surface has function of feeding and avoidance from enemy. The user can form complex shape by using those functions.

Keywords: autonomy, shape modeling, free-form surface, haptic

1. Introduction

Industrial designers often make simple mockups using urethane or styrenes boards in order to study the theme of the form at the early stage of design development. This process is called form study[1]. We developed autonomous free-from surface in virtual environment as a tool for from study. The basic theme of the from is created through deformation of the surface.

Design of 3D shapes is a major application area of virtual reality. Direct manipulation of 3D shapes has been realized in virtual environment. In this case, shape of the object is originally determined by a human designer. This paper proposes autonomously growing objects in virtual environment. Designers are often inspired by shapes of living creature.

The user of our system can interact with autonomous surface in its morphological process. Parameters of congenital characteristics can be interactively changed. Shape of the surface can be directly manipulated by the user during its growing process. In this way, autonomous shape and intentional shape are mixed.

We have developed a software tool for programmers of haptic virtual environment called VECS (Virtual Environment Construction System). In this system, controller of force display, description of virtual space, and user application are divided into modules. Autonomous free-form surface is implemented as a user application of VECS.

2. Virtual Environment Construction System (VECS)

2.1 Basic Structure of VECS

Virtual world technology usually employs various types of input/output devices. Manipulation of virtual objects essentially requires force feedback. However, methods for force feedback are at a fumbling stage. We have developed several kinds of force displays. Software of virtual environment has been tightly connected to control program of force displays. This problem is a hazard for development of further application of haptic virtual environment. Therefore, we developed a software tool for programmers of haptic virtual environment, in which control program of force display, description of virtual space, and user application are divided into modules. The system is called VECS (Virtual Environment Construction System). VECS is developed by C language on UNIX. Various types of force displays can be plugged into VECS. The system supports two force displays. Two users can simultaneously interact in the same virtual environment. This function enables easy construction of groupware program[2].

Physical laws for the virtual world are contained in VECS. Gravity, elasticity, and viscosity are currently implemented. Collision between virtual objects are detected in real time. Shapes and attributes of virtual objects are defined in the user application module. Users of VECS programs the methods for interaction between virtual objects and operators.

VECS is composed of following three programs:

(1)program for object data
  supervising behavior of virtual objects
(2)program for device data
  communication with force display
(3)program for application data
  detection of user intention and updating virtual environment

Dividing into these programs, force displays and physical laws in virtual environment are easily reconfigured. Moreover, this system defines "time" of virtual environment. Time of virtual environment increases independently from the user. This function enables autonomous growth of virtual objects.

VECS is composed of two processes: kernel and user application. Kernel of VECS determines behavior of virtual objects and generates graphic image of virtual environment. This process runs autonomously. User application determines the methods for interaction between virtual objects and operators. Shared memory is used for communication between these processes.

VECS is currently implemented on SGI IRIS Indigo. Exchanging graphics library, the system can be ported to other graphics work station. In our laboratory, it also runs on HP9000/425t with personal VRX graphics engine.

2.2. User Interface of VECS

Visual image of user interface of VECS is shown in Figure 1. The user of the system sees his/her virtual hand, virtual objects, and virtual control panels. Virtual control panels include buttons or slide bars. Command input and parameter setting are done through these devices. If the virtual hand comes close to these buttons, the hand is pulled toward the center of the buttons by force display. This applied force assists the user to operation of control panels. If the user grasp the button, the color of the button changes and command is input. VECS supports two force displays, and two users can simultaneously interact in the same work space as shown in Figure 1.

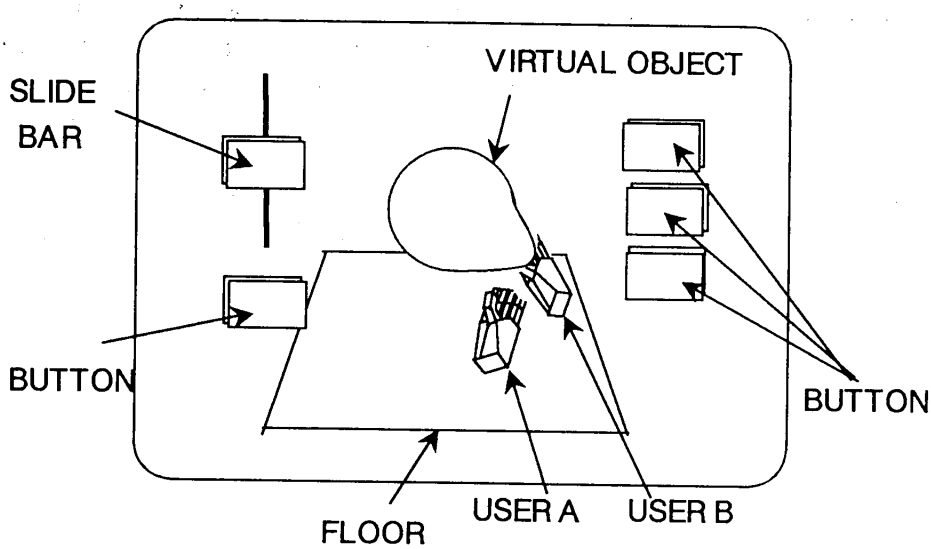


Figure 1. User interface of VECS

3. Methods for Interaction with Autonomous Virtual Objects

Interaction with autonomous virtual objects can be done through following 3 parameters:
(1)Time
Our virtual environment has time clock which is supervised by the kernel of VECS. Growth or autonomous deformation occurs according to this time clock. The user can freely change speed of time and he/she can also reverse it. Direct manipulation of time increases freedom of design process.

(2)Congenital characteristics
Autonomous 3-D shapes have congenital characteristics which determine their morphological process. The user can arbitrary change the congenital characteristics. The variation of congenital characteristics results in different shapes. Manipulation of congenital characteristics leads to unexpected form of virtual objects. In our system, congenital characteristics can be changed in growing process of virtual objects.

(3)Acquired characteristics
Acquired characteristics is obtained by direct manipulation of virtual objects by the user. The user can deform autonomous virtual objects at any time.

VECS supports implementation of these parameters[3].

4. Function of Autonomous Free-form Surface

We developed autonomous free-from surface in virtual environment as a tool for from study. The original shape of the surface is a sphere. The user can freely deform the surface. The basic theme of the from is created through deformation of the sphere. We implemented three functions in the autonomous surface:

(1) restoration

Each lattice of the surface is connected by four springs(Figure 2). These springs generates surface tension. If the surface is pulled or pushed by the user, the surface tension restores the surface to the original sphere(Figure 3). Unexpected shapes are found during autonomous deformation process. The user can manipulate the surface while it is autonomously deforming.

In this case, congenital characteristics is determined by spring constant of surface tension. The user can change the spring constant by a slide bar. If the spring constant is large, deformation spreads to wide area. Figure 4(a) shows an example of deformation with large spring constant. Figure 4(b) shows an example of deformation with small spring constant.

(2) reaching action to food

The user can put "food" for the surface. If the food comes near, the surface reaches out to it. Motion of each lattice is caused according to the distance between the surface and the food. Transition from the original surface is determined by negative exponential function(Figure 5). If the food is large, large area of the surface deforms. Figure 6 shows an example of reaching action.

(3) avoidance from enemy

The user can put "enemy" for the surface. If the enemy comes near, the surface avoids it. Motion of each lattice is caused according to the distance between the surface and the enemy. Transition from the original surface is determined by negative exponential function(Figure 7). If the enemy is large, large area of the surface deforms. Figure 8 shows an example of avoidance.

5. Usability Study

As a usability test of the autonomous free-form surface, we examined modeling task of complex curved surface. We prepared three patterns which represent shapes of form study for car design. Figure 8 shows an example of the patterns. Subjects are instructed to make these patterns from a spherical surface.

Two conditions are set for the experiment:

(1) with function of restoration

The surface autonomously deforms according to its surface tension.

(2) without function of restoration

In this case, the surface is passive. The subjects make shapes by direct manipulation of the free-form surface. Deformed surface is determined by sine curve. We have developed this method in the research of pen-based haptic virtual environment[4].

We took 6 volunteer subjects from the students of our university. We examined accuracy of the modeling task. Deformation distance at each lattice from the original surface is calculated. The total deformation distance is normalized by that of target pattern. If the error value is 1, the task is perfect. Figure 9 shows the normalized deformation distance of the two conditions. The value of the condition (1) is 9 times smaller than that of the condition (2). Required time for each task is approximately 2 minutes in both conditions. Subjects often abandon making shapes in condition(2).

6. Conclusions

We have developed autonomous free-from surface in virtual environment. The surface has function of restoration, reaching action to food, and avoidance from enemy. These functions

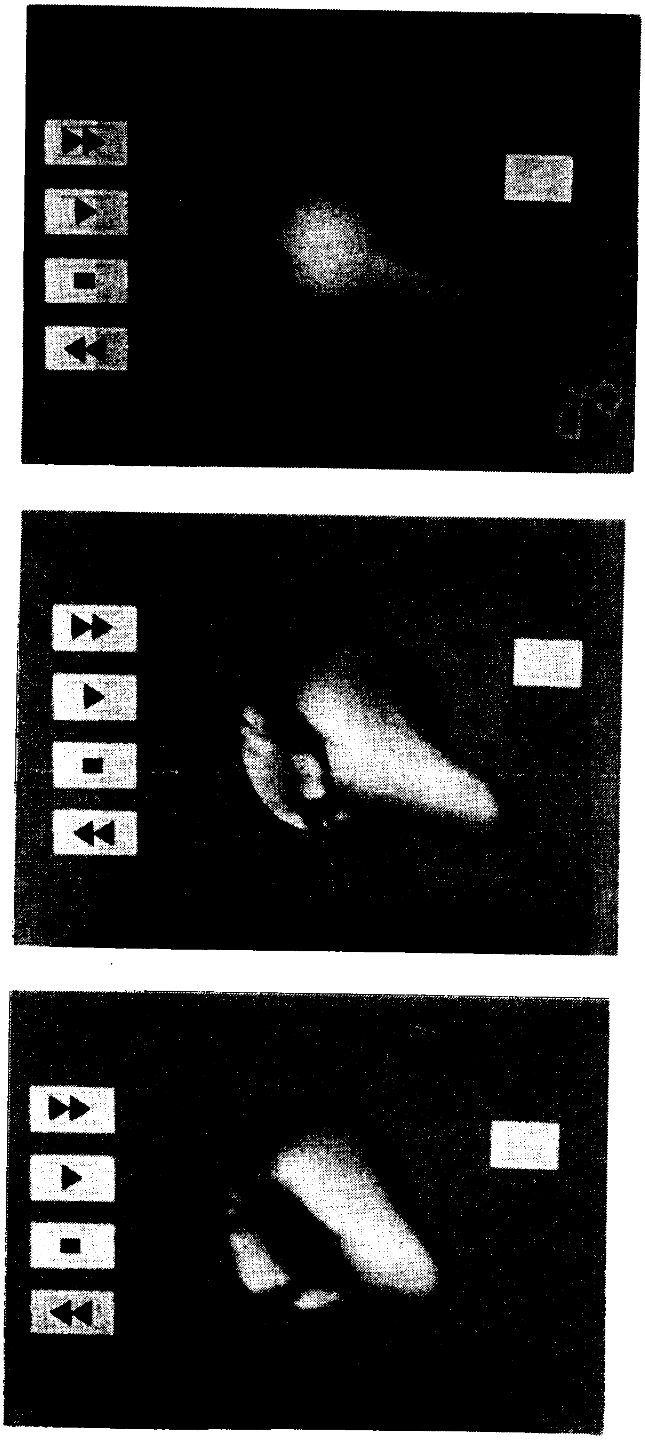


Figure 3. An example of autonomous deformation

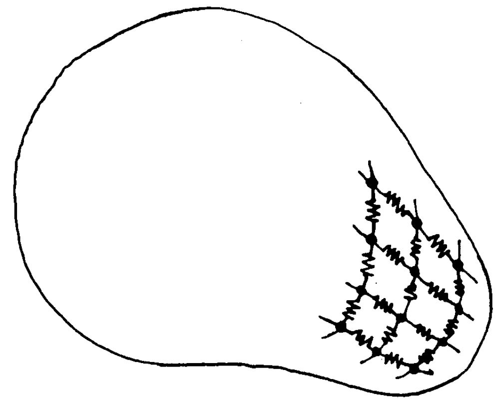
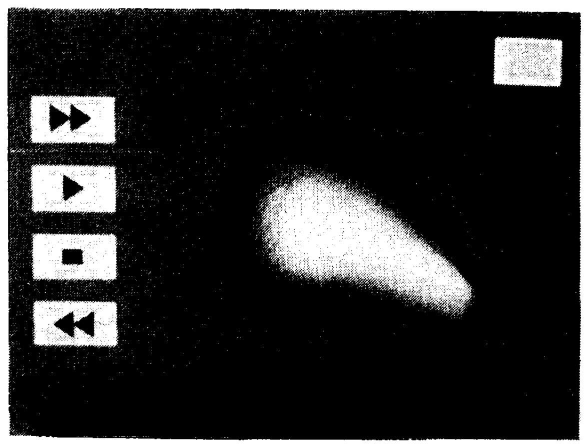
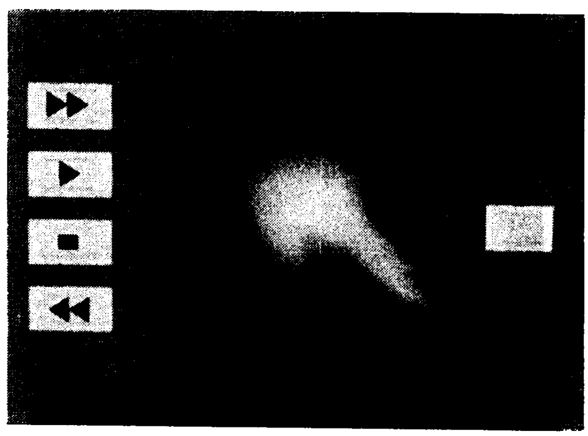


Figure 2. Mechanism of surface tension



(a)



(b)

Figure 4. Examples of modified surface tension

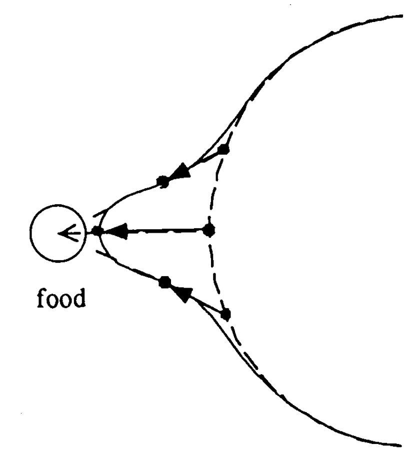


Figure 5. Mechanism of reaching action to food

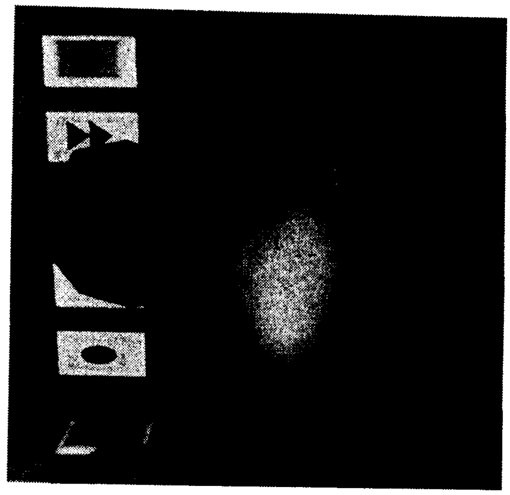


Figure 6. An example of reaching action to food

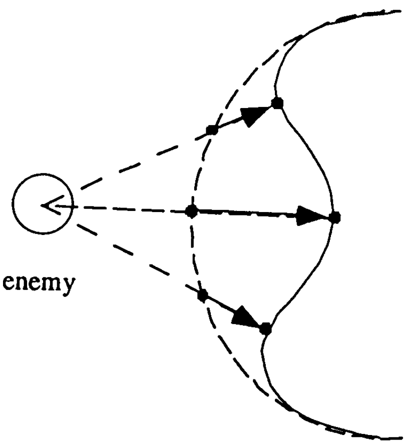


Figure 7. Mechanism of avoidance from enemy

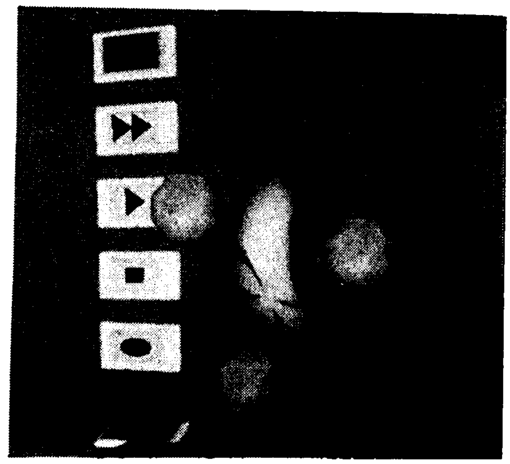


Figure 8. An example of avoidance from enemy

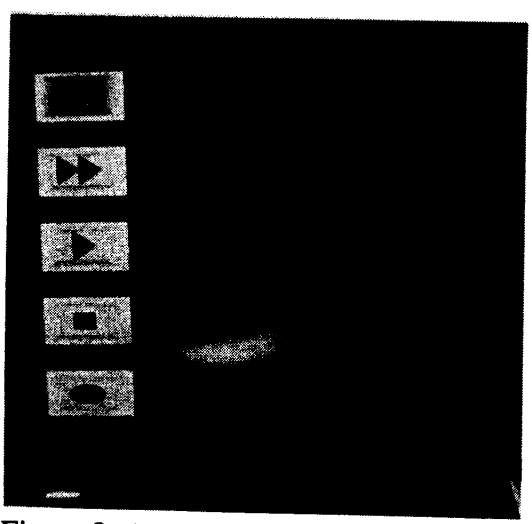


Figure 9. An example of pattern for form study of car design

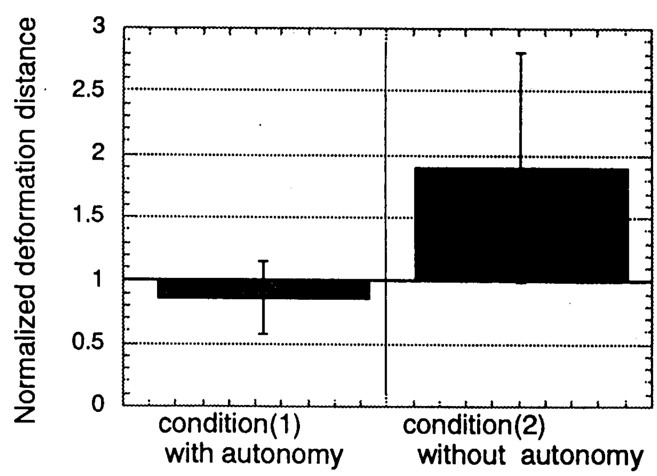


Figure 10. Accuracy of modeling

are effective in designing organic shapes. Currently, principle of the autonomy is fairly simple. However, Principles of living systems are very intricate. Future direction of our research is investigation of which principle is effective for design of 3D shapes.

References

[1] Car Styling,San'ei Shobo Publishing, No.97 (1993)

[2] H.Yano,T.Nakagawa, and H.Iwata, "Cooperative Work in Virtual Space by Using Force Display" Information Processing Society of Japan, SIG Note, Vol.93, No.34 (1993)

[3] H.Iwata, H.Yano, "Artificial Life in Haptic Virtual Environment" Proc. of ICAT'93 (1993)

[4] H.Iwata, " Pen-based Haptic Virtual Environment" Proc. of VRAIS'93 (1993)