ME 534 COMPUTER-BASED MODELING AND SIMULATION
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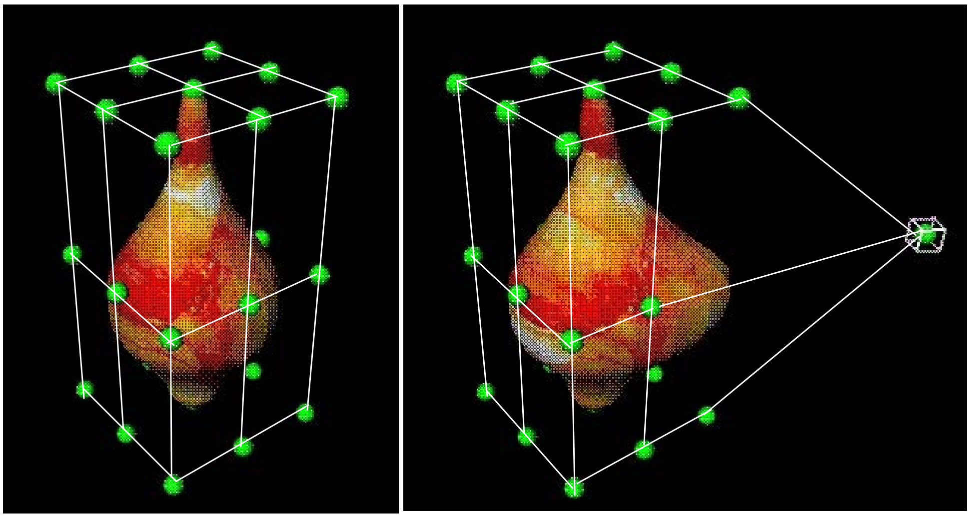
FREE FORM DEFORMATION



Free-form deformation of a texture mapped 3D object. A total of 27 control points are placed at the corners of the 3D lattice structure as shown in the first frame. One of the control points is moved to a new location to deform the object in the second frame.

Graphical simulation of deformable surfaces have been extensively studied in computer graphics and computer aided engineering. Various *direct* or *indirect* deformation techniques have been developed to manipulate the surfaces and to modify the local or global shape of the objects. One way to categorize the deformation techniques is according to the approach followed by the researchers to deform the surfaces: *geometric* or *physically-based* deformations. In geometric deformations, the object or the surronding space is deformed based purely on geometric manipulations In general, the user manipulates the control points that surround the 3D object to modify the shape of the object. Geometric-based deformation techniques are faster, and are relatively easier to implement. But they do not simulate the underlying mechanics of deformations. Hence, the emphasis is on visual display and the goal is to make deformations appear smoother to the end-user. On the other hand, physically-based deformation techniques aim to model the physics involved in the motion and dynamics of interactions. Models simulate physical behavior of objects under the affect of external and internal forces. Dynamical equations with constraint relations are solved to describe the behavior of movement.

In this project, you will implement the approach proposed by Sederberg and Parry (1986) to simulate the global geometric deformations of a 3D object. Sederberg and Parry (1986) suggested a Free-Form Deformation (FFD) technique for deforming the space that encloses the object. FFD enables the user to interactively modify the object shape by repositioning the lattice of control points that surround the 3D object. Any point within the lattice is defined as:

$$Q(u,v,w)=\sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3}P_{ijk}B_i(u)\,B_j(v)\,B_k(w)$$

or, in matrix form

$$Q = BP$$

where, P_{ijk} are the cartesian coordinates of control points, and $B_i(u)$, $B_j(v)$, $B_k(w)$ are known as the third degree Bernstein polynomials. For example, the Bernstein polynomials in parametric coordinates *u* is defined as

$$B_0(u)=(1-u)^3$$
$$B_1(u)=3u(1-u)^2$$
$$B_2(u)=3u^2(1-u)$$
$$B_3(u)=u^3$$

The volume enclosing the 3D object can be parameterized (u, v, w $\in$ [0,1]) using the cartesian coordinates and their minimum and maximum values in x,y, and z directions as

$$u(x)=\frac{x-x_{\min}}{x_{\max}-x_{\min}} \qquad v(y)=\frac{y-y_{\min}}{y_{\max}-y_{\min}} \qquad w(z)=\frac{z-z_{\min}}{z_{\max}-z_{\min}}$$

References:

1. Sederberg, T.W., Parry S.R., 1986, "Free-form Deformation of Solid Geometric Models", *SIGGRAPH Proceedings on Computer Graphics*, Vol. 20, No. 4, pp. 151-160.