Interactive Deformation Using Volumetric Constraints

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Introduction

We present novel mesh deformation techniques using volumetric constraints:
(1) A fast volume-preserving deformation method for 2D closed meshes.
(2) A method for preserving the internal structure of 3D meshes.

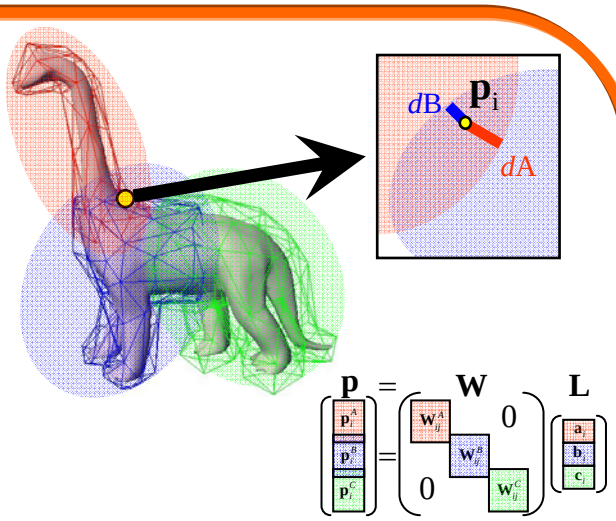
Propagation

Fast Volume-Preserving Deformation :*Overlapping Lattices*

Subspace gradient domain mesh deformation[Huang et al. 2006] enclosed a mesh model with a single sparse lattice and reduced the number of variables by representing all vertex positions by linear combinations of points in the lattice.

In our method, we enclose a mesh model using multiple overlapping lattices so that some vertices are shared by two or more lattices. Such shared vertices mediate to propagate deformation between disconnected lattices. Suppose the coordinates of the lattices *A* and *B* are $\{\mathbf{a}_i\}$ and $\{\mathbf{b}_j\}$. When vertex $\mathbf{p}_i$ is enclosed by the two lattices, we can represent $\mathbf{p}_i$ in two ways using mean value coordinates [Ju et al. 2005] as:

$$\mathbf{p}_i = \sum_j w_{ij}^A \mathbf{a}_j = \sum_k w_{ik}^B \mathbf{b}_k$$



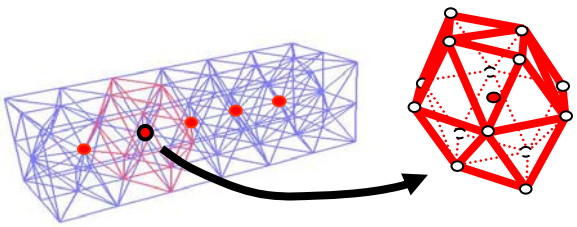
We blend these representations as:

$$\mathbf{p}_i = \alpha \sum_j w_{ij}^A \mathbf{a}_j + (1-\alpha) \sum_k w_{ik}^B \mathbf{b}_k$$

where $\alpha = d_B / (d_A + d_B)$; d_A and d_B are the distances from $\mathbf{p}_i$ to each lattice.

Then, volume-preserving deformation can be calculated efficiently, because the matrix **W** has sparse structure.

Deformation of 3D Mesh Models :*Simple Linear Constraints*

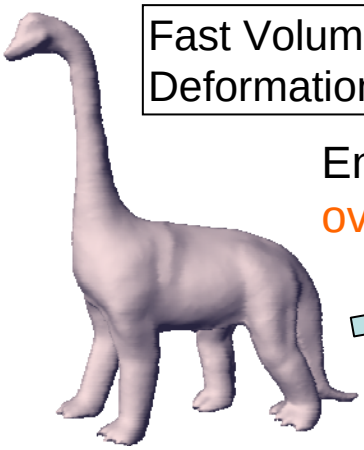


$$\mathbf{p}_i - \sum_{j \in N(i)} w_{ij} \mathbf{p}_j = 0$$

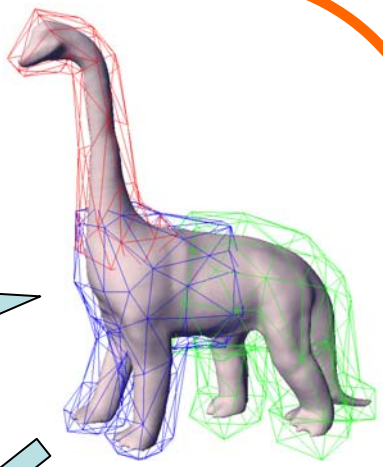
A 3D mesh, which consists of tetrahedra, has internal structure, in which attributes may be embedded. To deform internal structure consistently, we introduce simple linear constraints. Since each interior vertex $\{\mathbf{p}_i\}$ is enclosed by adjacent tetrahedra, its position can be represented by a weighted sum of the positions of the connected vertices $\{\mathbf{p}_j\}$ using mean value coordinates. By adding these constraints the internal structure can be also maintained during deformation.

Examples

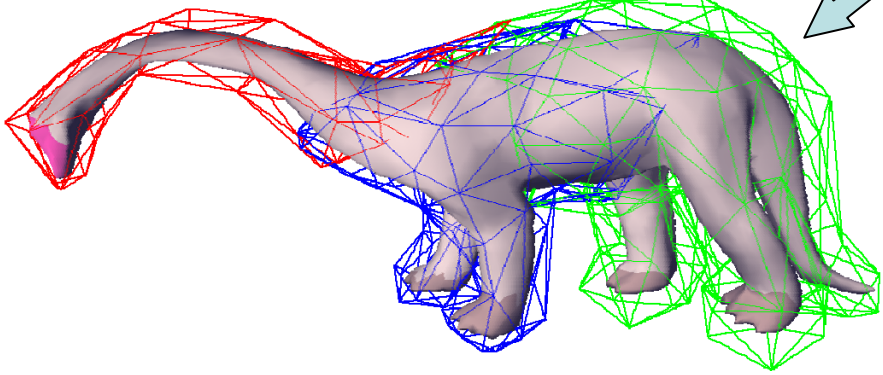
Fast Volume-Preserving Deformation

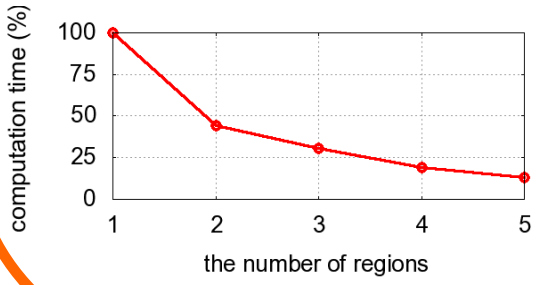


Enclosing with multiple overlapping lattices



Deform!





Computation time of our volume-preserving deformation in the interactive phase. We solved non-linear minimization using the Gauss-Newton method. In this experiment, we used the same total number of points for lattices, but subdivided the enclosed space into the different number of overlapping regions. This result indicates that the computation becomes significantly fast when the number of lattices increases.

Deformation of 3D Mesh Models

Example of the 3D mesh deformation. Both the boundary and interior of the 3D mesh model could be consistently deformed.