Interactive Free-Form Level-Set Surface-Editing Operators
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MOTIVATION

\[
S = \{ x | f(x, t) = 0 \},
\]
\[
\frac{\partial S}{\partial t} = -\nabla f \cdot \nabla f(x, t) D^2 S(x, t),
\]

- Generate a low-level volumetric representation of the geometry of deformable implicit surfaces that are based on formulating and solving a partial differential equation (PDE).
- Build a well-developed surface editing framework that provides robust numerical techniques for evaluation and evolution.
- Guaranteed to deliver simple cross-anisotropic and cross-linear surfaces.
- Easily change topological genus, making them ideal for representing complex structures of unknown or unknown genus.
- Provide the advantages of implicit models, such as supporting straightforward solid modeling operations and calculations, simultaneously offering surface modeling paradigms.
- In medicine and science
  - as an intermediate of data volume, usually contains 3D surfaces that are of interest to physicians and scientists that must be processed, rendered, and analyzed.
  - Frequently the volume datasets and the surfaces embedded in them need to be fixed, adjusted, and/or edited to meet the requirements of the specific application.
- In computer graphics
  - Many surface reconstruction algorithms generate volumetric implicit models through solving an implicit surface that represents the volumetric data.
  - Advanced special effects in various computerized physical simulation to produce computer-generated fluid flows of fluids, storms, pressurized spraying liquids, etc., and produce dynamic volume datasets as output.

CONTRIBUTIONS

- The narrow-band data structures have been extended to localize all computations and updates to an optimized region.
- We describe the level set framework that implements the surface editing operations.
- A level set surface can be deformed through a split-stitch-and-pull interface that allows a user to identify a point or region of influence (ROI) to be modified on the surface.
- The user may then pull a point or a region curve within the ROI to apply a free-form deformation.
- surface smoothing
- surface carving
- surface smoothing
- Sketch-based technique that pulls the surface toward a profile curve.
- A 3D painting capability is also been added to the system.
- Our work stands apart from previous work in that (i) it is the first to develop free-form editing operators, which provide simple, intuitive, and user-friendly editing functionalities to be used by professional FSE-based systems; and (ii) it is also able to interactively modify a volumetric implicit surface by solving a PDE.

DATA STRUCTURES

- Three additional data structures are added over the narrow-band data structure that achieves interactive rates while solving the level set FSE.
- They limit computation to the subset of the level set surface that is actually being modified.
- Implemented as C++ vectors of pointers that pointers to data within the linked lists.
- These lists create an easy way to access a set of voxels that are mutually connected. Links are created using a level set FSE algorithm.
- The user can click in the interface and watch the PDE effects on the surface.
- A 3D array of pointers provides constant-time access to any narrow-band element.

EDITING OPERATORS

1. Pulling on a point, symmetric ROI

2. Pulling on a point, arbitrary ROI

3. Pulling on a curve, symmetric ROI

4. Pulling on a curve, arbitrary ROI

5. Surface-drawing

6. Carving

7. Sketching a single cross-section

8. Interactive smoothing

RESULTS

- A cartoon character is created by adding horns and pointy ears to the main character. The color, eyes, and nose are also modified, and some hair details are added.
- Lake with unusual inhabitants.
- Plastic duck
- Cartoon fox
- Plastic toy shark
- Left: Topological repair of a vascular dataset. Right: The volume is manipulated using a sketching to separate two parts that were merged due to an error in 3D scanning. Right surface. The volume is manipulated to uncover lost detail by connecting two ends that were separated.