Deformable Models

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Outline

Deformation

- Definition from engineering mechanics - change in shape or volume due to an applied force
- Can be a result of tensile (pulling) forces, compressive (pushing) forces, shear, bending or torsion (twisting)
- Real objects are flexible, not rigid
- Deformable objects exhibit complex motion that is tedious to animate by hand
- Animating humans and animals
- The challenge - create efficient and user-friendly methods of simulating deformable characters

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Gradient Domain Editing of Deforming Mesh Sequences (SIGGRAPH 2007)

Weiwei Xu, Kun Zhou, Yizhou Yu*, Qifeng Tan†, Qunsheng Peng†, Baining Guo
Microsoft Research Asia, *UIUC, †State Key Lab of CAD & CG, Zhejiang Univ.

Gradient Domain Editing of Deforming Mesh Sequences (SIGGRAPH 2007)

Introduction

- Generalizes gradient domain static mesh editing to deforming mesh sequences
- Keyframe based
- Goal
  - Adapt existing deforming mesh sequences to conveniently produce desired ones that satisfy both user and environment requirements
  - Minimize user intervention
  - System should permit flexible and precise user control
  - Given very sparse constraints, results should preserve both temporal coherence and important characteristics of deformations in original mesh sequences

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Gradient Domain Editing of Deforming Mesh Sequences

Related work

- Previous work on surface and meshless deformations [Alexa 2003, Sheffer and Kraevoy 2004, Huang et al. 2006 . . .]
- Multiresolution mesh editing [Zorin et al. 1997, Kobbelt et al. 1998 . . .]
- Mesh inverse kinematics [Sumner et al. 2005 . . .]

Gradient Domain Editing of Deforming Mesh Sequences

Editing deforming mesh sequences

- User chooses to edit an arbitrary subset of frames. Each edited frame becomes a keyframe
- At each keyframe, user can also edit an arbitrary subset of handles
- Handle - subset of nearby vertices within the same frame
- For manipulating a handle, user only needs to drag one vertex in the handle to provide a positional constraint

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Advanced editing

- E.g. porting a walking sequence from a plane to an uneven terrain would require a lot of user interaction
- Hence advanced editing modes are built on top of the editing framework
  - Footprint editing
  - Path editing
  - Handle-based deformation mixing - Duplicating handle movements from a source sequence to a target sequence
  - Spacetime morphing

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Footprint editing

- During walking or running, at least one support leg in contact with ground - footprint
- Interval of frames where a handle remains fixed on the ground
- User defines handle that represents the foot.
- Detected by checking in what interval the position of the handle is unchanged or changes are less than a threshold
- Frames with footprints are set as keyframes
- Time saved by editing one handle at several frames simultaneously
- Footprints correctly capture constraints that should be satisfied in walking motion

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Path editing

- User only needs to sketch a curve on the ground as a new motion path
- Projects centroids of meshes in original sequence onto ground
- Fits a B-spline curve through these projected points
- Builds correspondence between original path and new one using arc length

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Handle-based deformation mixing

- Start with two deforming meshes and generate a new sequence that mixes the large-scale deformations of the first with the small-scale deformations of the second
- Uses motion trajectories of a sparse set of handles on the first mesh to define its large-scale deformations
- Forces the corresponding handles on the second mesh to follow these trajectories
- Align two corresponding trajectories using a global transformation
- Set transformed handle positions and rotations from first trajectory as constraints for corresponding handle on the second mesh

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Spacetime morphing

- Morphs a source deforming mesh A^s to a target deforming mesh A^t in terms of both shape and deformation
- E.g. A walking dinosaur morphs into a walking lion
- Preprocessing step - Both sequences are remeshed so that every pair of corresponding frames have same topology
- Uses cross-parametrization from [Kraevoy and Sheffer 2004]
- Constraints such as footprints should be handled in spacetime morphing as well

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Results

- Editing session has both online and offline stages
- Online keyframe editing - interactive frame rates using approximate initial solutions
- Followed by offline computation to obtain entire edited sequence
- Horse sequence - 29k triangles, 420 frames, 50 minutes of precomputation time, 30 minutes for solution, 1 hr session time (on a 3.2 GHz Intel Xeon with 4 GB memory). Includes virtual memory paging time

Gradient Domain Editing of Deforming Mesh Sequences

Summary

- Novel editing scenarios
- Intuitive editing
- Multithreading and novel acceleration techniques to improve performance

Embedded Deformation for Shape Manipulation (SIGGRAPH 2007)

Robert W. Sumner, Johannes Schmid, Mark Pauly
Applied Geometry Group, ETH Zurich

Embedded Deformation for Shape Manipulation

Introdution

- Embedded deformation - Deform space through direct manipulation of objects embedded within it, while preserving objects' features
- Motivation
  - Generality - Wide range of shape representations. Defined by affine transformations
  - Efficiency - Simple, general and independent of any particular geometry representation
  - Detail preservation - Small scale details should be preserved when a broad change in shape is made
  - Direct manipulation - Optimization problem where positional constraints are specified

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Embedded Deformation for Shape Manipulation
Background

- Related work
  - Singh and Fiume, 1998 - 'Wires' concept motivated by armatures used in traditional sculpting
  - Huang et al., 2006 - Subspace method for increased efficiency and stability
  - Sheffer and Kraevoy, 2004 - Nonlinear methods - highest quality at higher computational costs
- In these methods, algorithm is intimately tied to shape representation

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Embedded Deformation for Shape Manipulation

Deformation graph

- Space deformation represented by a collection of affine transformations organized in a graph structure.
- Each transformation induces a deformation on the nearby space
- Nodes (g_j) are connected by undirected edges
- Graph edges connect nodes of overlapping influence to indicate local dependencies
- Affine transformation for node j is specified by a 3x3 matrix R_j and a 3x1 translation vector t_j
- $\tilde{p} = R_j(p - g_j) + g_j + t_j$

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Embedded Deformation for Shape Manipulation

Results

- Detail preservation - Comparable or better results than previous work
- Intuitive editing - High quality edits by using a handful of single-vertex handle constraints
- Mesh animation - Online and offline mode. Preserves geometric details.
- Efficiency - Interactive performance

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Embedded Deformation for Shape Manipulation

Summary

- Comparable or better than existing methods
- Applies to variety of shapes
- Deformation graph is easy to construct and corresponds closely to embedded shape
- Complexity of deformation algorithm is not tied to geometric complexity of the embedded object

References

- Wikipedia - Interactive_skeleton-driven_simulation, Skeletal_animation, Deformation
- http://grail.cs.washington.edu/projects/deformation/