Real-Time Example-Based Elastic Deformation

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Example-Based Elastic Materials
[Martin11]

Our method

Shape Matching
[Müller05]

Finite Element Method

Speed up

Use
Example-Based Elastic Materials [Martin11]

Our method

Shape Matching [Müller05]

Finite Element Method (FEM)

Speed up
Example-Based Elastic Materials

[Martin11]

Rest shape + Example pose → Result of simulation
Advantages

1. Artist-friendly simulation
   – Direct design of deformations

2. No pre-defined scenarios
   – Useful for games...?
Limitation of [Martin11]

- **Slow**
  - not real-time, not interactive
  - Finite Element Method (FEM)
  - Non-linear optimizations

Our motivation: real-time, interactive
Real-Time Demo

Rest shape + Example pose
Example-Based Elastic Materials [Martin11]

Our method

Speed up

Finite Element Method

Shape Matching [Müller05]
Shape Matching [Müller05]

- Method for deformable objects
  - Geometry, not physics
  - Fast, robust, and stable
Key ideas

Rest shape \rightarrow A = RS \rightarrow Current shape

\( A \in \mathbb{R}^{3\times3} \)
- Linear transformation

\( R \in \mathbb{R}^{3\times3} \)
- Rotation

\( S \in \mathbb{R}^{3\times3} \)
- Stretch and shear

Polar decomposition
Extension to multi-region

- Overlapping local regions
  - Increasing the range of deformation
Deformation Descriptor

\[ A_1 = R_1 S_1 \]
\[ A_2 = R_2 S_2 \]
\[ A_3 = R_3 S_3 \]

\[ S = \left( S_1^T \quad S_2^T \quad \cdots \quad S_m^T \right)^T \in \mathbb{R}^{6m} \]
Goal pose
(Standard shape matching)
Goal pose
(Our method)

Rest pose

Current pose

Goal pose

Example Pose
Details of projection

1. Linear projection

\[ w_0 S^0 + w_1 S^1 \]
Details of projection

2. Clamping to avoid extrapolation

Constraints: $0 \leq w_i \leq 1$
Details of projection

3. Ensuring the deformation will return
Modifying the Shape Matching

\[ \tilde{S} = \left( \tilde{S}_1^T \tilde{S}_2^T \cdots \tilde{S}_m^T \right)^T \]

Goal strain of each local region

Region \( i \)

\[ R_i \tilde{S}_i \]
Non-linear vs Linear

[Martin11] FEM

Our Method
Shape Matching
Results and Discussions
Results
Rough comparison

1. Quality

- Very similar effect of example pose

<table>
<thead>
<tr>
<th>[Martin11]</th>
<th>Our Method</th>
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Rough comparison

2. Performance

- Two, or three orders magnitude faster

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<thead>
<tr>
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<tbody>
<tr>
<td>Vertices</td>
<td>325</td>
<td>225</td>
</tr>
<tr>
<td>Time [ms]</td>
<td>528 / 3064</td>
<td>0.33</td>
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(twisting cuboid)
Limitation

• Physical accuracy
  [Good] FEM
  [Poor] Shape Matching
Future Work

2D structures (e.g. cloth)  1D structures (e.g. hair)

[Müller11]
Summary

- New method for example-based materials
  - Based on shape matching technique
  - Real-time, interactive
  - Decreased physical accuracy
Case of two examples
(manifold should be a plane)
Local Examples

- Separate groups
- Manipulated independently
Comparison

Martin et al.

Our method
Shape Matching

Model = A set of particles

Rest configuration
Shape Matching

Rest configuration

Current configuration
Shape Matching

Goal configuration
Shape Matching

Goal configuration

Rigid transformation
(Translation + Rotation)
Shape Matching

Rigid transformation
(Translation + Rotation)

Pull towards the goal positions