Skinning Mesh Animations

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Skinning Mesh Animations

Outline

• Introduction & Motivation
• Overview & Details
• Results
• Discussion
Introduction

• Mesh sequence:
General setting

• Animation simplification
  – Direct data reduction (PCA, ...)
  – Skeleton subspace deformation (SSD)
Skinning Mesh Animations

General setting

Traditional skeleton:
• Hierarchy
• Joints
• Angles

This paper’s approach:
• No hierarchy
• Only transformations
Premises

• Mesh sequence:
  \[ \mathbf{P} = (p^1, p^2, \ldots, p^S) \]
  \[ t = 1..S: \text{“time“} \]
  \[ p^t: \text{All vertices at step } t \]
• Rest (or reference) pose: \[ \tilde{p} \]
Goal

• Linear Blend Skinning:
  - \( p^t \approx T^t \bar{p} \)
  - \( T^t_i = \sum_{b \in \mathcal{B}_i} w_{ib} \bar{T}^t_b \)

• We are looking for \( \bar{T}^t_b \), \( \mathcal{B}_i \) and \( w_{ib} \)
Overview

- Identify near-rigid structures
- Estimate bone transforms
- Estimate vertex weights
- Progressive skin corrections
Overview

- Identify near-rigid structures
- Estimate bone transforms
- Estimate vertex weights
- Progressive skin corrections
Identify structures

- Triangle rotation sequence:

- Polar Decomposition: $F = RW$

  - Rotation
  - Stretch
Identify structures

- \( z_j = \left( \text{vec}(R_j^1), \ldots, \text{vec}(R_j^S) \right) \)
- Mean shift clustering over \( z_j \)
Identify structures

- Triangles within $\varepsilon$ of found modes/bones are core triangles
  - Strongly associated with bone
  - Make up near-rigid structure
  - Total fraction of core triangles determines quality
Identify structures
Overview

• Identify near-rigid structures
• **Estimate bone transforms**
• Estimate vertex weights
• Progressive skin corrections
Estimate bone transforms

• Rigid bones
  – Rotation and translation
  – Take average rotation of core triangles
    ⇒ Arithmetic mean of triangle rotation mat.
  – Find translational part by fitting to the core triangle centroids
Estimate bone transforms

• Flexing bones
  – Bones can stretch and shear (not bend)
  – Rigid bones: rotation/translation pair \((R,v)\)
  – Flexing bones: \((F,v)\) with \(F = RW\)
  – LS fit to match motion of core triangle
Overview

• Identify near-rigid structures
• Estimate bone transforms
• **Estimate vertex weights**
• Progressive skin corrections
Estimate mesh skin

- Remember: \[ T_i^t = \sum_{b \in B_i} w_{ib} \bar{T}_b^t \]

- Find \( B_i \):
  - Find \( \beta \) bone transforms \((\bar{T}_b^t)\) which individually lead to the best possible result
Estimate mesh skin

- Find vertex weights $w_{ib}$:
  - Match transformed vertices to mesh sequence
    \[
    \sum_{b \in B_i} (\tilde{T}^t_b \tilde{p}_i) w_{ib} = p^t_i, \quad t = 1 \ldots S
    \]
  - Weights must sum up to 1
    \[
    \sum_{b} w_{ib} = 1
    \]
Estimate mesh skin
Estimate mesh skin

- Weight over-fitting
  - Negative weights lead to unstable skins
  - Use nonnegative least squares (NNLS) to obtain strictly positive weights
Almost there...

Source animation

Approximation
Overview

• Identify near-rigid structures
• Estimate bone transforms
• Estimate vertex weights
• Progressive skin corrections
Progressive skin corrections

- As described in Kry, Paul G. et al. 2002: EigenSkin

- Transform errors back to rest pose
- Perform data reduction (PCA, SVD)
- Add result to rest pose
Results

• Benefits of skinned meshes:
  – Animation compression
Results

• Benefits of skinned meshes:
  – Hardware acceleration
Results

- Benefits of skinned meshes:
  - Rest pose editing
Results

• Benefits of skinned meshes:
  – Fast collision detection
Results

• Problems:
  – Highly deformable models
Results

• Benefits of skinned meshes:
  – Animation compression
  – Hardware acceleration
  – Rest pose editing
  – Collision detection

• Problems:
  – Highly deformable models

• Computation of skin: Order of Minutes
Opinions & Discussion