Sensitivity-optimized Rigging for Example-based Real-time Clothing Synthesis

Weiwei Xu*
Nobuyuki Umentani*
Qianwen Chao
Jie Mao
Xiaogang Jin
Xin Tong

(*=joint 1st authors)
Motivation

- Fast clothing synthesis for interactive application

[Winning Eleven 2014] [Assassins Creed]
Key Assumption: Pose-to-Clothing Mapping
Example-based Clothing Synthesis

Input: body pose (i.e. joint rotations)
Database
Output: clothing (i.e. vertex positions)
CPU Implementation 60FPS
CPU+GPU 200 Characters 20FPS
Related Works: Example-based Clothing

[de Aguiar et al. 2010]  [Peng et al. 2010]  [Wang et al. 2010]  [Kavan et al. 2010]

[Wang et al. 2013]  [Kim et al. 2008]  [Feng et al. 2010]  [Hahn et al. 2014]
State of the Art (quality vs. speed)

- Regression + Regularization
- Multi-resolution
- Detailed wrinkle
- Regression
- Multi-character detailed wrinkle

Our approach

Real-time Multi-character
Our Approach: Rigged Clothing

We use Linear Blend Skinning for clothing

\[
x = \sum_b w_b \left( R_b x_0 + T_b \right)
\]

\[
y = \sum_b w_b \left( R_b y_0 + T_b \right)
\]
Challenges for Rigged Clothing

• Clothing move differently from body forming wrinkle
Dividing Clothing Into Parts

• Global joint-clothing influence
• Locality of the clothing wrinkle
Multi-prediction approach

- Clothing deformation is very nonlinear

Rigging

- Right arm up
- Left arm up
- Both arms up

+ ≠
Our Approach: Rigged Clothing

We use Linear Blend Skininning for clothing

\[ x = \sum_b w_b \left( R_b x_0 + T_b \right) \]

\[ y = \sum_b w_b \left( R_b y_e + T_b \right) \]
Procedure: Rigging & Blending

Input pose

Examples

Nearest examples

Rigging

Blend

Output cloth
Procedure: Skinning & Blending

1. Input pose
2. Examples
3. Nearest examples
4. Rigging
5. Blend
6. Output cloth
Database: Example Poses & Clothing
Procedure: Rigging & Blending

Input pose

Examples

Nearest examples

Rigging

Blend

Output cloth
Procedure: Skinning & Blending

Input pose

Examples

Nearest examples

Rigging

Blend

Output cloth
Procedure: Skinning & Blending

- Input pose
- Examples
  - Nearest examples
- Rigging
- Blend
- Output cloth
Contributions

Examples’ rigging model

Sensitivity-optimized rigging

Find nearest examples to

Sensitivity distance measure

Determine example poses

MCMC approach
Procedure: Skinning & Blending

Input pose

Examples

Nearest examples

Rigging

Blend

Output cloth
1st order Prediction of Clothing Deformation

\[ d = \frac{\partial}{\partial \vartheta} d \]
Sensitivity for Pose change

- Good representation around example 😊
- Memory intensive 😞
- Linear approximation 😞
Skinning Weight Optimization

Linear Blend Skinning

\[ y' = \sum_{b} w_b (R_b y + T_b) \]

\[ \text{arg min } w_b \left| \frac{\partial}{\partial} \right| \text{rigged} - \left| \frac{\partial}{\partial} \right| \text{simulated} \]
Sensitivity for Pose Change

- Optimize weight to best approximate sensitivity
Optimized Clothing Rigging Weight

Body weight

Naïve clothing weight

Optimized clothing weight
Comparison against Naïve Weight

Example cloth

Naïve clothing weight

Optimized clothing weight
Procedure: Skinning & Blending

1. Input pose
2. Examples
   - Nearest examples
3. Rigging
4. Blend
   - Output cloth
Selecting & Blending with Distance Measure

• K-Nearest neighbor interpolation
Distance Measure

- Compare **body shape or joint angles** difference

Distance = | Input pose | example pose |
          |           |           |
          | Input    | Distance  |
          | example  | Distance  |
          | example  | Distance  |
          | example  | Distance  |
Drawback of the Typical Approach

• Cannot tell amount of influence of joint to cloth

90 degree Knee bending

90 degree shoulder bending

Same distance

similar
different
Distance Measure: Our approach

• Compare clothing shape difference

Distance = | cloth on input pose | cloth on example pose |
Sensitivity-based Distance

- Difference between sensitivity predictions

Typical distance

Our distance

Pose

cloth shape
Comparison with Naive Approaches

unrealistic nearest example (same database is used)

All joints angle  Nearest joint for each region  Our approach
Procedure: Skinning & Blending

Input pose --> Nearest examples --> Skinning --> Blend --> Output cloth

Examples
Incremental Database Construction

1. Find the maximum residual pose (MCMC method)
2. Solve cloth deformation at the pose
3. Add the deformation to database
More Results
Manipulating 200 characters using GPUs
Kinect “try-on”
Comparison with Physics Simulation

our synthesis  physics simulation
Limitations

- Secondary motion
- Hysteresis
- Database accuracy guarantee
Acknowledgement

• We would like to thank:
  – Anonymous Reviewer
  – CMU MoCap data
  – Ryan Schmidt and Michel Tao

• Funded by:
  – NSFC 61272392, 61322204, 61272298, 61328204
  – State Key Lab of CAD&CG, A1307
  – National High-tech R&D Program 2012AA011503
Thanks for Your Attention!

- **Summary:**
  Fast example-based clothing synthesis using rigging approach
# Database Size

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<th>LS</th>
<th>Sh</th>
<th>LP</th>
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</table>
Fast Cloth-Body Intersection Resolving

1. Blend deformed example
2. Project blended deformation for each example
3. Blend the deformation again
Result of Intersection Resolution

*Without* Resolution

*With* Resolution