POSE-SPACE IMAGE-BASED RENDERING

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Virtual Dressing Room

Nice and realistic clothes are expensive!
Virtual Dressing Room

Body-pose dependent image-based rendering: interpolate and merge clothing appearance in *pose-space*
Assumptions

• Aim: perceptually correct visualization instead of accurate reconstruction
  → allows image-based approach

• Wrinkles, creases and appearance of tight-fitting clothes are pose-dependent
  → allows modeling of appearance as a function of body poses

• Wrinkling behavior is mainly influenced by the nearest joints
  → allows partition of the pose-space (interpolation domain) into subspaces related to body parts
Related Work

• **Image-based rendering (IBR):** View-dependent appearance examples, synthesis restricted to viewpoint change
  - Unstructured Lumigraph [Buehler2001], Unstructured Lightfields [Davis2012]
  - View-Dependent Texture Mapping [Debevek1996, Porquet2005]...
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• **Pose-space deformation (PSD):** Pose-dependent shape deformation examples, shapes for new poses are interpolated in *pose-space*
  - Wrinkle synthesis [Wang 2010]
Related Work

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- **Pose-space deformation (PSD):** Pose-dependent deformation examples, shapes for new poses are interpolated in pose space
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Our work: **Pose-Space Image-Based Rendering (PSIBR)= pose-dependent interpolation of appearance**
Database Representation

Images $\mathcal{I}_i$

3D meshes $\mathcal{M}^3 : \{ \mathbf{V}_i^3, \mathcal{F}_i \}$
with skinning weights
[Snavely2008, Baran2007]

Pose representation $\mathbf{q}_i$
[Fechteler2012]
Database Representation

Images $I_i$

3D meshes $M^3 : \{V^3_i, F_i\}$
with skinning weights
[Snavely2008, Baran2007]

Pose representation $q_i$
[Fechteler2012]

Database warps $W_{i \rightarrow j}$
[Hilsmann2010]

Pose space
Database Warps

Joint spatial and photometric image warps

\[ \mathcal{W}_p(\mathcal{I}_i(\mathcal{W}_s(x))) \approx \mathcal{I}_j(x) \]

Mesh-based warps:

Spatial warp \( \mathcal{W}_s : \{V_i, F_i, \Delta V_{i \rightarrow j}\} \)

Photometric warp \( \mathcal{W}_p : \{V_i, F_i, \rho_{i \rightarrow j}\} \)

Joint warp \( \mathcal{W} : \{V_i, F_i, \Delta V_{i \rightarrow j}, \rho_{i \rightarrow j}\} \)
Database Warps

**SSD-warp:** SSD (skeletal subspace deformation)-animation of 3D mesh and projection into new view

\[ \mathcal{W}_{i \rightarrow j}^{SSD} : \{ V_i, F_i, \Delta V_{i \rightarrow j}^{SSD}, 1, \} \]

SSD-warp only coarsely animates the image but does not capture real texture deformation and changes in shading.
Database Warps

Additional fine-scale warp: accurate registration of images close to each other in pose-space [Hilsmann2010]

\[ W_{i \rightarrow n}^{fine} : \{ V_i + \Delta V_{i \rightarrow n}^{SSD}, F_i, \Delta V_{i \rightarrow n}^{fine}, \rho_{i \rightarrow n}^{fine} \}, n \in N_i \]

Final warp: \[ W_{i \rightarrow n} = W_{i \rightarrow n}^{SSD} \oplus W_{i \rightarrow n}^{fine} \]
Database Warps

\[ \mathcal{W}_{i \rightarrow n} : \mathcal{W}^{SSD}_{i \rightarrow n} \oplus \mathcal{W}^{fine}_{i \rightarrow n} \]

: \{ \mathbf{V}_i, \mathcal{F}_i, \Delta \mathbf{V}^{SSD}_{i \rightarrow n} + \Delta \mathbf{V}^{fine}_{i \rightarrow n}, \rho^{fine}_{i \rightarrow n} \}

SSD-warps
- Animates the image, but does not capture
  - real deformation
  - texture and shading differences

Final warp
- An additional fine-scale warp corrects these errors both in the spatial as well as the photometric domain
Pose-Space Image-Based Rendering
Pose-Space Image-Based Rendering

\[ \tilde{\mathcal{W}}_{i \rightarrow a} = \mathcal{W}_{i \rightarrow a}^{SSD} \oplus \tilde{\mathcal{W}}_{i \rightarrow a}^{fine} \]
Pose-Space Image-Based Rendering

Interpolated warps

$$\tilde{\mathcal{W}}_{i \rightarrow a} = \mathcal{W}_{i \rightarrow a}^{SSD} \oplus \mathcal{W}_{i \rightarrow a}^{fine}$$

defined by geometry and skeleton

unknown and interpolated from example warps

Scattered data interpolation: smooth weighting function \(w_n(q)\) per example warp

$$\Delta \tilde{V}_{i \rightarrow a}^{fine} = \sum_{n \in \mathcal{N}_i} w_n(q_a) \cdot \Delta V_{i \rightarrow n}^{fine}$$

$$\tilde{\rho}_{i \rightarrow a}^{fine} = \sum_{n \in \mathcal{N}_i} w_n(q_a) \cdot \rho_{i \rightarrow n}^{fine}$$

K-nearest neighbors [Buehler2001]
Image Blending

\[ I_a(x) = \sum_{i=1}^{m} b_i(q_a) \cdot \tilde{\mathcal{W}}_{i\rightarrow a}(I_i(x)) \]
Definition of Subspaces

- Pose-space is very high-dimensional
- Wrinkling is mostly affected by the nearest joints \[\text{[Wang2010]}\]
  - Subspaces related to body parts (e.g. left/right)
  - Different pose-graphs per subspace
  - Local warp interpolation and blending
  - Influence weights per body part and vertex
Results
Image Matching

- Distance in pose-space
  \[ d_{ai} = \| q_a - q_i \| \]
  alone is not a good measure for the appropriateness of a database image

- Known warps have to be taken into account
  \[ e_{ai} = \| q_a - \sum_{n \in N_i} w_n q_n \| , 0 \leq w_n \leq 1 \]

- Combined distance measure
  \[ d'_{ai} = (1 - \alpha) \cdot d_{ai} + \alpha \cdot e_{ai} \]

- Introduction of a consistency measure for a smooth animation
  \[ d''_{ai} = (1 - \beta) \cdot d'_{ai} + \beta \cdot d_{pri} \]
Results – Pose Selection

- distance in pose-space only
- with warp consideration
- with additional temporal consistency

α = 0, β = 0

α = 0.9, β = 0

α = 0.9, β = 0.01
Results - Extrapolation
Limitations

• Original piece of clothing needs to be captured and processed in advance, no variation of appearance (e.g. texture)
  → combination with retexturing methods

• Variety of possible pose images depends on sampling of the pose-space
  → dense sampling

• SSD artifacts for extreme animation
  → other base animation methods

• Occlusions
  → include occlusions in database
Conclusions and Future Work

- Pose-dependent image-based rendering approach
- Interpolation of image warps and appearances in pose-space
- Subdivision of the pose-space allows for a larger variety of poses
- Generally not restricted to clothing

Future Work

- Occlusion handling
- Other underlying animation methods than SSD/LBS
- Combination with retexturing methods to allow for texture modification

[Hilsmann2011]
Thank you!
References