POSE-SPACE IMAGE-BASED RENDERING

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Virtual Dressing Room

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
  - Lumigraph [Gortler1996], Lightfields [Levoy1996]
  - Unstructured Lumigraph [Buehler2001], Unstructured Lightfields [Davis2012]
  - View-Dependent Texture Mapping [Debevek1996, Porquet2005]...

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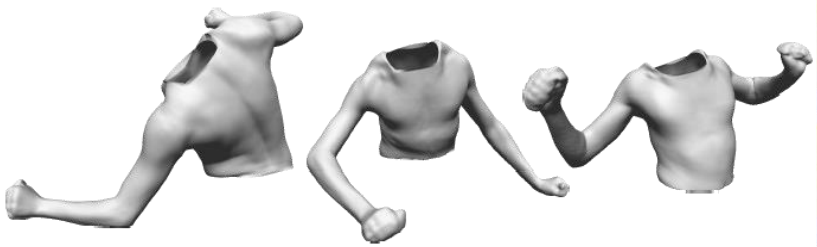
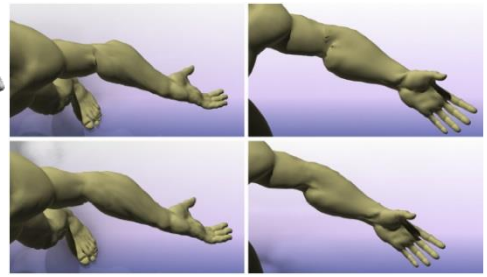
- Pose-space deformation (PSD): Pose-dependent shape deformation examples, shapes for new poses are interpolated in *pose-space*
  - Scattered interpolation of muscle deformations [Lewis 2000, Sloan 2001, Weber2007]
  - Wrinkle synthesis [Wang 2010]



[Allen2001]



[Weber2007]

[Wang 2010]

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Our work:
Pose-Space Image-Based Rendering (PSIBR)= pose-dependent interpolation of appearance

[Allen2001]

[Weber2007]

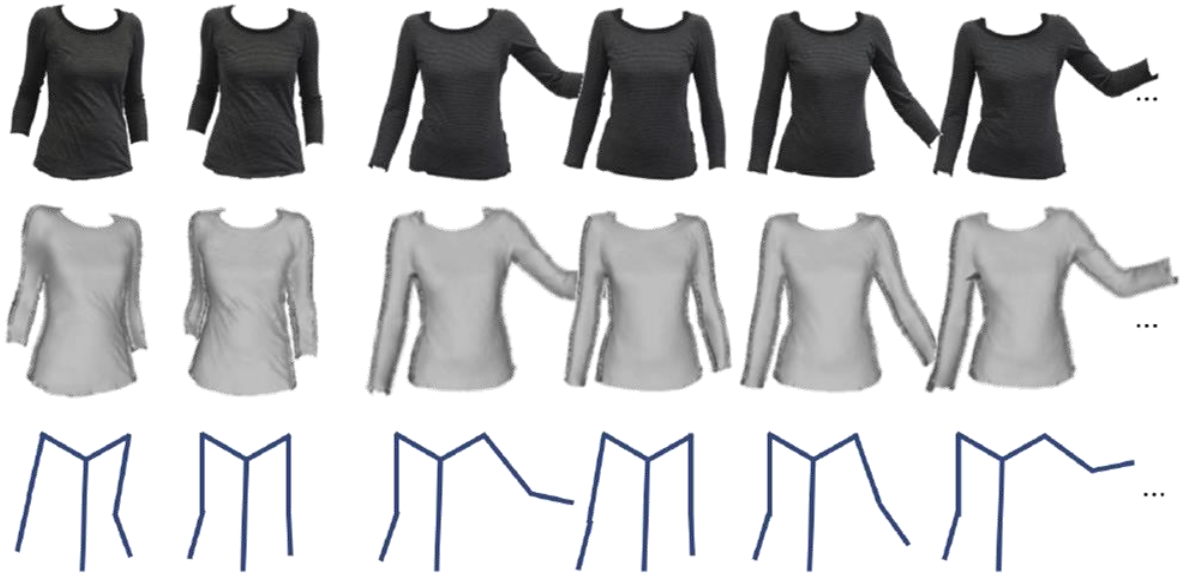
[Wang 2010]

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]



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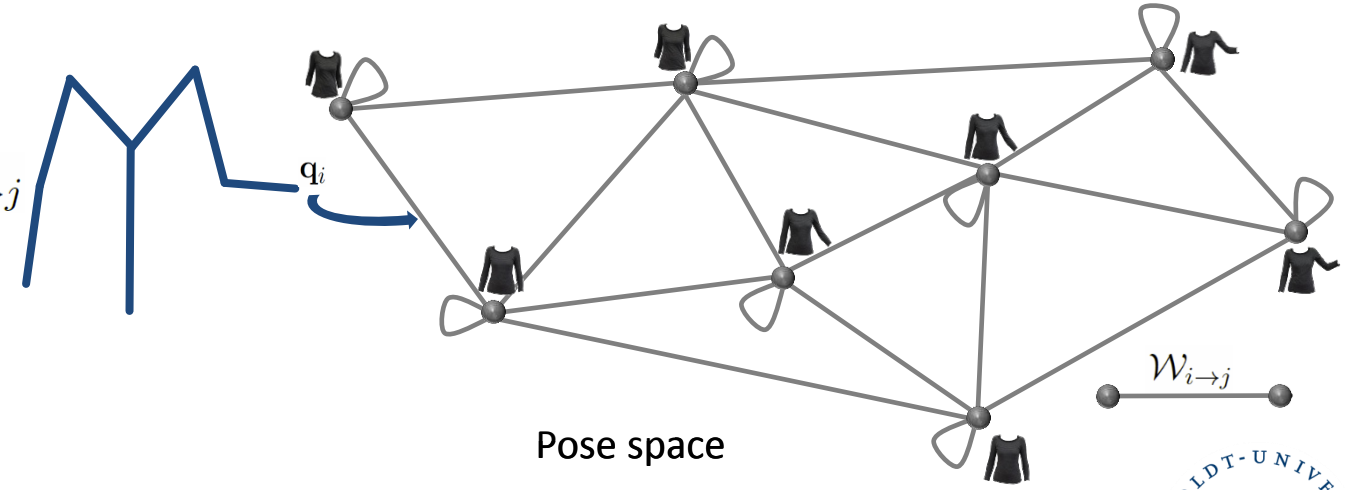
Database warps $\mathcal{W}_{i \to j}$
[Hilsmann2010]



Pose space

Database Warps

Joint spatial and photometric image warps
[Hilsmann2010]

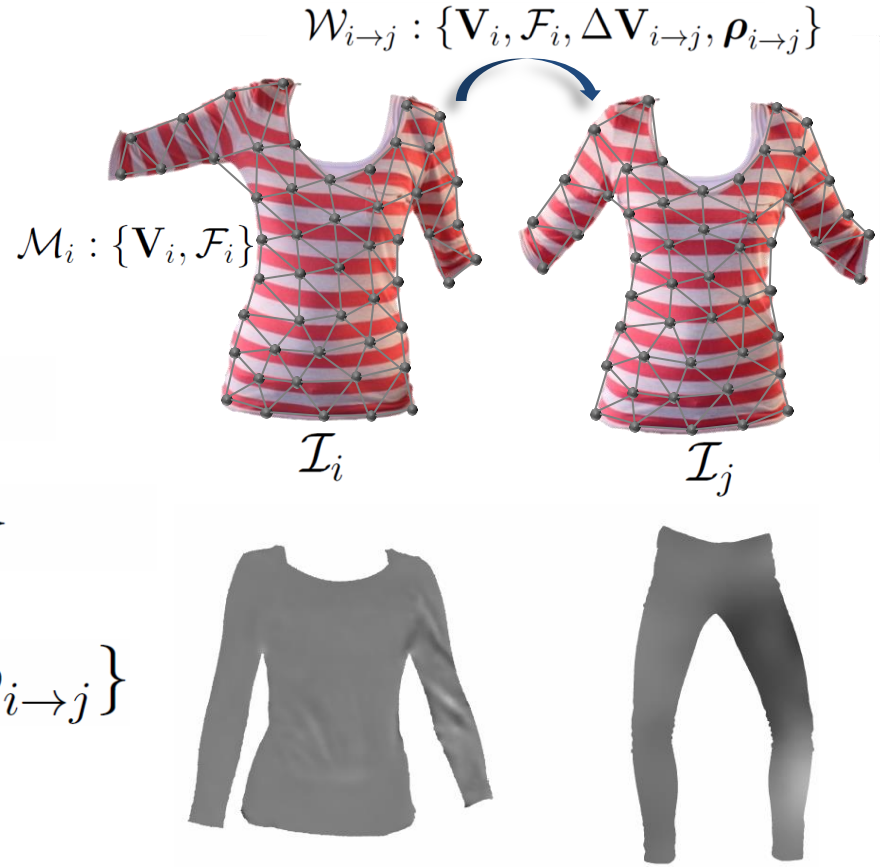
$$\mathcal{W}_p(\mathcal{I}_i(\mathcal{W}_s(\mathbf{x}))) \approx \mathcal{I}_j(\mathbf{x})$$

Mesh-based warps:

Spatial warp $\mathcal{W}_s : \{\mathbf{V}_i, \mathcal{F}_i, \Delta\mathbf{V}_{i\to j}\}$

Photometric warp $\mathcal{W}_p : \{\mathbf{V}_i, \mathcal{F}_i, \boldsymbol{\rho}_{i\to j}\}$

Joint warp $\mathcal{W} : \{\mathbf{V}_i, \mathcal{F}_i, \Delta\mathbf{V}_{i\to j}, \boldsymbol{\rho}_{i\to j}\}$



Database Warps

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

$$\mathcal{W}_{i\to j}^{\mathcal{SSD}} : \{\mathbf{V}_i, \mathcal{F}_i, \Delta\mathbf{V}_{i\to j}^{\mathcal{SSD}}, \mathbf{1}, \}$$

$$\mathcal{W}_{i\to j}^{\mathcal{SSD}}(\mathcal{I}_i) \leftrightarrow \mathcal{I}_j$$

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

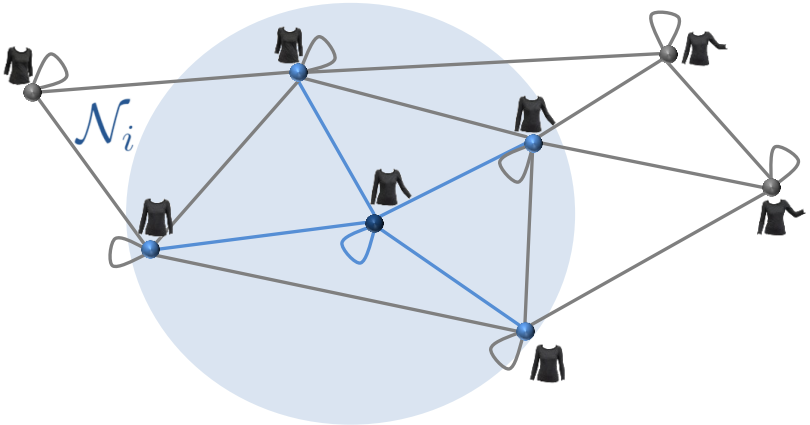
Database Warps

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

$$\mathcal{W}_{i\to n}^{fine} : \{\mathbf{V}_i + \Delta\mathbf{V}_{i\to n}^{\mathcal{SSD}}, \mathcal{F}_i, \Delta\mathbf{V}_{i\to n}^{fine}, \boldsymbol{\rho}_{i\to n}^{fine}\}, n \in \mathcal{N}_i$$

Final warp: $\mathcal{W}_{i\to n} = \mathcal{W}_{i\to n}^{\mathcal{SSD}} \oplus \mathcal{W}_{i\to n}^{fine}$

$\mathcal{W}_{i\to n}(\mathcal{I}_i) \leftrightarrow \mathcal{I}_n$



Database Warps

$$\mathcal{W}_{i\to n} : \mathcal{W}^{\mathcal{SSD}}_{i\to n} \oplus \mathcal{W}^{fine}_{i\to n}$$
$$: \{\mathbf{V}_i, \mathcal{F}_i, \Delta\mathbf{V}^{\mathcal{SSD}}_{i\to n} + \Delta\mathbf{V}^{fine}_{i\to n}, \boldsymbol{\rho}^{fine}_{i\to n}\}$$

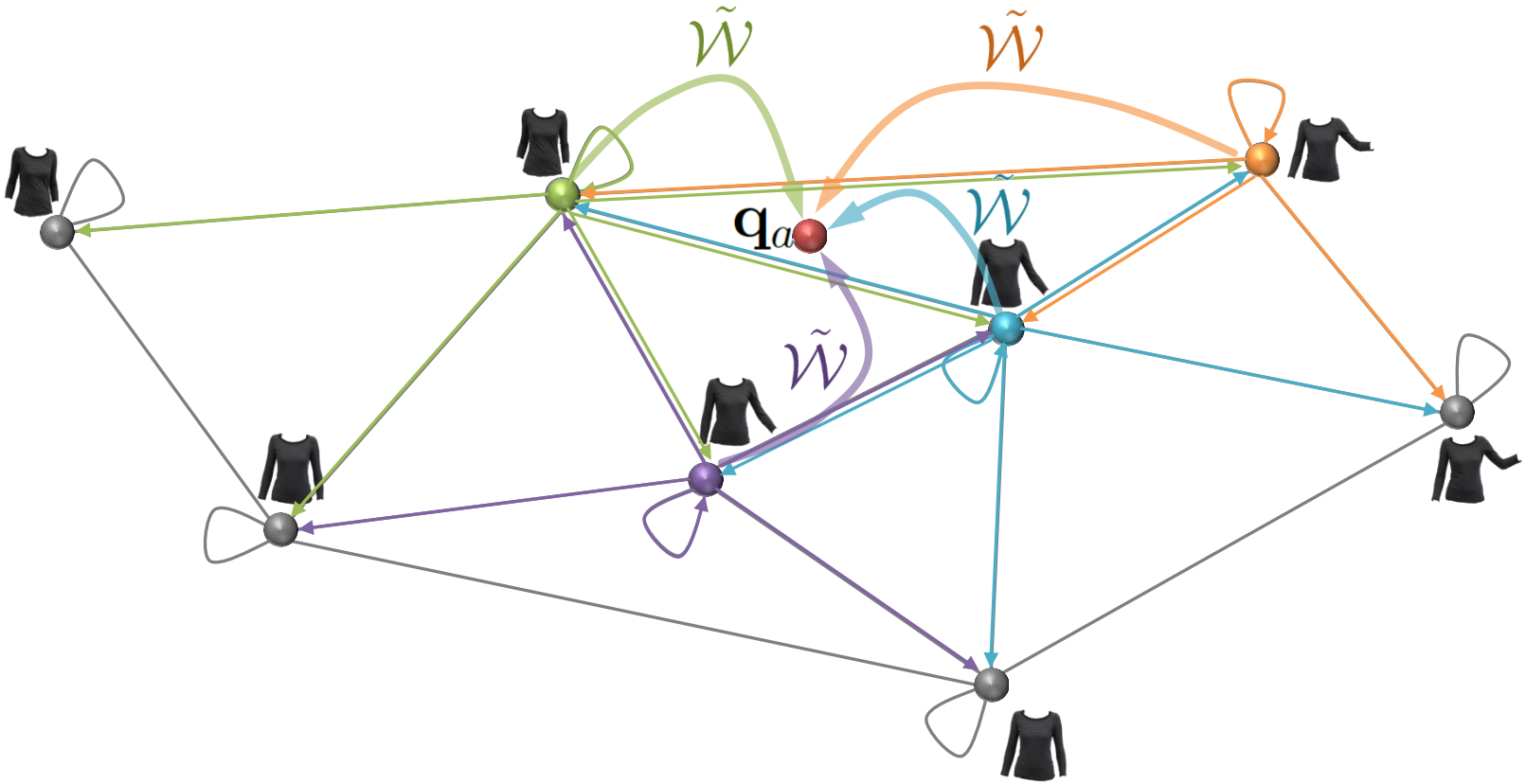
SSD-warp

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

Final warp

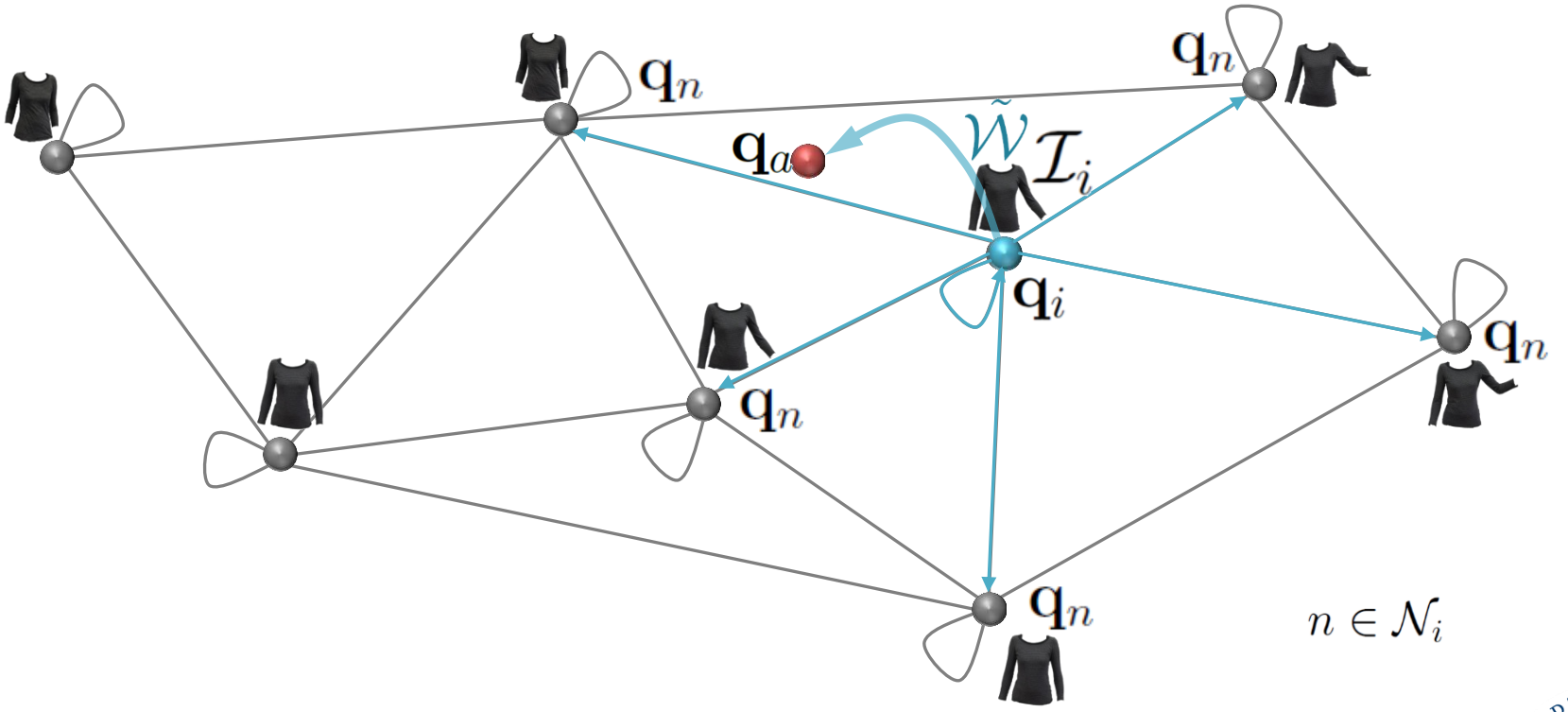
- An additional fine-scale warp corrects these errors both in the spatial as well as the photometric domain

Pose-Space Image-Based Rendering



Pose-Space Image-Based Rendering

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



Pose-Space Image-Based Rendering

Interpolated warps $\tilde{\mathcal{W}}_{i\to a} = \mathcal{W}^{\mathcal{SSD}}_{i\to a} \oplus \tilde{\mathcal{W}}^{fine}_{i\to a}$

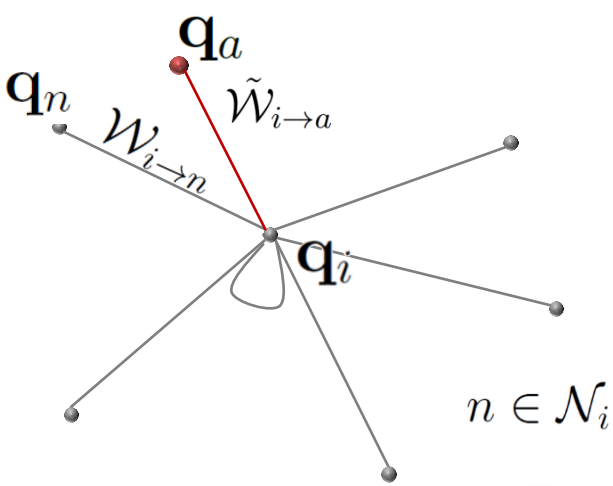
defined by geometry and skeleton

unknown and interpolated from example warps

Scattered data interpolation: smooth weighting function $w_n(\mathbf{q})$ per example warp

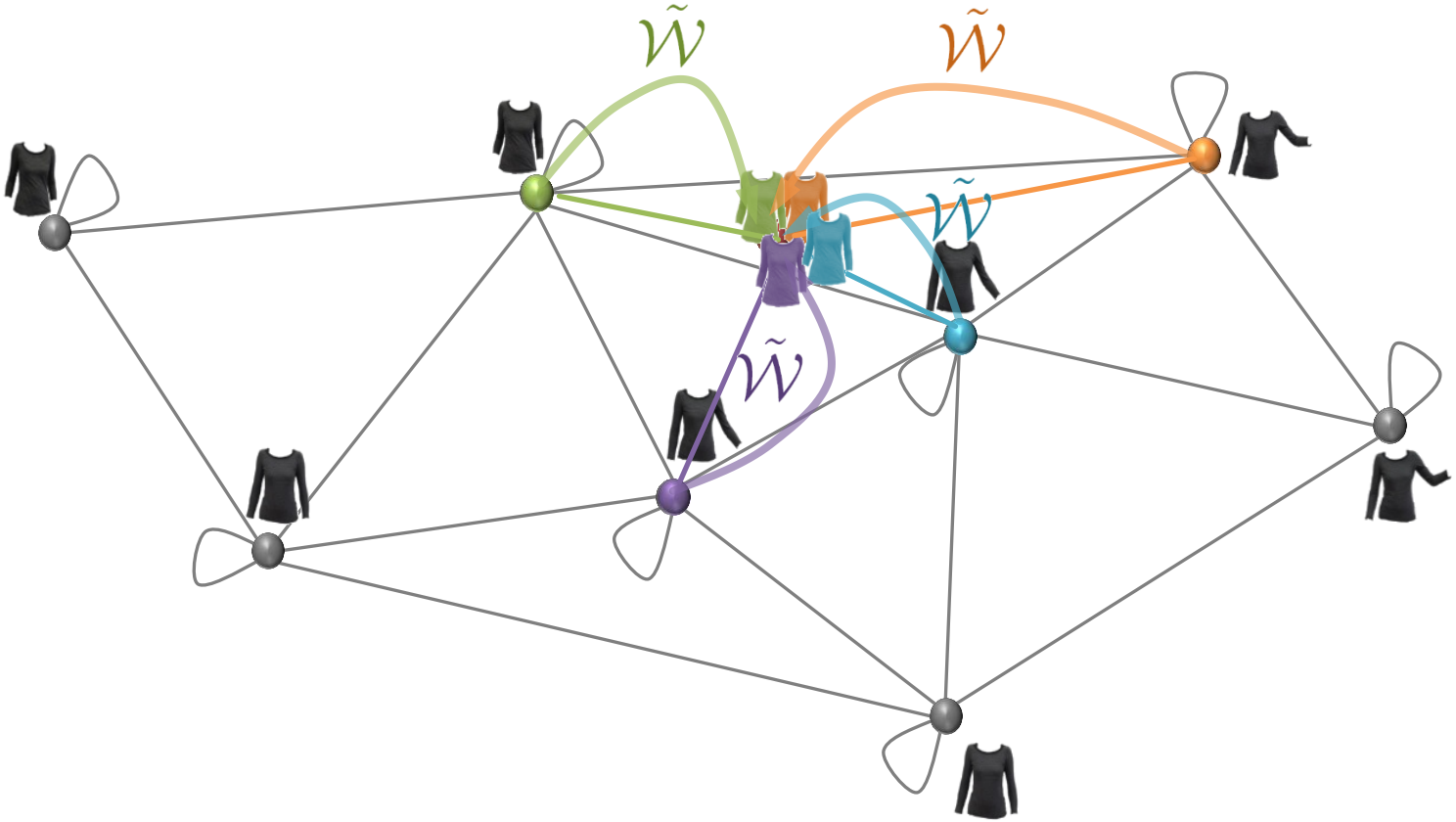
$$\Delta\tilde{\mathbf{V}}^{fine}_{i\to a} = \sum_{n\in\mathcal{N}_i} w_n(\mathbf{q}_a)\cdot\Delta\mathbf{V}^{fine}_{i\to n}$$

$$\tilde{\boldsymbol{\rho}}^{fine}_{i\to a} = \sum_{n\in\mathcal{N}_i} w_n(\mathbf{q}_a)\cdot\boldsymbol{\rho}^{fine}_{i\to n}$$



K-nearest neighbors [Buehler2001]

Image Blending



$$\mathcal{I}_a(\mathbf{x}) = \sum_{i=1}^{m} b_i(\mathbf{q}_a) \cdot \tilde{\mathcal{W}}_{i \to a}(\mathcal{I}_i(\mathbf{x}))$$

Definition of Subspaces

- Pose-space is very high-dimensional
- Wrinkling is mostly affected by the nearest joints [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

Local

Global

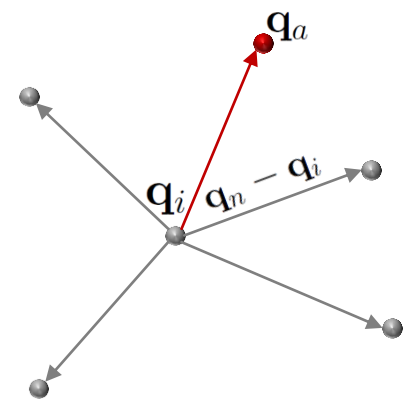
Results

Image Matching

- Distance in pose-space

$$d_{ai} = \|\mathbf{q}_a - \mathbf{q}_i\|$$

alone is not a good measure for the appropriateness of a database image



- Known warps have to be taken into account

$$e_{ai} = \|\mathbf{q}_a - \sum_{n \in \mathcal{N}_i} w_n \mathbf{q}_n\| \ , 0 \leq w_n \leq 1$$

- Combined distance measure

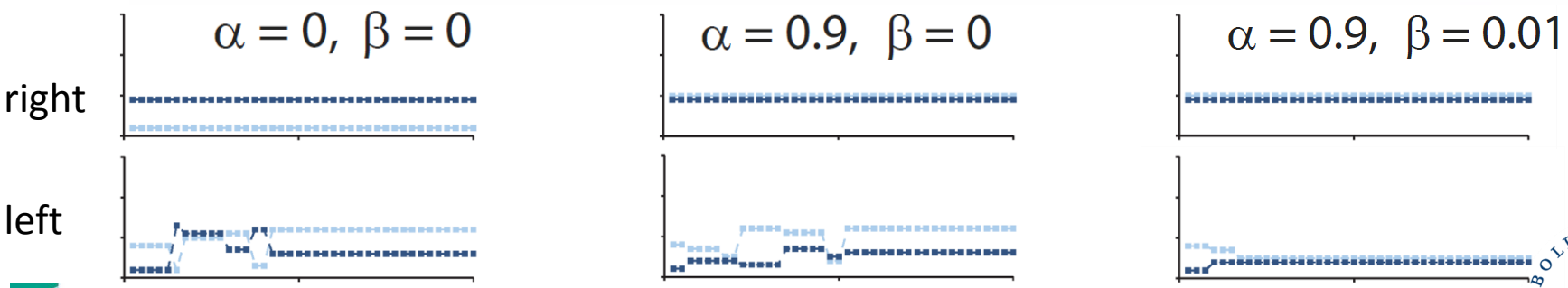
$$d'_{ai} = (1 - \alpha) \cdot d_{ai} + \alpha \cdot e_{ai}$$

- Introduction of a consistency measure for a smooth animation

$$d''_{ai} = (1 - \beta) \cdot d'_{ai} + \beta \cdot d_{\mathrm{prv}i}$$

Results – Pose Selection

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



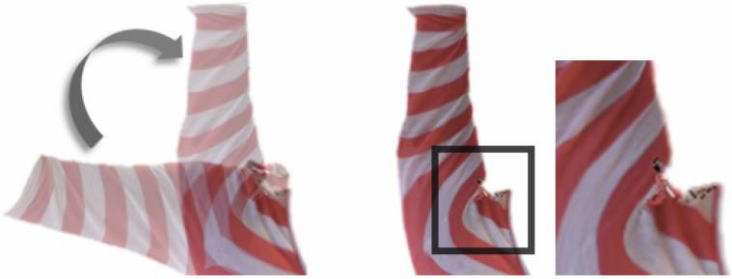
Results - Extrapolation

Limitations

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

[Hilsmann2011]

- 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!

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