18 September 2017

DEFORMATION TRANSFER OF 3D HUMAN SHAPES AND POSES ON MANIFOLDS

ICIP 2017

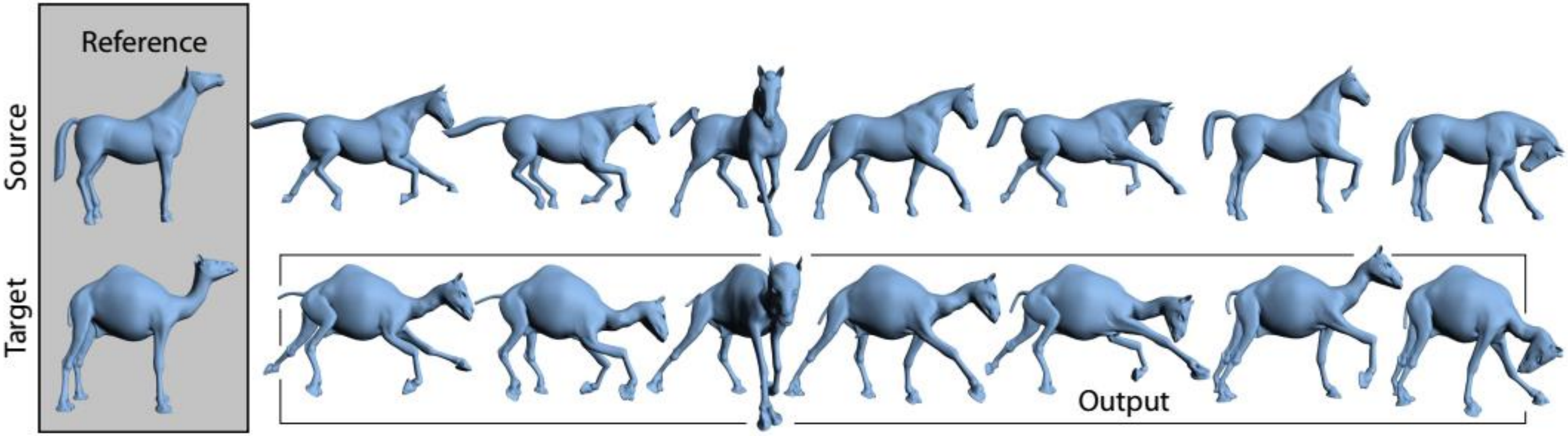
Abd El Rahman Shabayek, Djamila Aouada, Alexandre Saint, Björn Ottersten

Interdisciplinary Centre for Security, Reliability and Trust
Signal Processing & Satellite Communications (SIGCOM) group

Agenda

1. Introduction
2. Manifold Representation of 3D Human Shape
3. Deformation Transfer on Manifolds
4. Results
5. Conclusion & Future work

Introduction

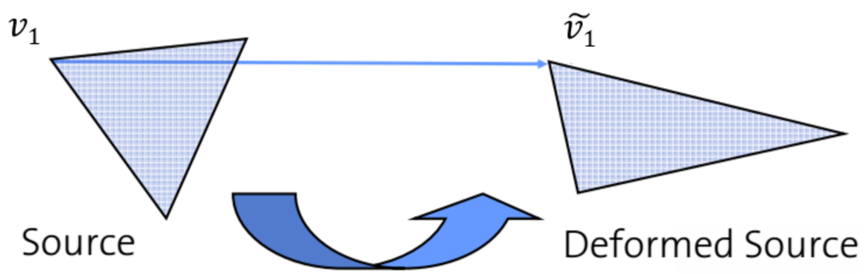


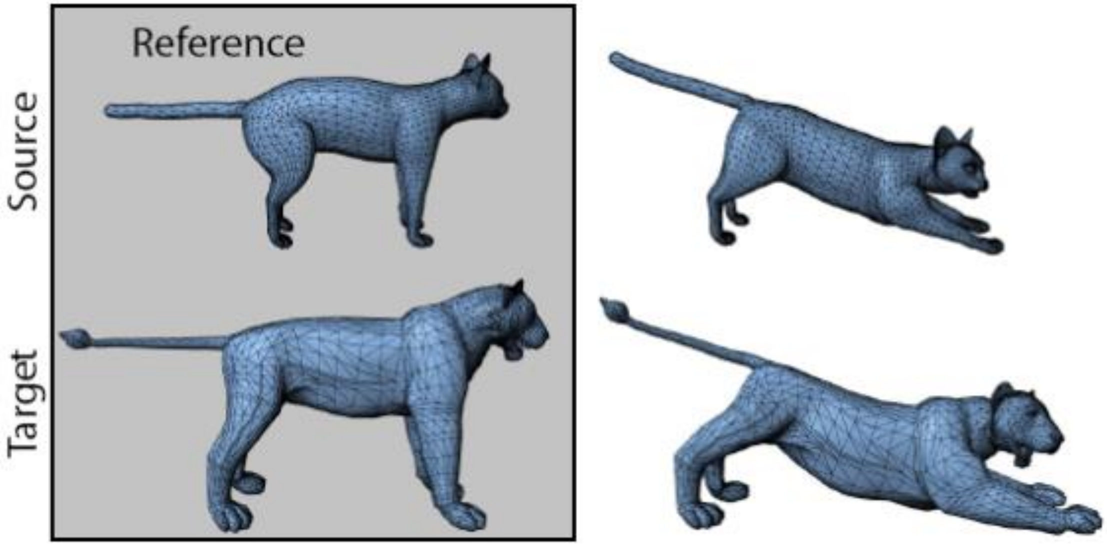
Deformation transfer copies the deformations exhibited by a source mesh onto a different target mesh.

Deformation Transfer for Triangle Meshes
Robert W. Sumner and Jovan Popovic
SIGGRAPH 2004.

Introduction: Euclidean Deformation Transfer for Triangle Meshes

- Deformation is based on a per-triangle affine transformation $Qv_i + d = \tilde{v}_i,\ i \in 1 \dots 4$





Introduction: Limitations of existing solutions

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- Existing methods are based on **Euclidean representations**.
- The triangle deformation: **3x3** deformation matrix and a **3D** displacement vector.
- The **9D (redundant DoF)** of deformations is **under-constrained** as **deformations outside the plane** of the triangle are **undefined**.
  - A fourth virtual vertex defined by the cross product of two of the triangle edges is added **heuristically** .
- Deformations may have **zero** or **negative** determinant (inconsistent deformations)
  - Thus **do not exclude non-physical deformations**.

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Introduction: How to solve the current problems?

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- We are seeking:
  - An accurate representation which **eliminates redundant** DoF.
  - Deformations to be computed in **closed-form without heuristics**.
  - **Consistent** deformations to **eliminate non-physical** deformations.

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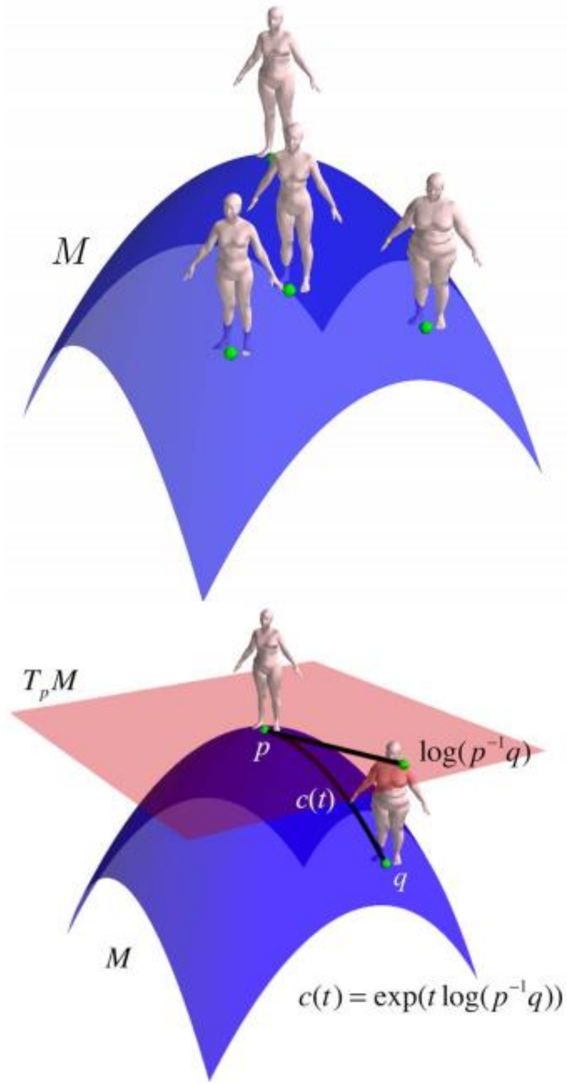
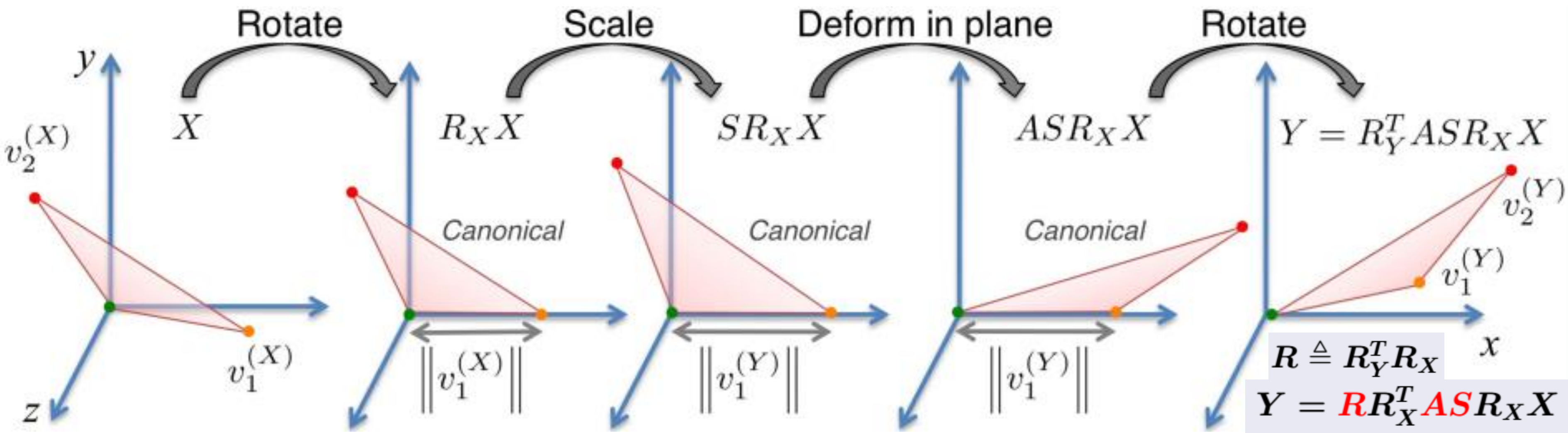
Manifold Representation of 3D Human Shape

- A shape is a point on a **non-linear manifold**, $M \triangleq G_T^N$.
  - G_T : is a **6D** Lie Group of triangle deformations
- **Advantages:**
  - Consistency (positive determinant)
  - No redundant DoF ⇒ less noise
  - Closed-form formulas



Freifeld, O., Black, M. J., Lie Bodies: A Manifold Representation of 3D Human Shape, In *European Conf. on Computer Vision (ECCV)*, pages: 1-14, Part I, LNCS 7572, (Editors: A. Fitzgibbon et al. (Eds.)), Springer-Verlag, October 2012.

Deformation Transfer on Manifolds (Triangles deformation)



If a triangle ***X* is not canonical**, there is always a rotation matrix, R_x such that ***$R_x X$* *is canonical*.**

$$S = {\|v_1^{(Y)}\|} \Big/ {\|v_1^{(X)}\|}, \quad A = \begin{bmatrix} 1 & U & 0 \\ 0 & V & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad U = {(v_{2_x}^{(Y)} - v_{2_x}^{(X)})} \Big/ {v_{2_y}^{(X)}}, \quad V = {v_{2_y}^{(Y)}} \Big/ {v_{2_y}^{(X)}}$$

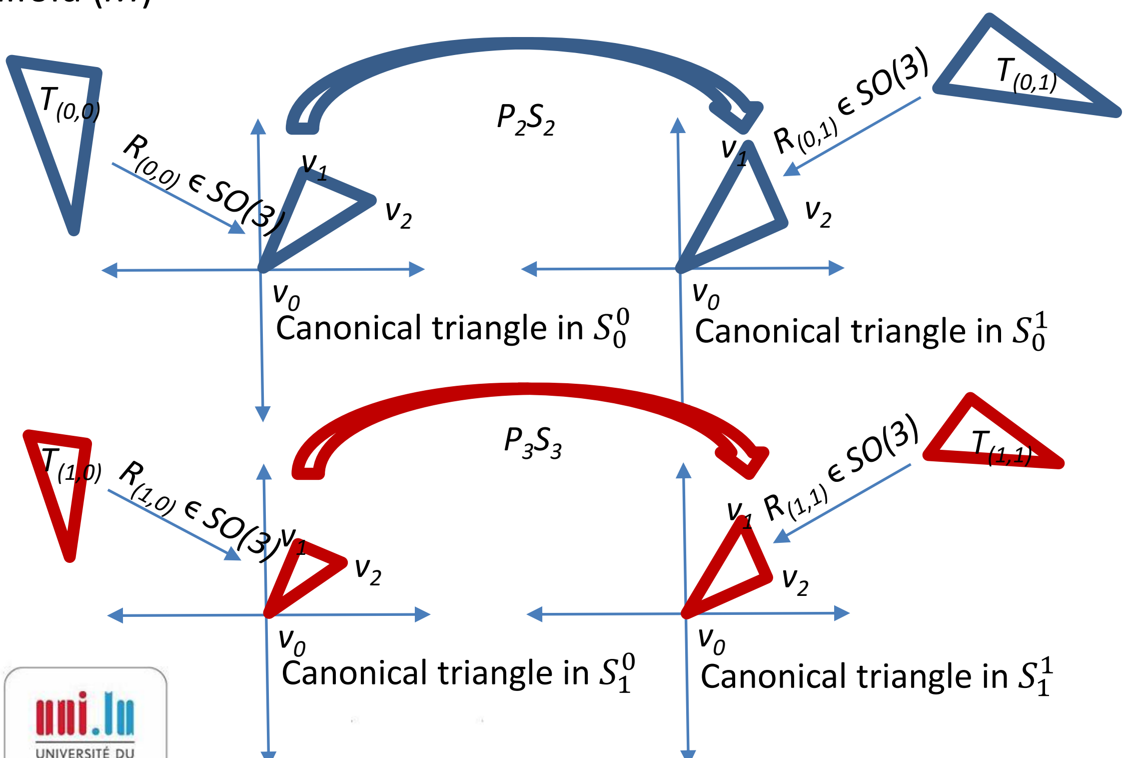
6D Lie Group of triangle deformation

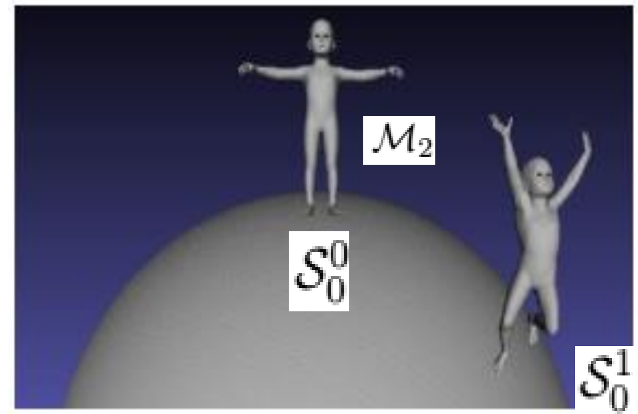
Deformation Transfer on Manifolds

Shape (S) Rotate (R) Deform (P) Scale (S) Rotate (R)

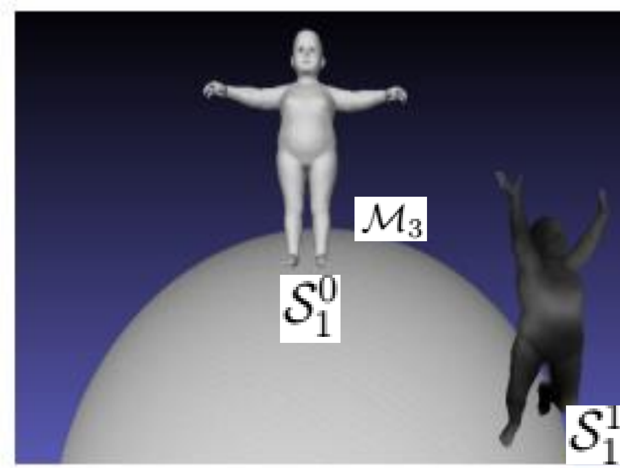
$$\begin{cases} \mathcal{M}_1 : & S_1^0 \ni T^k_{(1,0)} = (R^k_{(1,0)})^T P^k_{\mathcal{M}_1} S^k_{\mathcal{M}_1} R^k_{(0,0)} T^k_{(0,0)}, \\ \mathcal{M}_2 : & S_0^1 \ni T^k_{(0,1)} = (R^k_{(0,1)})^T P^k_{\mathcal{M}_2} S^k_{\mathcal{M}_2} R^k_{(0,0)} T^k_{(0,0)}, \\ \mathcal{M}_3 : & S_1^1 \ni T^k_{(1,1)} = (R^k_{(1,1)})^T P^k_{\mathcal{M}_3} S^k_{\mathcal{M}_3} R^k_{(1,0)} T^k_{(1,0)}. \end{cases}$$

Manifold (M) Deformed triangle (T) Input triangle (T)





(a)



(b)

Deformation Transfer on Manifolds

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$$\exists A^k \in SO(3) \quad \text{s.t.} \quad R^k_{(1,0)} = A^k R^k_{(0,0)}, \quad \forall k.$$

$$P^k_{\mathcal{M}_2} S^k_{\mathcal{M}_2} \cong P^k_{\mathcal{M}_3} S^k_{\mathcal{M}_3}, \quad \forall k.$$

$$\hat{R}^k_{(1,1)} = A^k R^k_{(0,1)}, \quad \forall k.$$

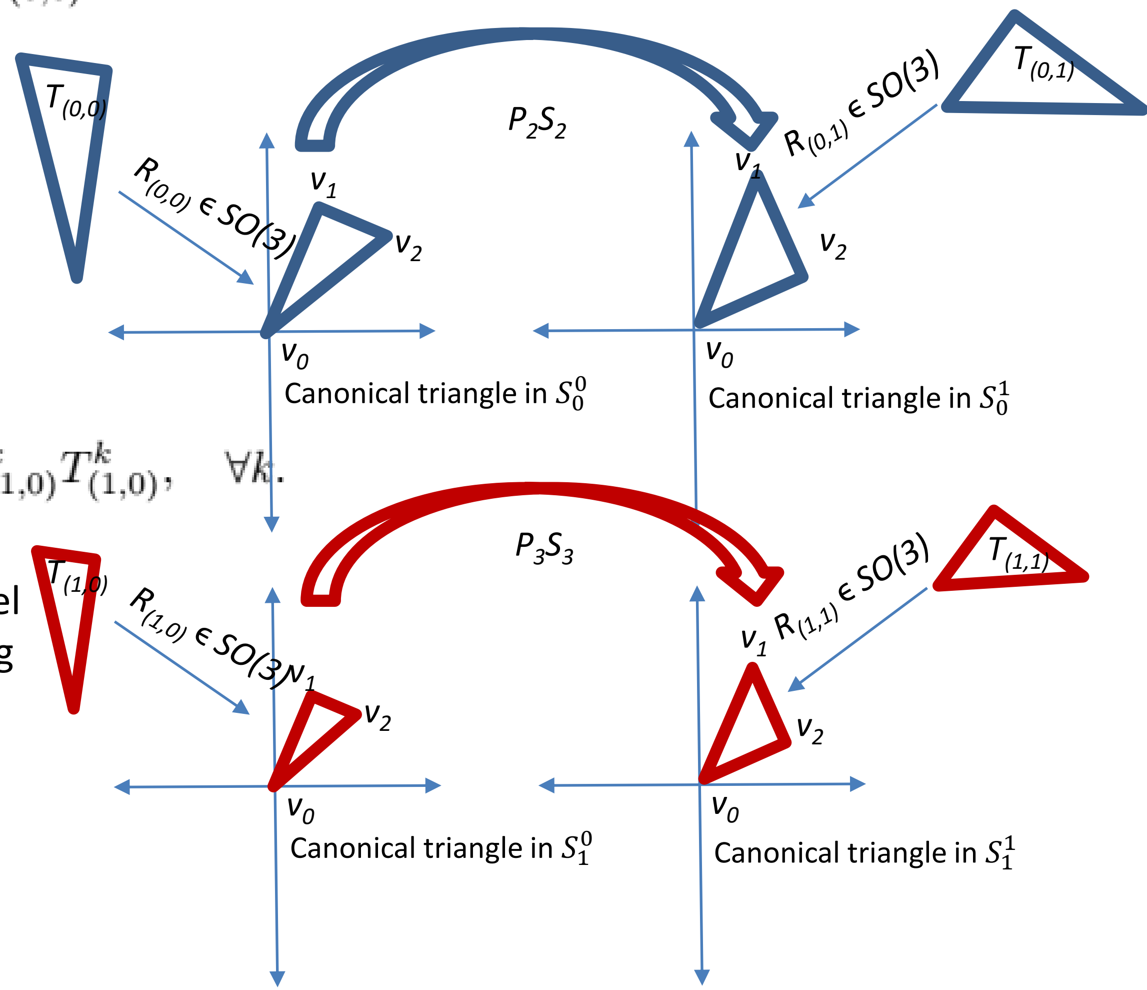
$$\hat{S}^1_1 \ni \hat{T}^k_{(1,1)} = (A^k R^k_{(0,1)})^T P^k_{\mathcal{M}_2} S^k_{\mathcal{M}_2} R^k_{(1,0)} T^k_{(1,0)}, \quad \forall k.$$

Deformed Triangle

Parallel Rotation

Parallel Deformation

Parallel Scaling



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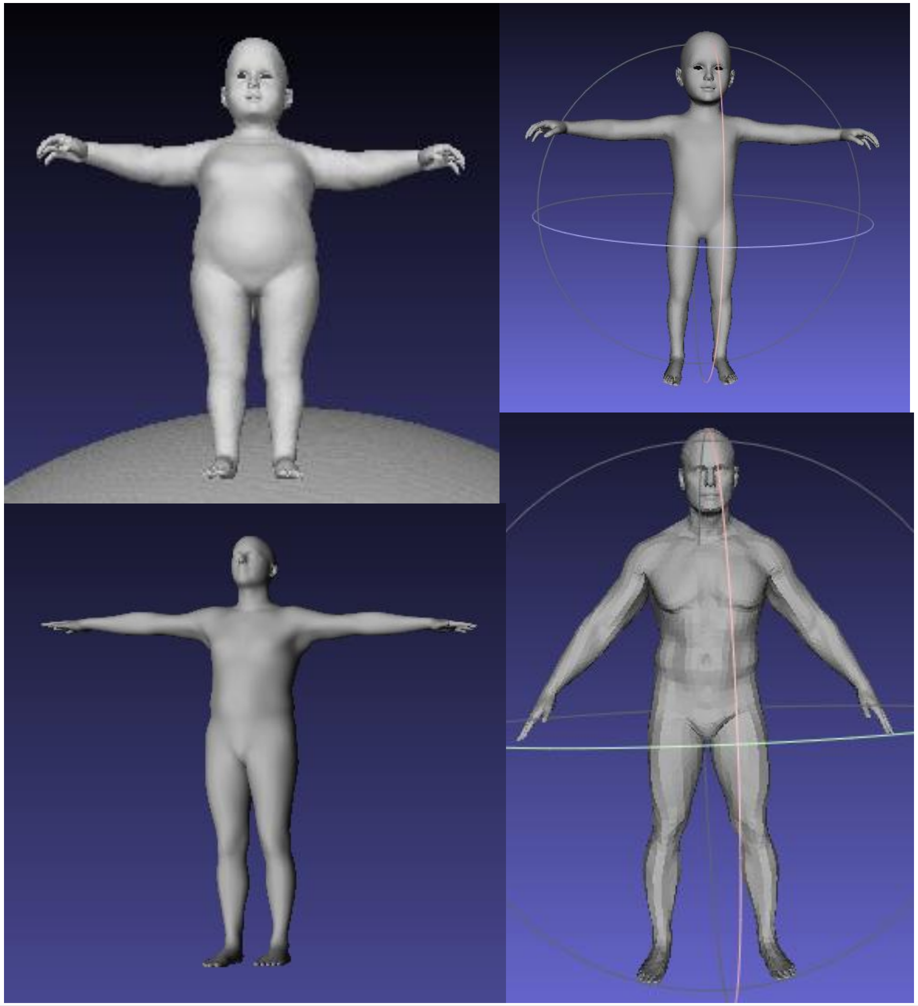
Results: 3D Human Datasets

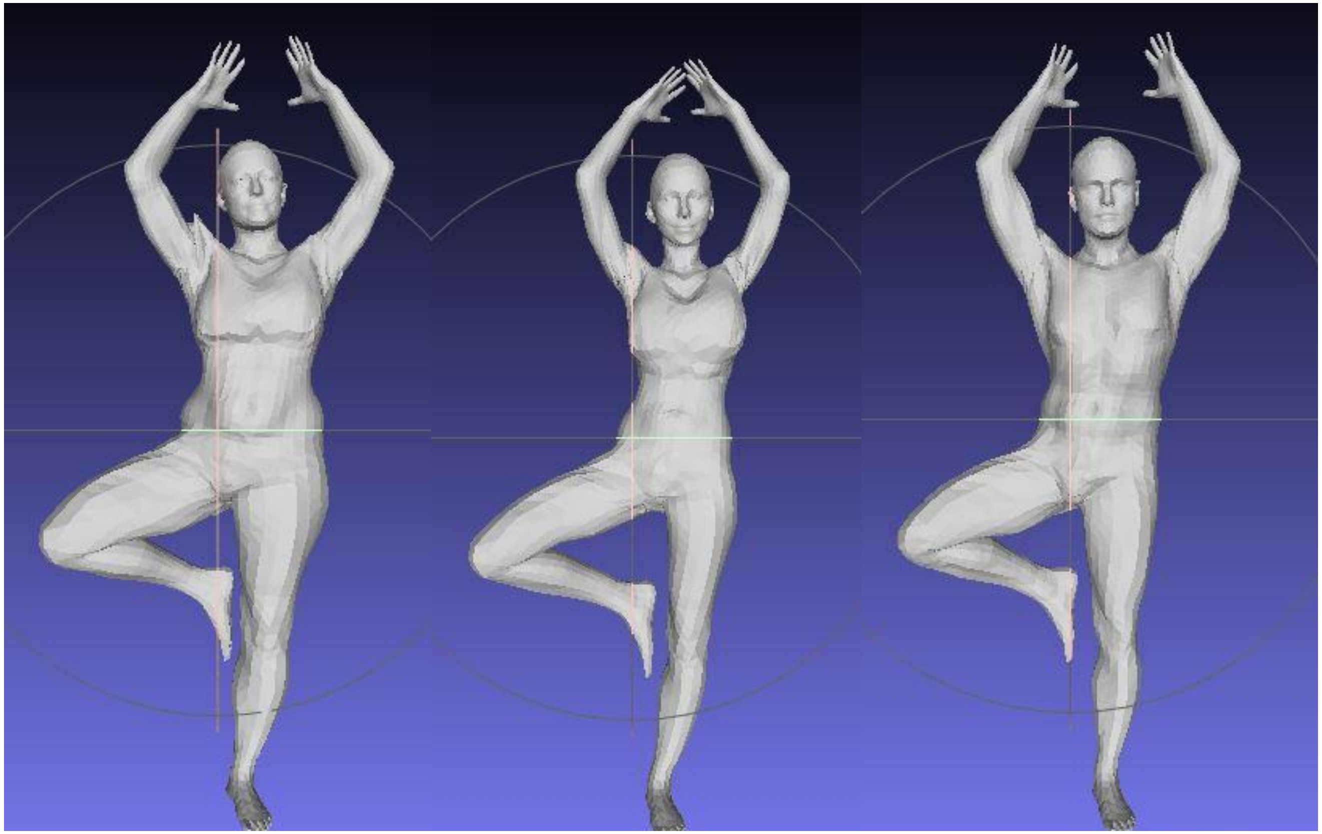
- Input:
  - Rest-poses for the template and the target model to be transformed.
  - New poses taken by the input.
- SHREC (32, 2 kids x 16 poses)
  - The registered models were directly used
- FAUST (300, 10 persons x 30 poses)
  - The registered models were directly used.
- SMPL based generated models.



Results: SHREC

1st row: Input poses, 1st col: Input rest-poses
2nd row: our method
3rd row: Popovic & Sumner 2004

Results: Deformation Transfer applied to different rest-poses



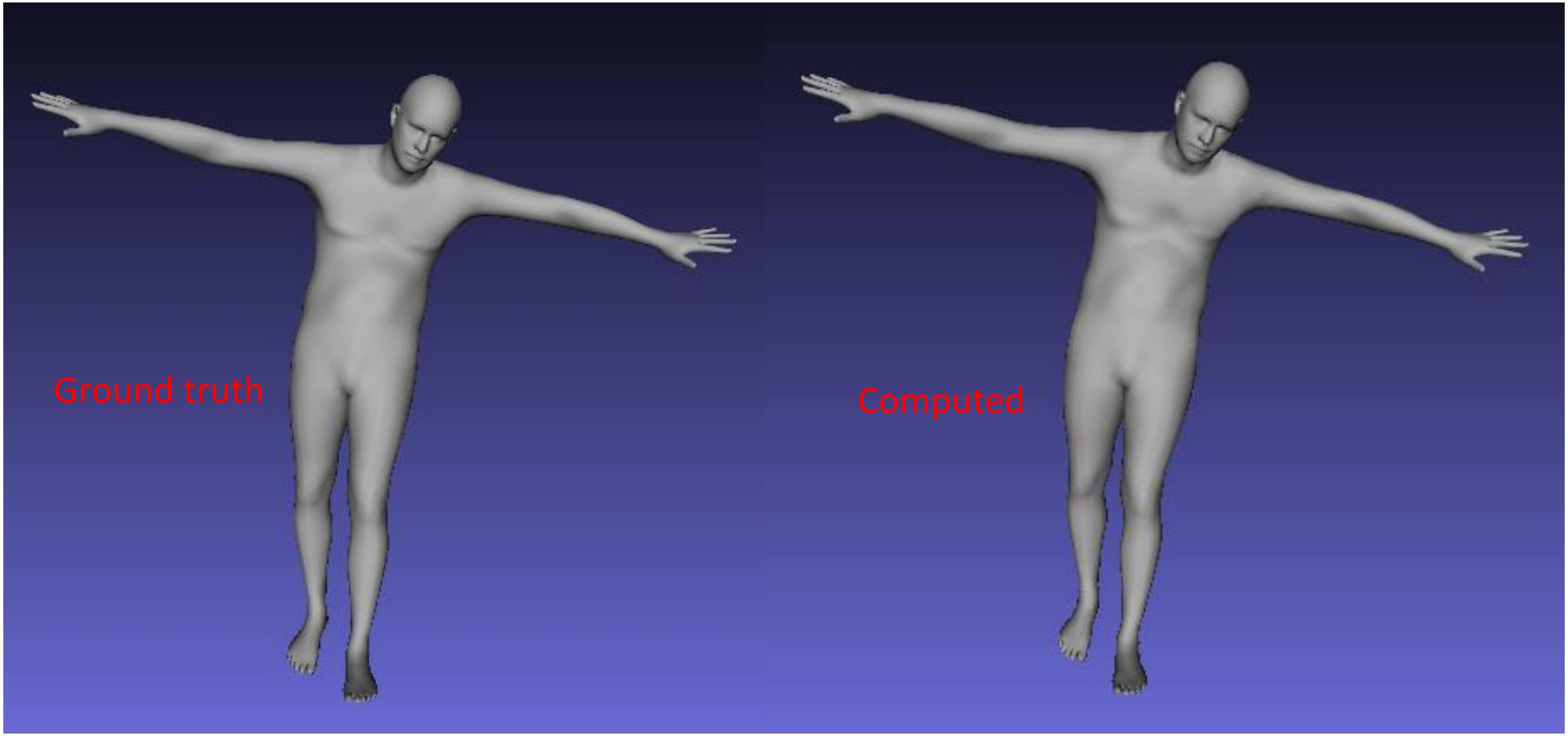
Output generated using **Popovic & Sumner 2004**

- Any pose can be taken as a starting (rest, template) pose as long as it is available for the input and target models.
- **The closer the rest-poses are, the more accurate the output is.**

Results: FAUST

1st row: Input poses
1st col: Input rest-poses
2nd row: our method
3rd row: Popovic & Sumner 2004

Results: SMPL



Matthew Loper, Naureen Mahmood, Javier Romero, Gerard Pons-Moll, and Michael J. Black. 2015. **SMPL**: a skinned multi-person linear model. ACM Trans. Graph. 34, 6, Article 248 (October 2015), 16 pages. DOI: ttps://doi.org/10.1145/2816795.2818013

Conclusion & Future Work

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- A novel deformation transfer technique to copy deformations on manifolds was proposed. Its advantages:
  - It uses minimal required DoF (**eliminates redundant DoF**).
  - Consistent deformations to **eliminate non-physical** deformations.
  - Deformations to be computed in **closed-form** without heuristics.
  - A **more accurate representation** than the traditional Euclidean representation.
  - **Less computationally expensive** (Parallel computations on triangles and no lifting up to the tangent space is required).
- Extend Manifold representation to broader applications like 3D Shape and Facial descriptors, Mesh encoding, Mesh editing, … etc.

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Thanks ☺

Questions ?

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