Landmark transfer with Minimal Graph

★submission to 3DOR

PhD student: Vasyl MYKHALCHUK

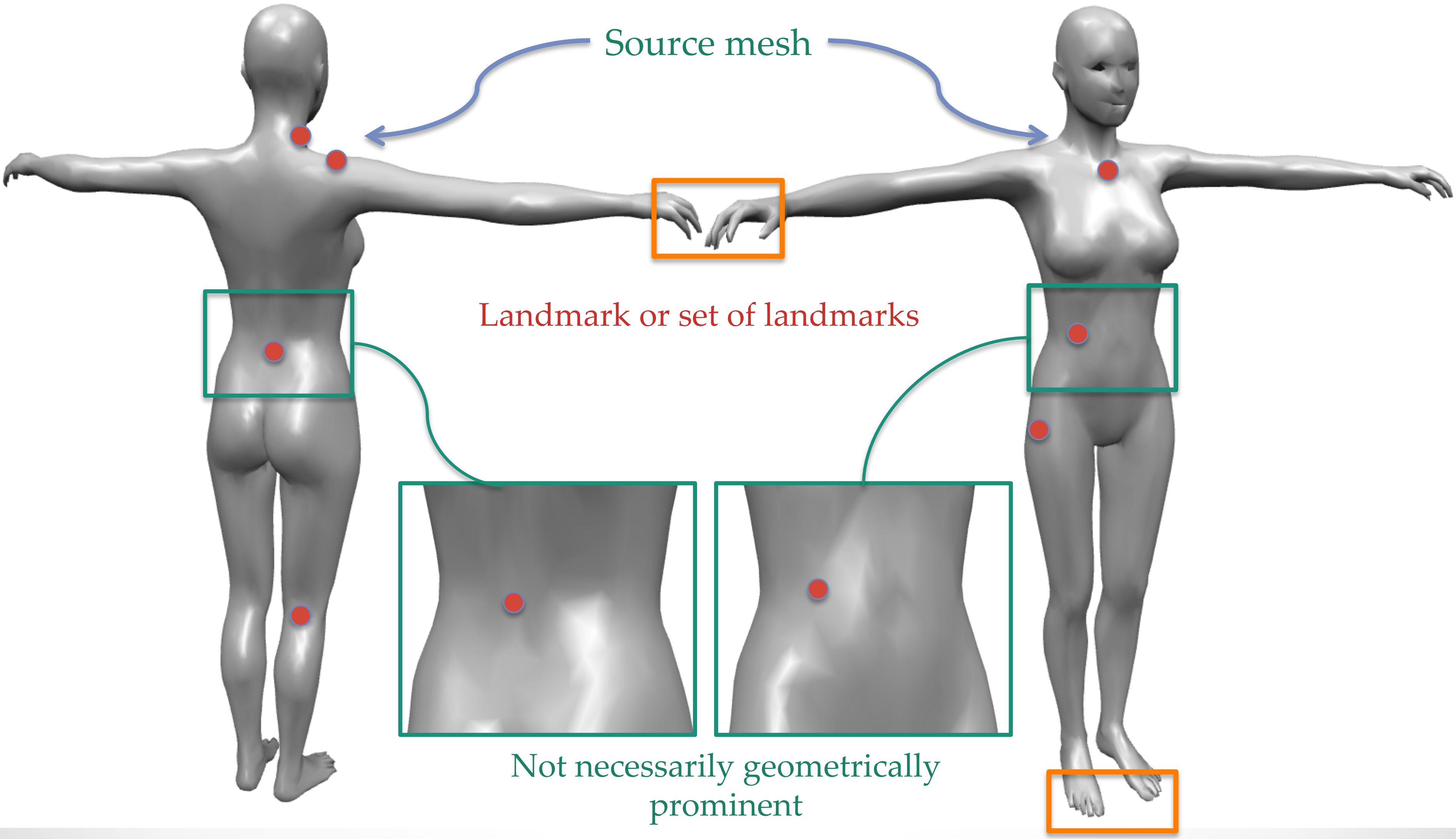
15 Nov. 2012

Université de Strasbourg, France

Overview

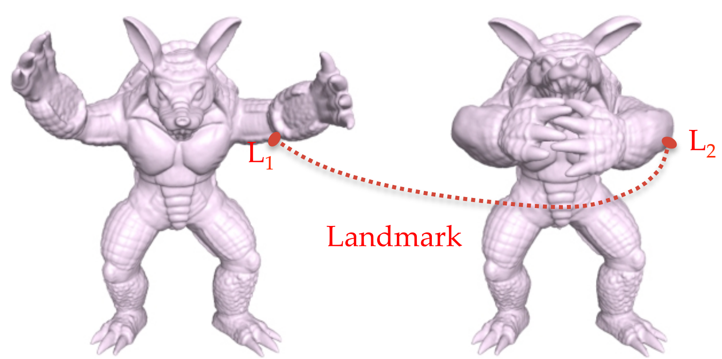
- Goal and Motivation
- Related approaches
- Landmark transfer technique
- Results
- Future plans

What is landmark?

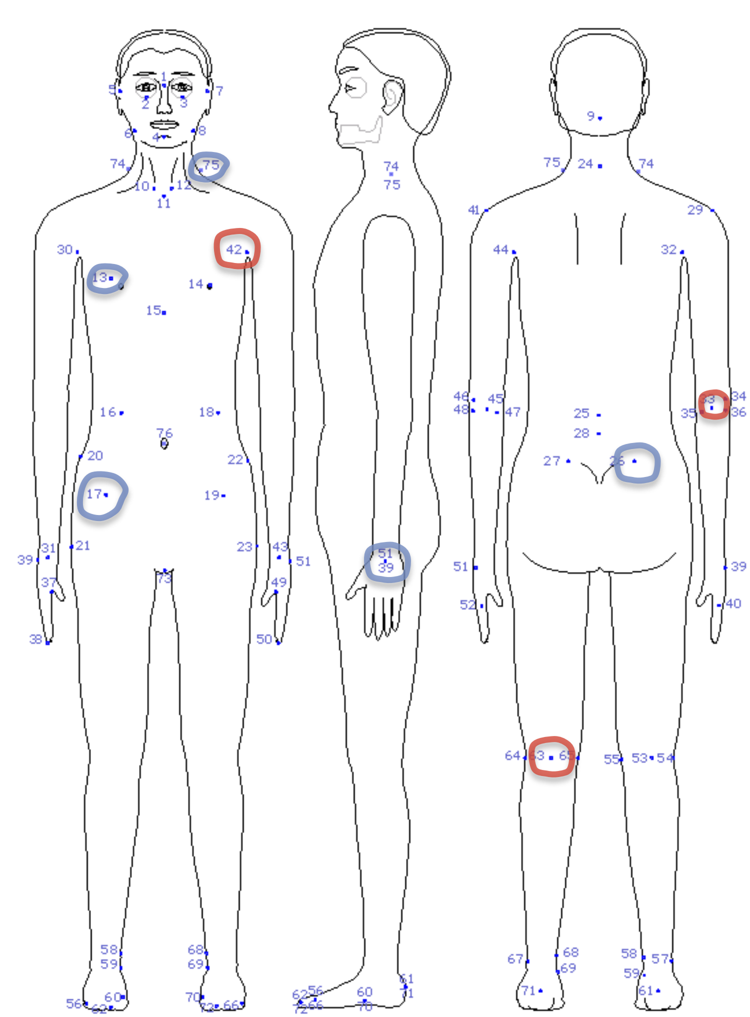


Why landmarks?

- Correspondence computation
- Shape analysis
- Anthropometric studies
- Initial step in full shape registration
- Reuse of application-specific **landmarks**



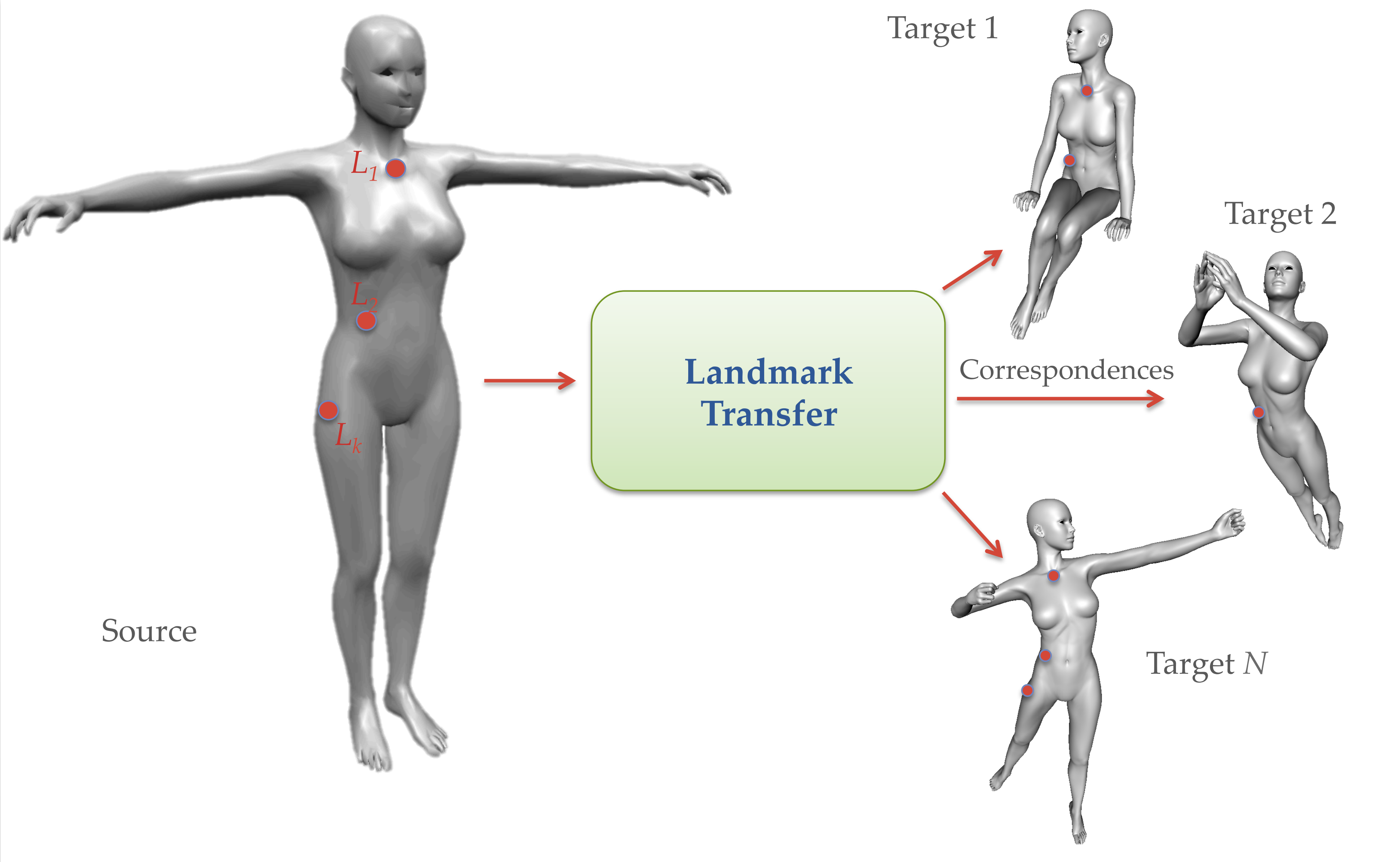
[The Armadillo AIM@SHAPE]



[Feature points for the human body, Humanoid animation]

ISO/IEC FCD 19774 -- Humanoid animation, Feature points for the human body, http://h-anim.org/Specifications/H-Anim200x/ISO_ IEC_FCD_19774/FeaturePoints.html

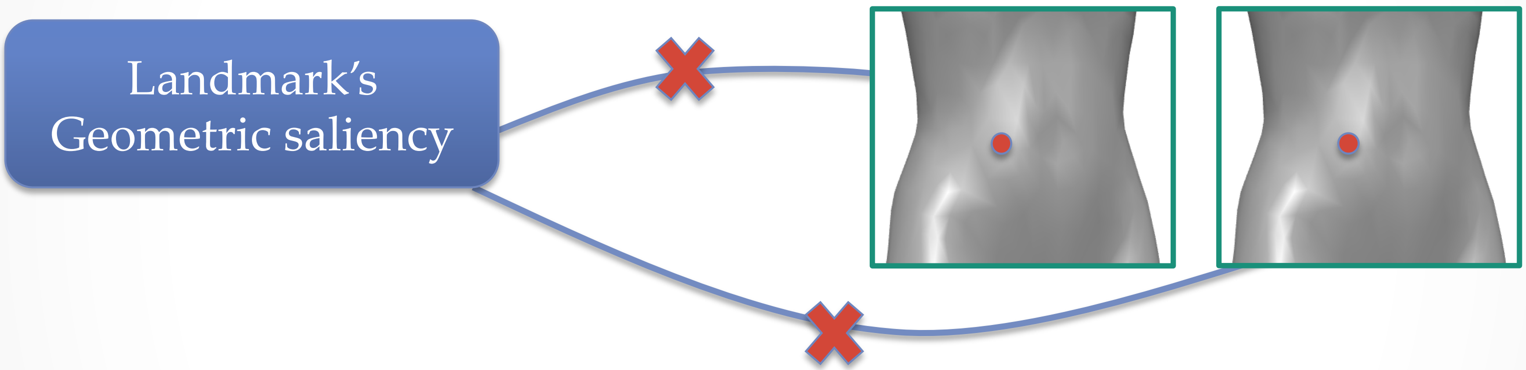
Objective

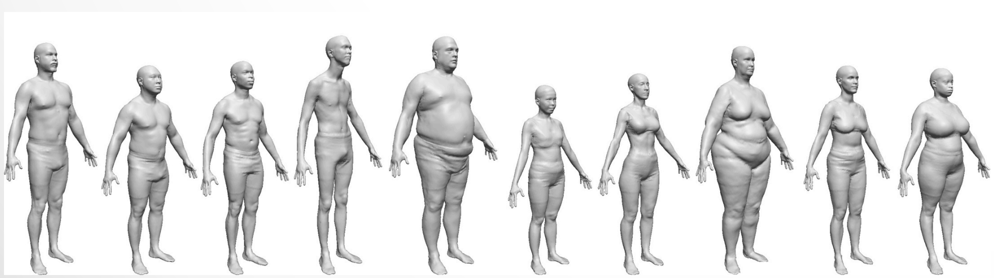


L_1
L_2
L_k
Source
Landmark Transfer
Target 1
Target 2
Correspondences
Target N

Objective

Requirements:

- **Robust** and **fast**
- **Transferred landmarks** are **persistent** across pose change
- Transfer efficiently to collection of **multiple target** shapes
- 

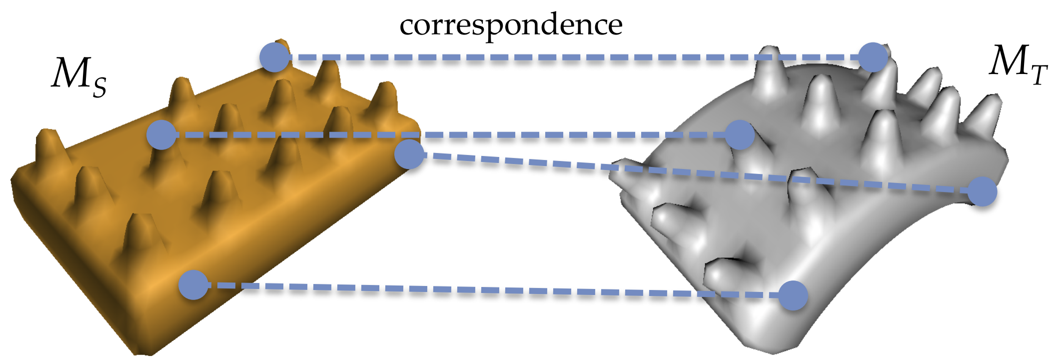


[CAESAR Project], etc.

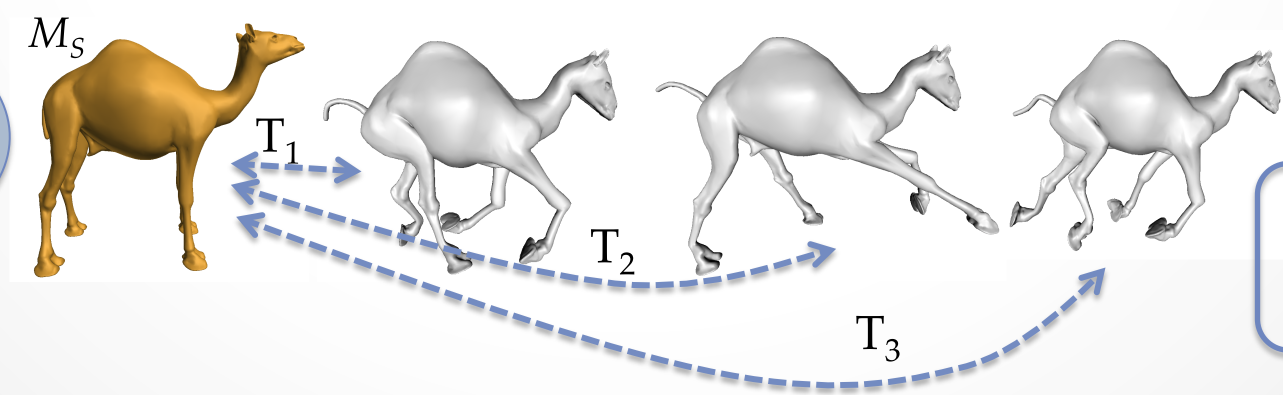
Why interesting?

Possible solution for landmark transfer:

- Approach as a problem of **full** shape registration
- Dense deformable shape registration gives us a set of all landmark correspondences



How about multiple targets?



Full registration is expensive

Related approaches

- Goal and Motivation
- Related approaches
- Landmark transfer technique
- Results
- Future plan

Related work

Nouvelle technique: there were no previous work on user-driven landmark transfer

Relevant publications:

- [Allen et al.]'02
- [Allen et al.]'03
- [Seo et al.]'03

manual

- [Chang et al.]'08
- [Huang et al.]'08
- [Tevs et al.]'09

regular

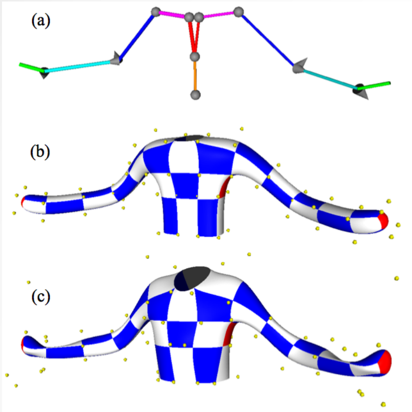
- [Tevs et al.]'11

planned

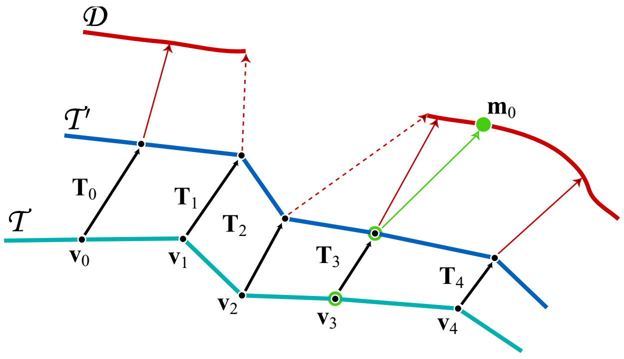
Registration techniques which rely on initial sparse and coherent correspondences

No shape is completely deformable. Every deformable shape matching method uses some deformable model

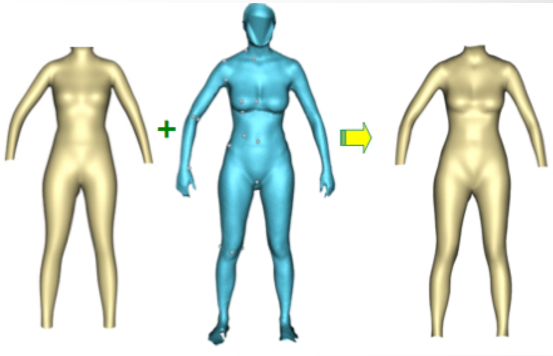
Marker correspondence: manual



[Allen et al.]’02



[Allen et al.]’03



[SEO et al.]

Manual marker assignment is used to drive ICP:

$$\operatorname{argmin}(\alpha \cdot E_{data} + \beta \cdot E_{smoth} + \gamma \cdot \boxed{E_{marker}})$$

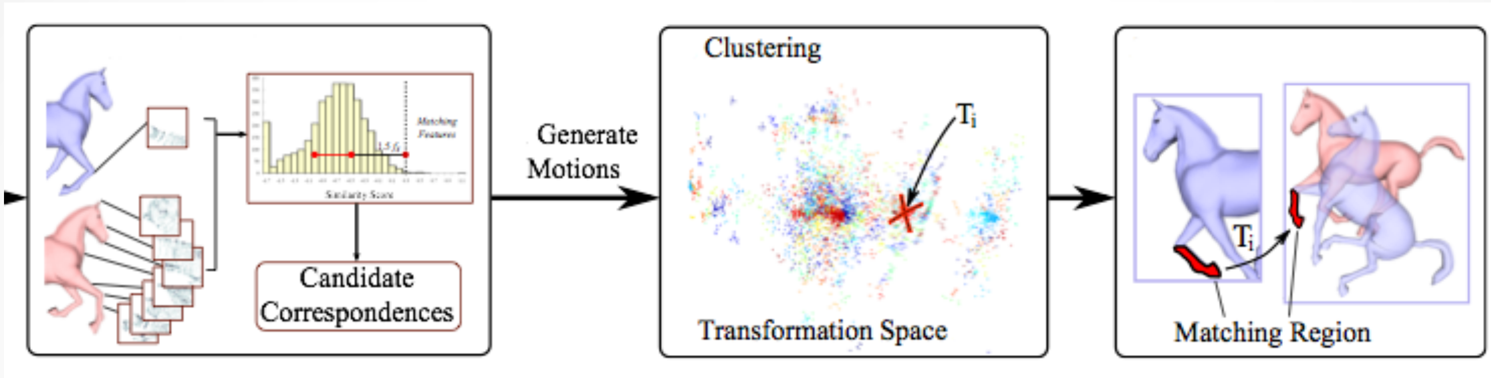
B. Allen, B. Curless, Z. Popović, The space of human body shapes: reconstruction and parameterization from range scans, Proc. ACM SIGGRAPH, pp.587-594, 2003.

B. Allen, B. Curless, Z. Popović, Articulated body deformation from range scan data, SIGGRAPH 2002, July 2002, San Antonio, Texas.

H. Seo, N. Magnenat-Thalmann, An automatic modeling of human bodies from sizing parameters, Proc. ACM symposium on Interactive 3D graphics, pp.19-26, 2003.

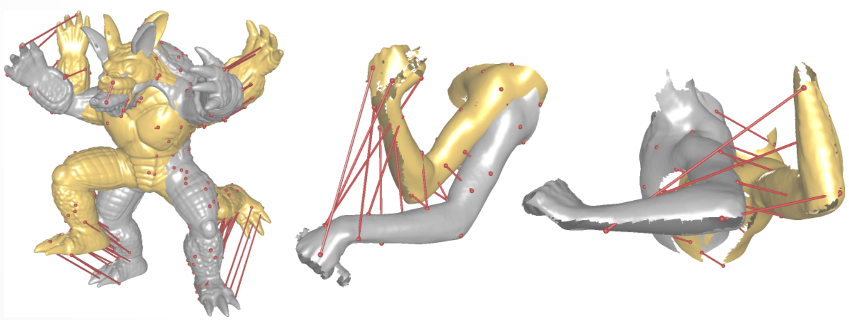
Marker correspondence: regular

[Chang et al.]



Poisson sampling

[Huang et al.]



Octree sampling

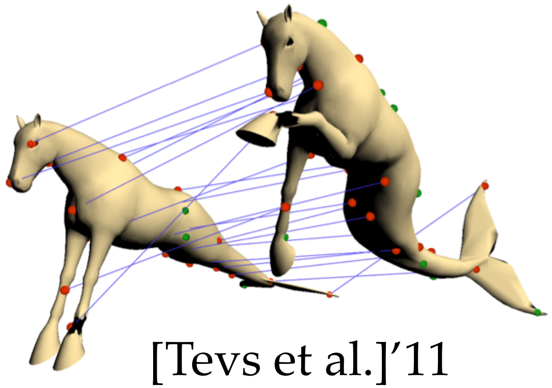
Q.-X. Huang, B. Adams, M. Wicke, L. J. Guibas, Non-Rigid Registration Under Isometric Deformations, Proc. of the Symposium on Geometry Processing, pp.1449-1457, 2008.

W. Chang, M. Zwicker, Automatic Registration for Articulated Shapes, Computer Graphics Forum (Proceedings of SGP 2008), 1459-1468, 2008.

Marker correspondence: planned

[Tevs et al.]’09

- Random sampling



[Tevs et al.]’11

Planned sampling

A. Tevs, M. Bokeloh, M. Wand, A. Schilling, H.-P. Seidel, Isometric Registration of Ambiguous and Partial Data, Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR '09), 2009.

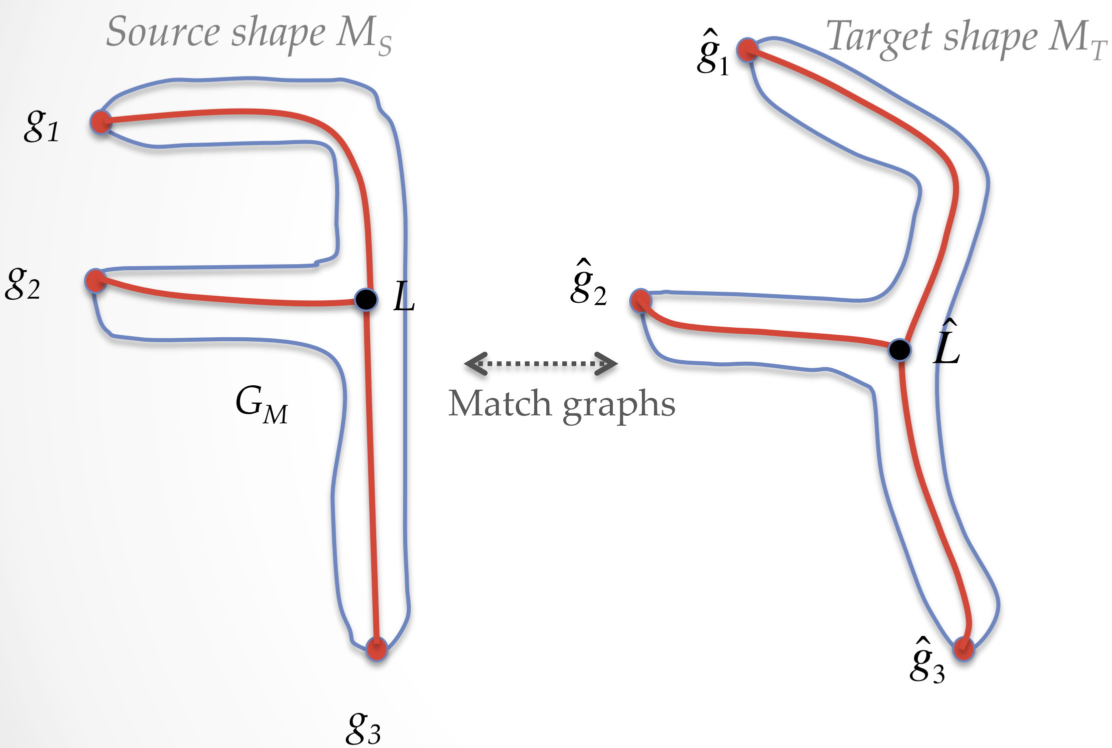
A. Tevs, A. Berner, M. Wand, I. Ihrke, H.-P. Seidel, Intrinsic Shape Matching by Planned Landmark Sampling", Eurographics, 2011

Landmark Transfer

- Goal and Motivation
- Related approaches
- Landmark transfer technique
- Results
- Future plan

Landmark transfer: key idea

Assumption: shapes are approximately **isometric**



Define landmark position L with respect to geometric **features** and **geodesic distances** to them

↓

Graph G_M

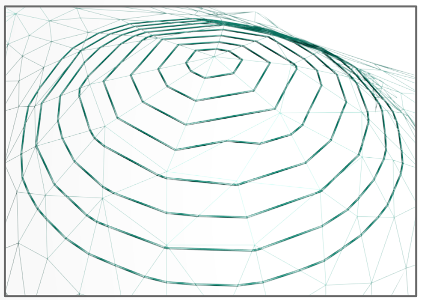
- Sufficient to define landmark
- As small as possible
- Unique

Intrinsic wave descriptor

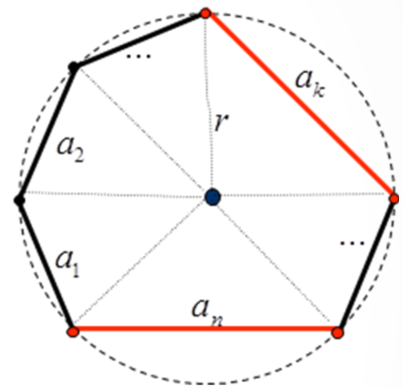
- In spirit of [Tevs et al.]
- **Isometry invariant**

$$D_x = \left(\frac{l_1}{2\pi r_1}, \frac{l_2}{2\pi r_2}, \ldots, \frac{l_{16}}{2\pi r_{16}}\right)^T$$

Intrinsic wave descriptor polygonal approximation



$$\exists a \in l_i : a \geq 0.1 p(l_i)$$

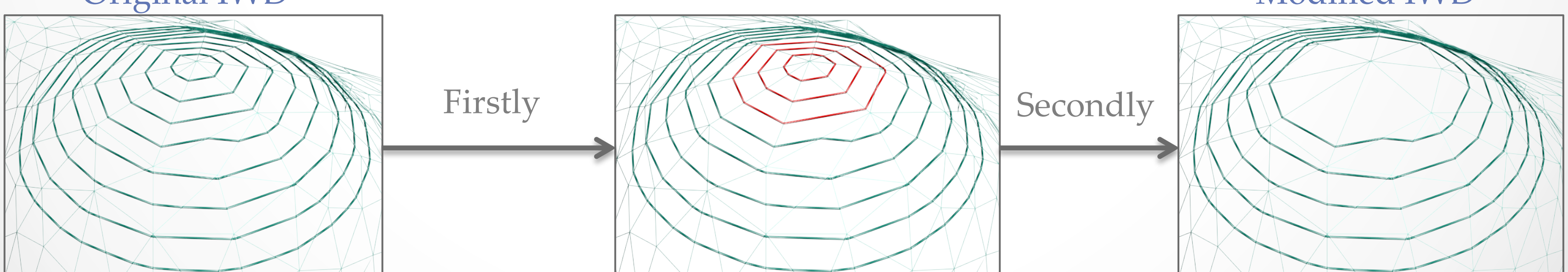


Problem

Further we **modify IWD** towards robustness to mesh sampling:

Original IWD

Modified IWD



All iso-contours

Identify distorted iso-contours

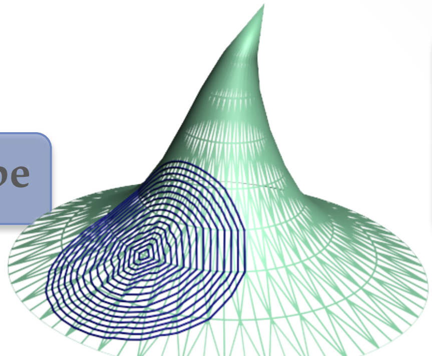
Retain $\lfloor \mu + \sigma \rfloor$

Extracting extremities

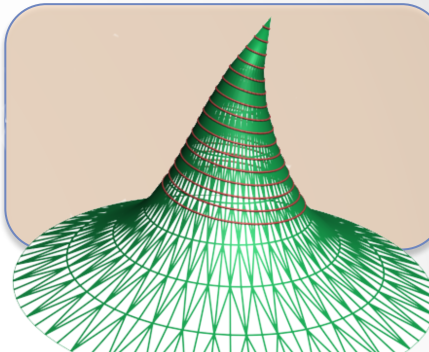
Def. Given modified intrinsic wave descriptor, $D_x^{'}$

$$\gamma(x) \equiv \left\| D_x^{'} \right\|_2^{-1}$$

- **Increases on the "sharp" features of the shape**
- Comes up to +∞ for a vertex on the tip of an infinitely sharp, needle-like shape

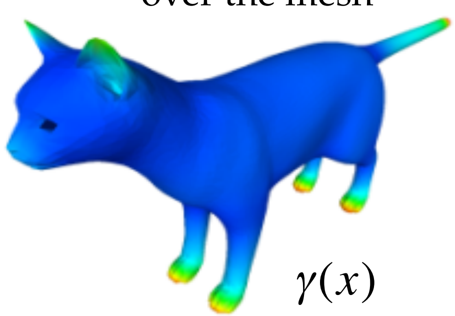


IWD on a flat patch



IWD on a sharp peak

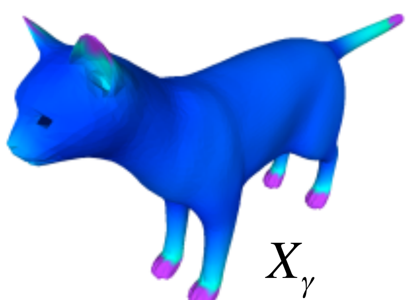
Compute convexity over the mesh



$\gamma(x)$

Step 1

Retain most prominent set with respect to $\gamma(x)$



X_γ

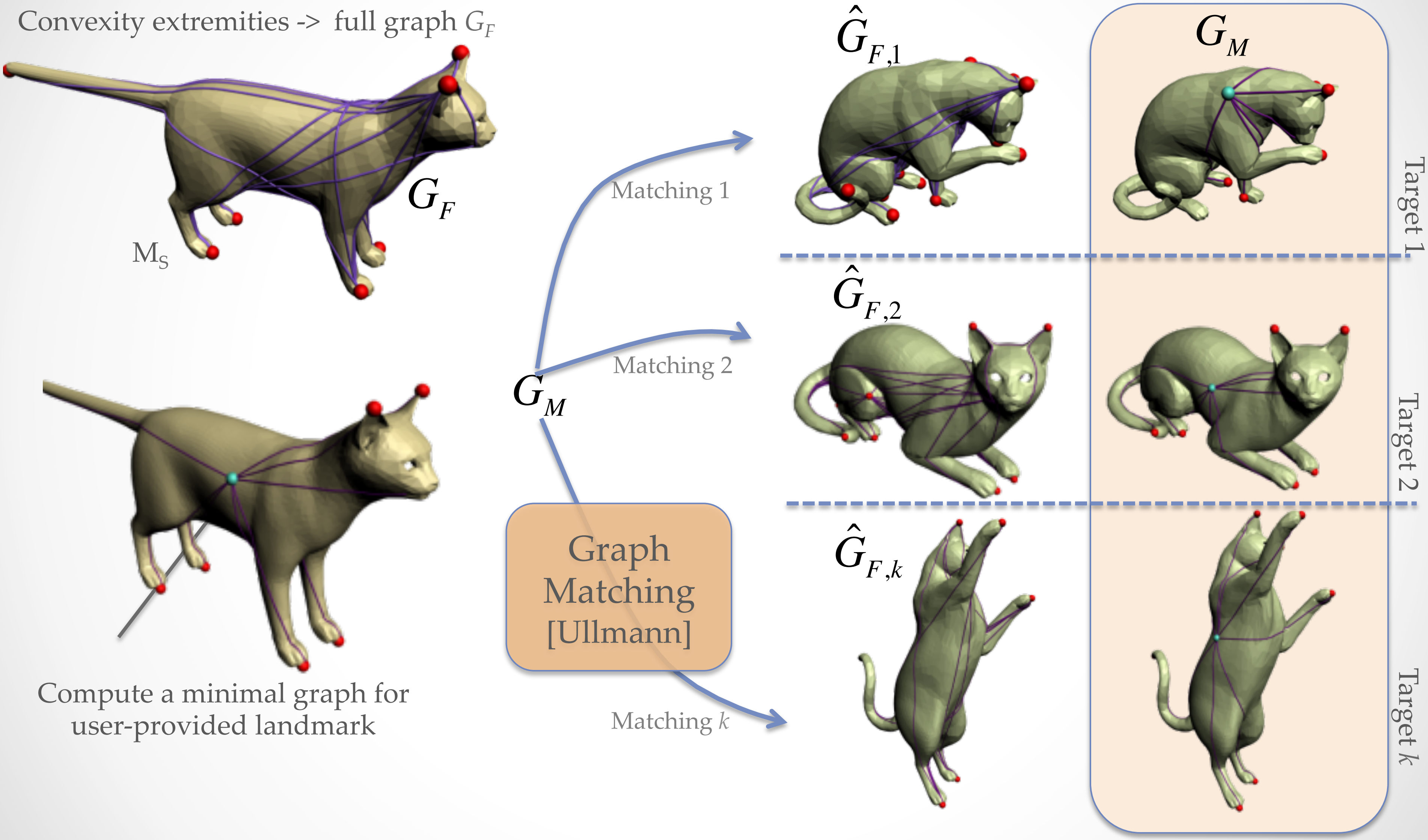
Step 2

Cluster X_γ and extract extremities

$\arg\max_{x \in C_{\gamma,i}} \delta(g,x)$

Step 3

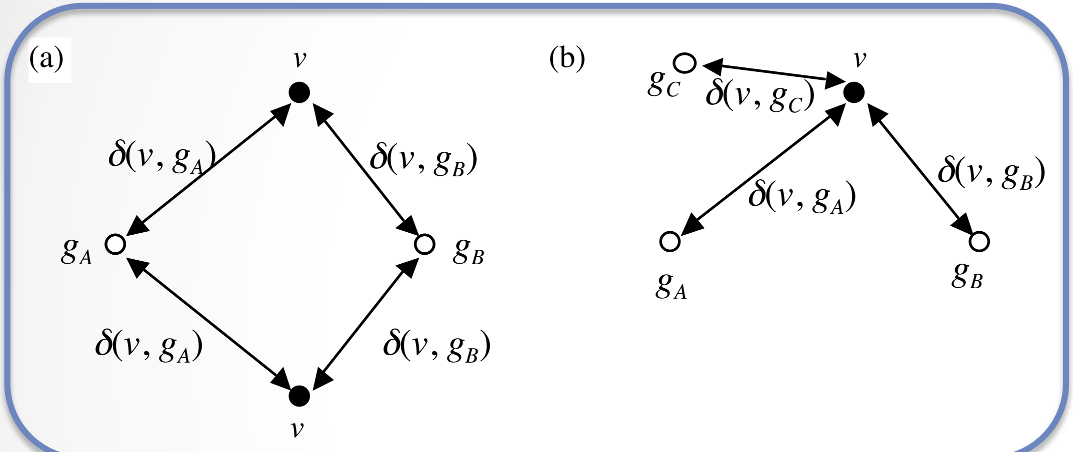
Landmark Transfer



Ullmann J.R., An Algorithm for Subgraph Isomorphism, Journal of the Association for Computing Machinery, vol. 23, pp. 31-42, 1976.

Minimal graph G_M construction

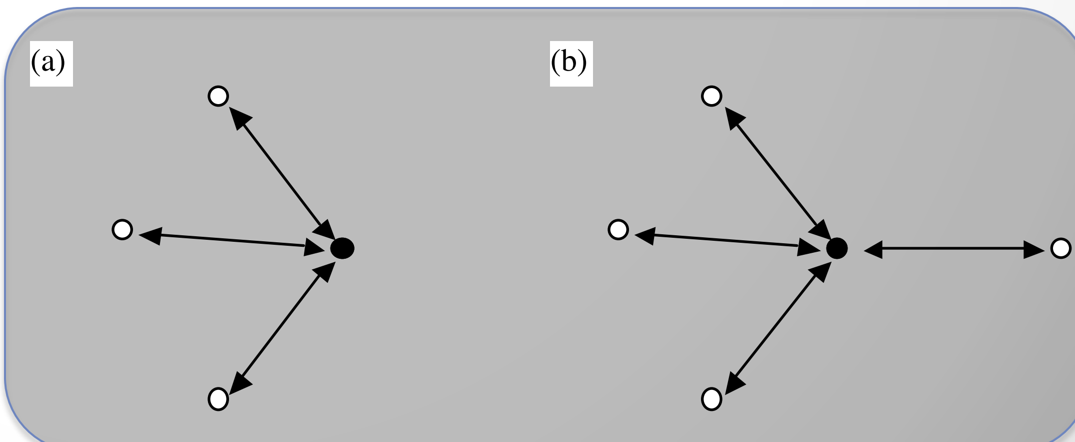
1. Position of the landmark is uniquely defined by its geodesic distances to each node in the minimal graph



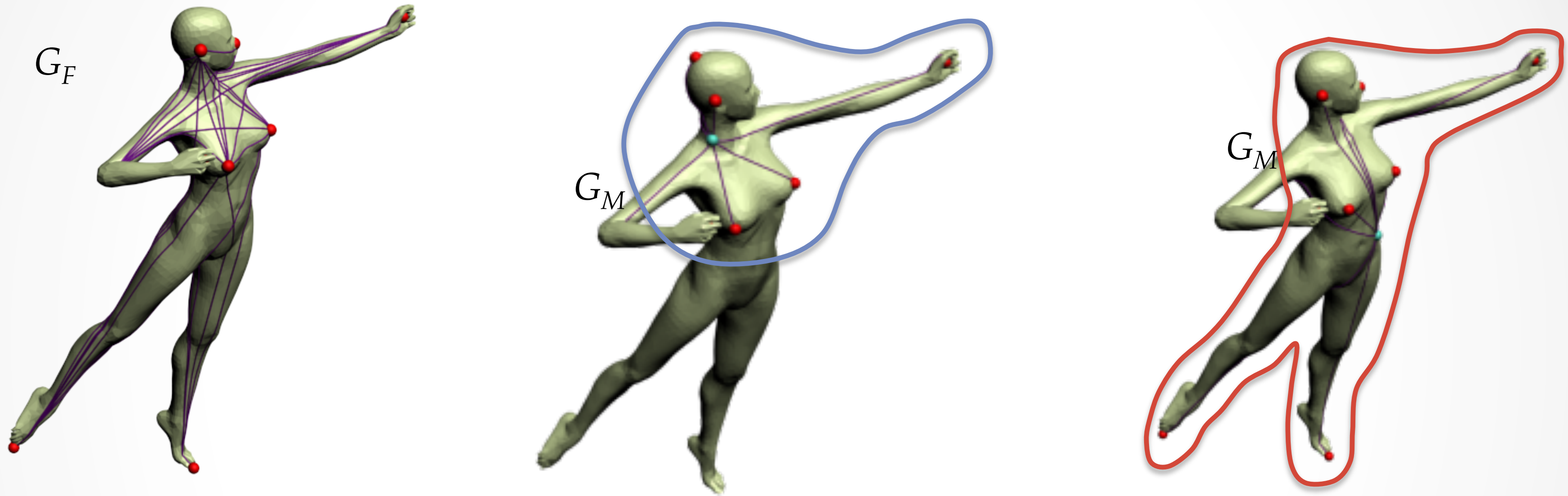
2. The landmark is inside a convex hull of the N-gon formed by the graph nodes

3. The minimal graph is a unique subgraph of the full graph

Checked by self-matching on the shape via Ulmann's approach



Minimal graph



Compact graph is preferred

Less desirable

Landmark transfer

M_S – source shape, M_T – target shape
$G_M = \{V_M, E_M\}$

Feature point coordinates (*FP*-coordinates) of v:

$$\delta_{M_S}(v) = (\delta(v, g_1), \ldots, \delta(v, g_k))^T$$

// FP-coordinates on the source M_S

Transferred point $\hat{v}$ must satisfy:

$$\boldsymbol{\delta}_{\mathbf{M_T}}(\hat{v}) = \boldsymbol{\delta}_{\mathbf{M_S}}(v)$$

$$\boldsymbol{\delta}_{\mathbf{M_T}}(\hat{v}) = (\delta(\hat{v}, \hat{g}_1), \ldots, \delta(\hat{v}, \hat{g}_k))^{\mathrm{T}}$$

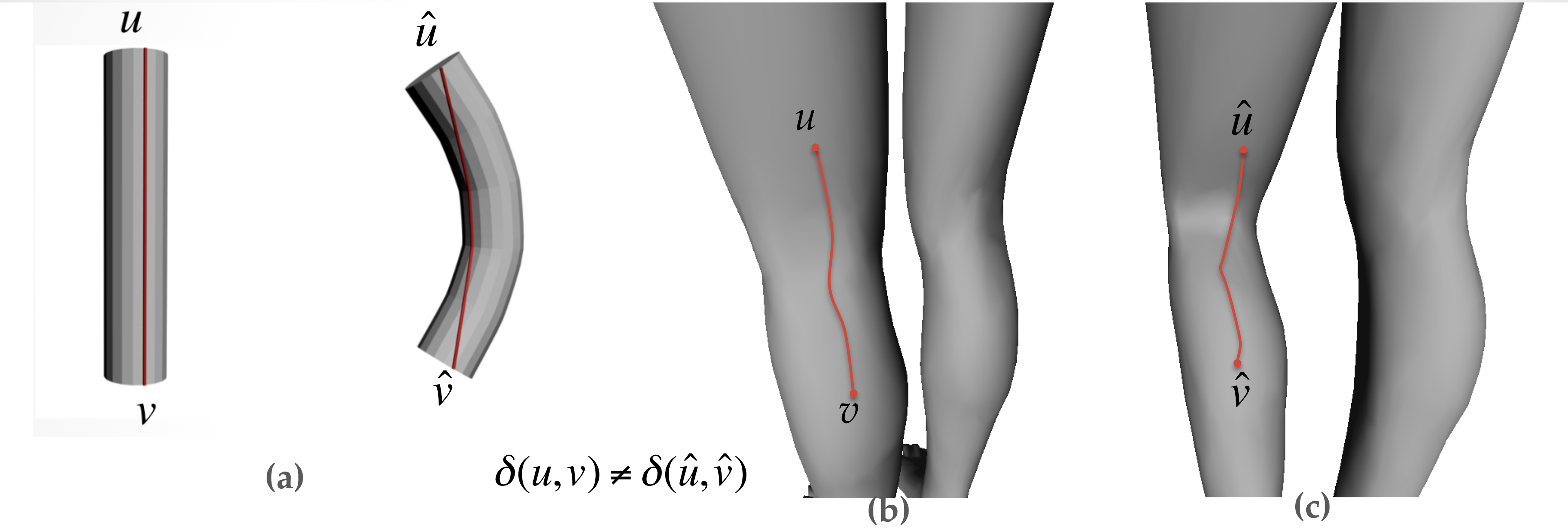
// FP-coordinates on the target M_T

However, in practice:

$$\boldsymbol{\delta}_{\mathbf{M_T}}(\hat{v}) \neq \boldsymbol{\delta}_{\mathbf{M_S}}(v)$$

Geodesic distance changes

Geodesic distance as a shortest distance on the surface:



Problem:

- Geodesic path and its length changes between u and v with a mesh deformation **(a) (b) (c)**
- In our experiments we observed up to 9% of change in geodesic distances

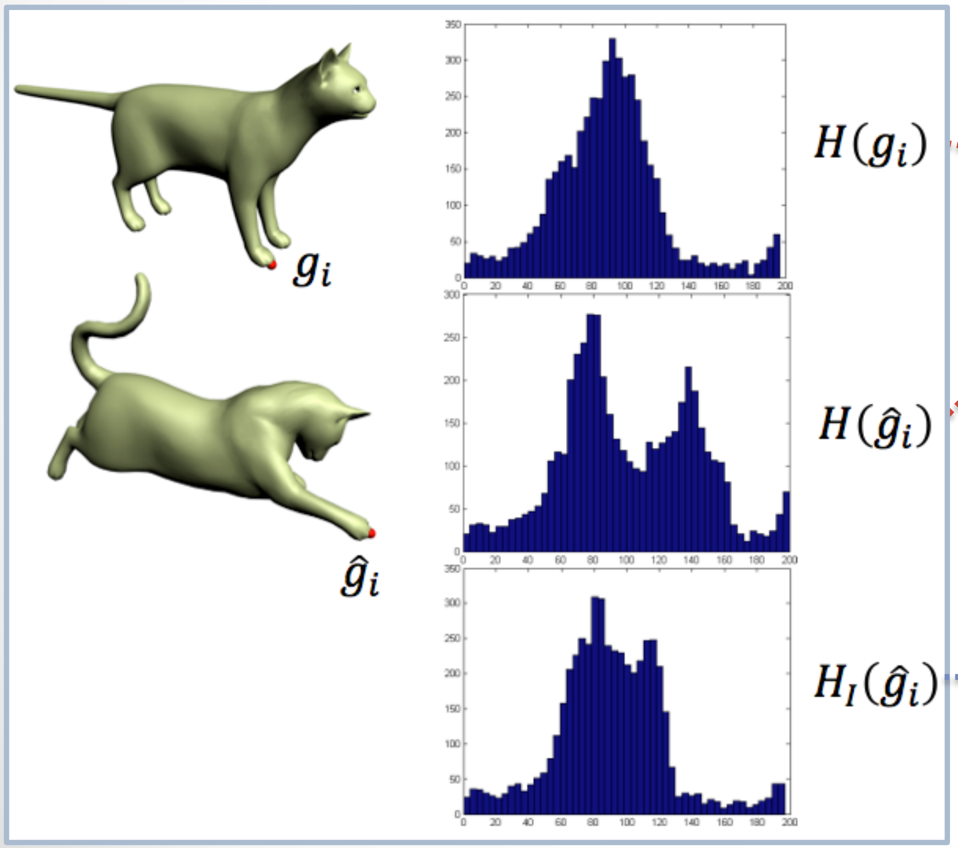
Solution:

- Modify geodesic distances on the target to make them similar to those on the source

Landmark transfer

$H(g_i)$ - **geodesic distance histogram**

Def. Distribution of the geodesic distances between the vertex g_i and all other vertices of the mesh M_S



Histograms $H(g_i)$ and $H(\hat{g}_i)$ might be dissimilar for corresponding vertices

Interpolated geodesic histograms make values of geodesic distances on the target closer to the source

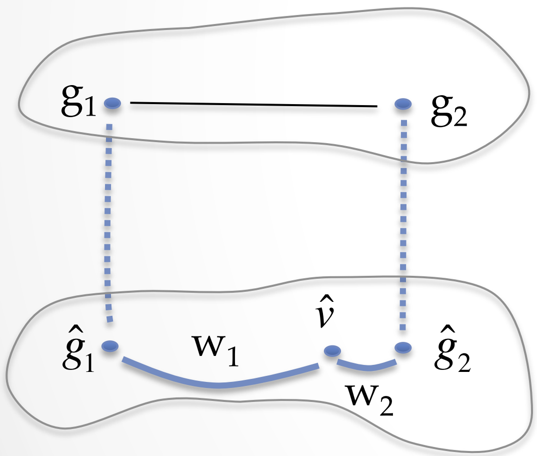
Interpolating geodesic distances

Def. $\delta_I(\hat{v},\hat{g}_i)$ interpolated geodesic distance:

$$\delta_I(\hat{v},\hat{g}_i) = \sum_{j=1}^{\hat{n}_M} \frac{w_j(\hat{v})\cdot\delta(g_j,g_i)}{\sum_{k=1}^{\hat{n}_M} w_k(\hat{v})}, \text{ where } w_j(\hat{v}) = \frac{1}{\delta(\hat{v},\hat{g}_j)^{p_j}}$$

Inverse distance weighting

Get power parameters p_j solving $\underset{p_j}{\operatorname{argmin}}(d(H_I(\hat{g}_i),H(g_i)))$



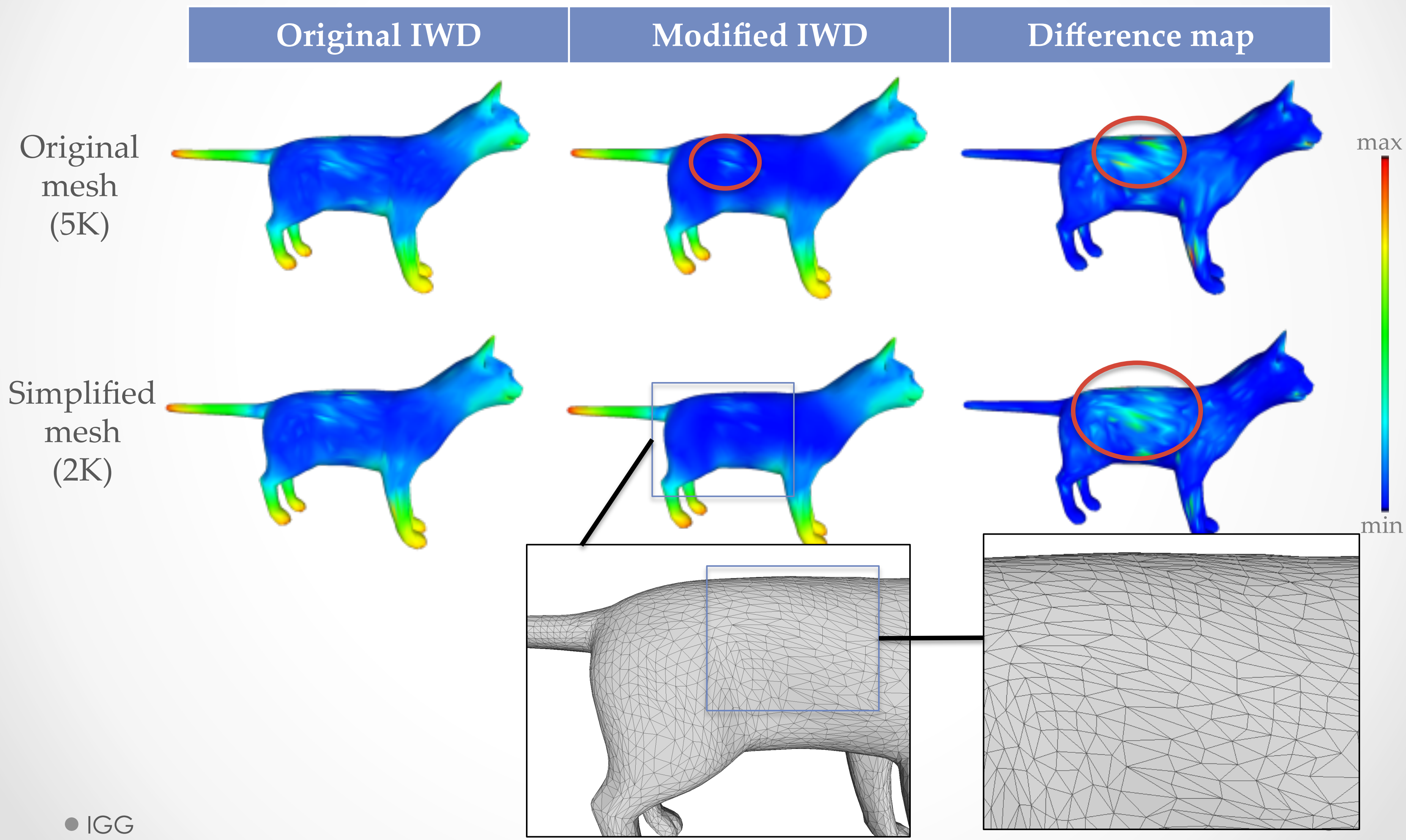
d is a histogram metric [Earth Mover's Distance]

RUBNER Y., TOMASI C., GUIBAS L. J.: The earth mover's distance as a metric for image retrieval. *Int. J. Comput. Vision 40*, 2 (2000), 99–121.

Results

- Goal and Motivation
- Related approaches
- Landmark transfer technique
- Results
- Future plan

Evaluation of the modified wave descriptor



Results

Computational time:

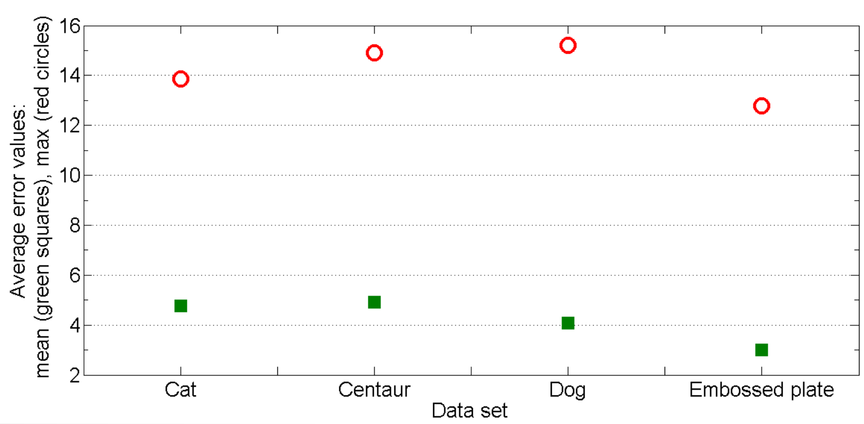
Data set	$\lvert X \rvert$	$\lvert T \rvert$	$\lvert t_{\delta} \rvert$	$\lvert t_{V_F} \rvert$	$\lvert G_M \rvert$	$\lvert t_{\hat{V}_F} \rvert + \lvert t_{\hat{G}_M} \rvert$	$\lvert t_H \rvert$
Cat	4994	9977	146ms	21ms	39ms	59ms	6.63s
Centaur	5002	10000	86ms	23ms	128ms	338ms	48.96s
Dog	5000	9991	104ms	20ms	33ms	39ms	5.98s
Embossed plate	1482	2960	19ms	7ms	85ms	1708ms	2.81s

10 cat models, **5** centaur models, **7** dog models from TOSCA Shape Repository
3 synthetic embossed plates

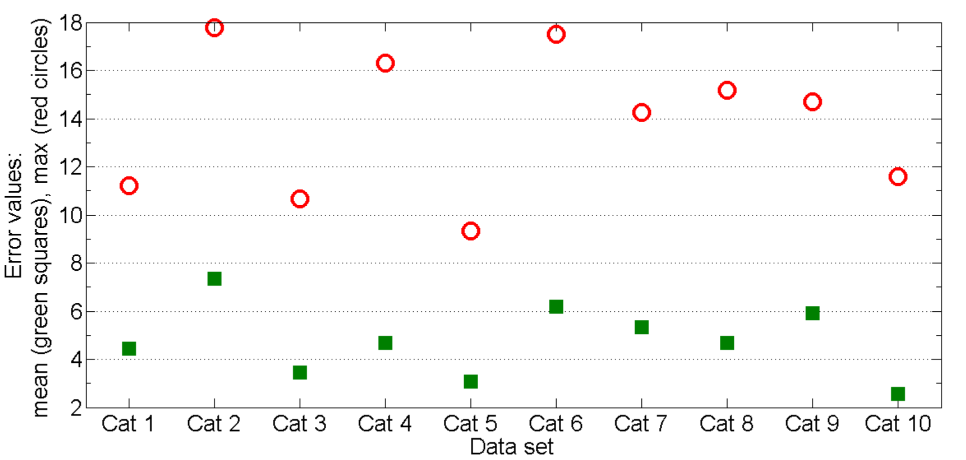
- Matlab implementation
- Update of geodesic distances is the most time consuming task
- Update of geodesics according to the histograms is required to be computed only once per each target mesh

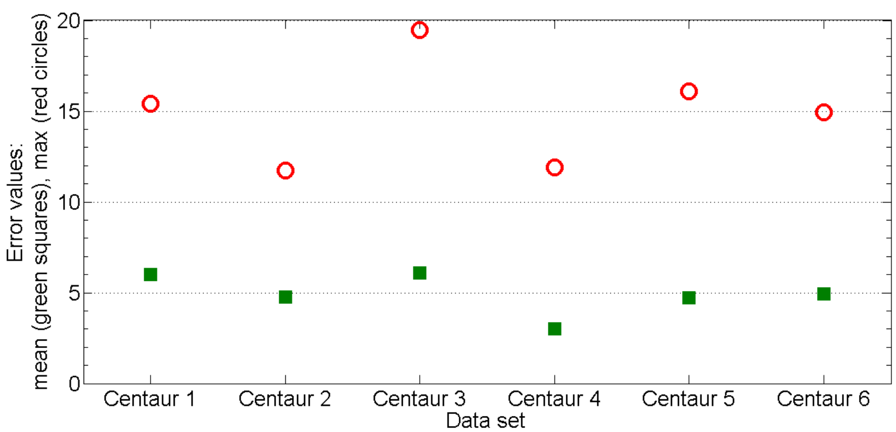
Results

Quality of transfer (QoT) with respect to ground truth



- Mixed data set of different subjects in different postures





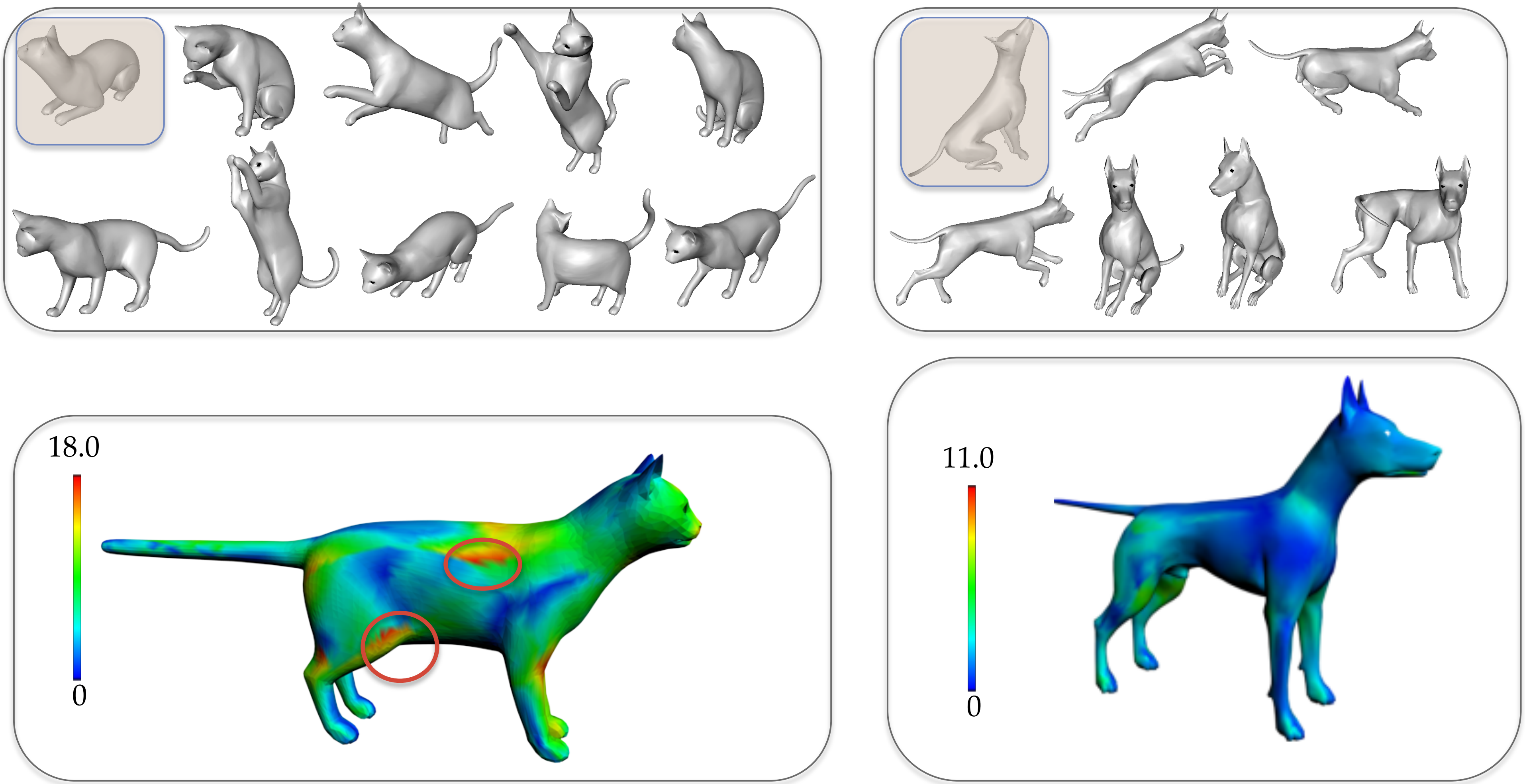
- Mean and Max error values vary from one posture to another due to imperfect isometries

○ max error

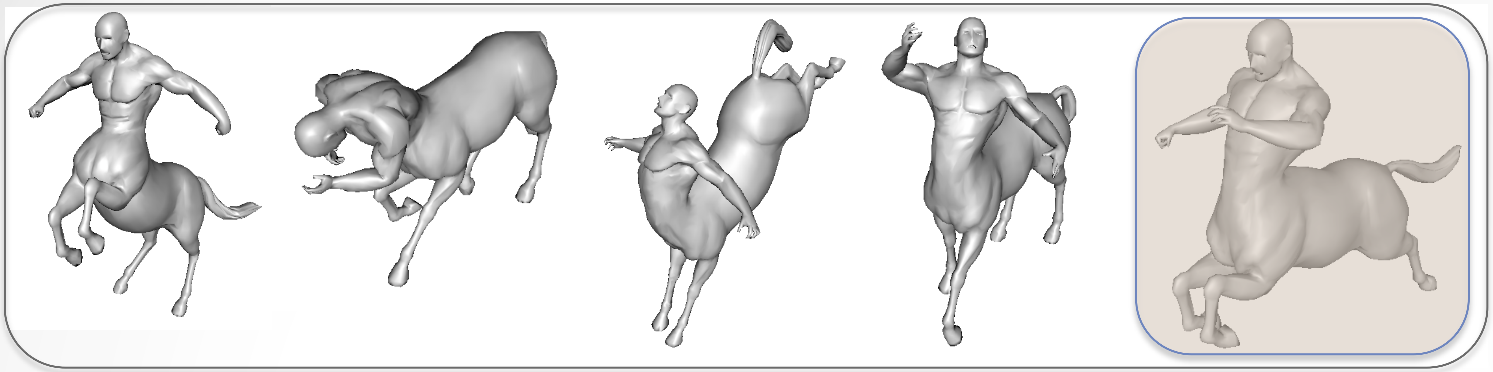
■ mean error

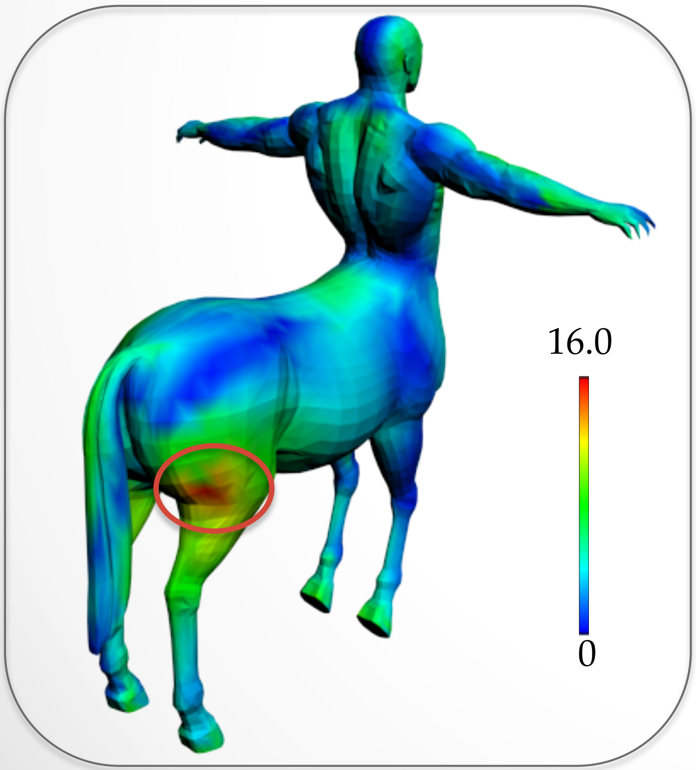
Results

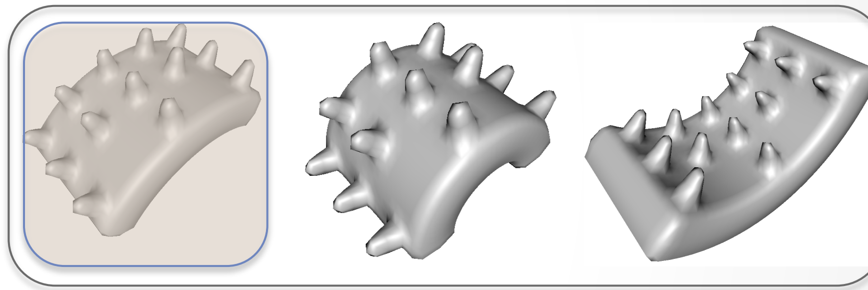
Quality of transferred landmark: the QoT is compared with the ground-truth correspondences from high-resolution TOSCA models

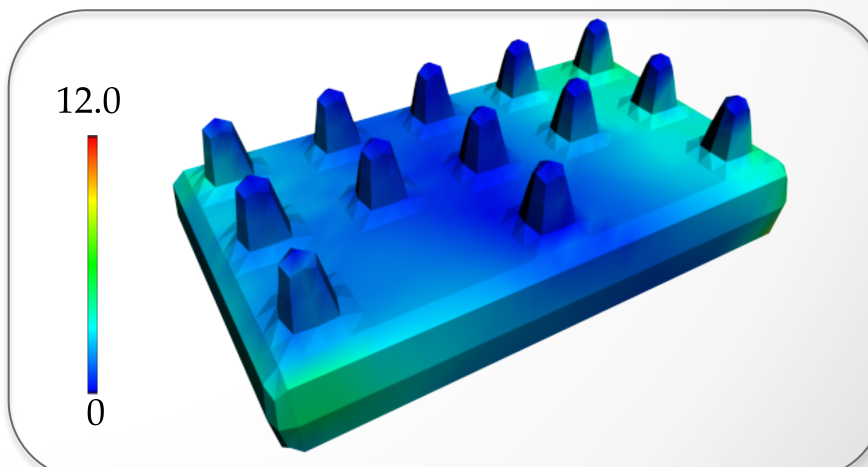


Results









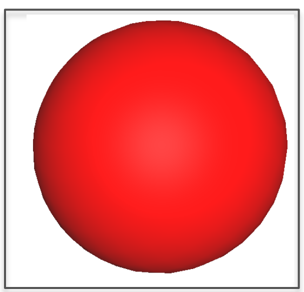
Limitations

- Missing data? Holes?

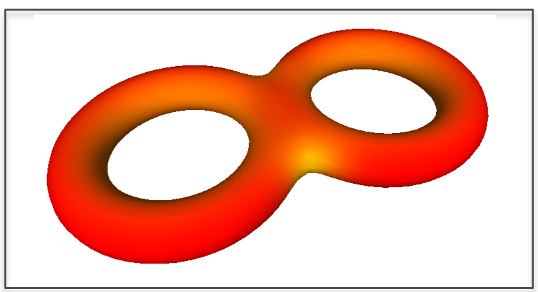
?

- Featureless objects

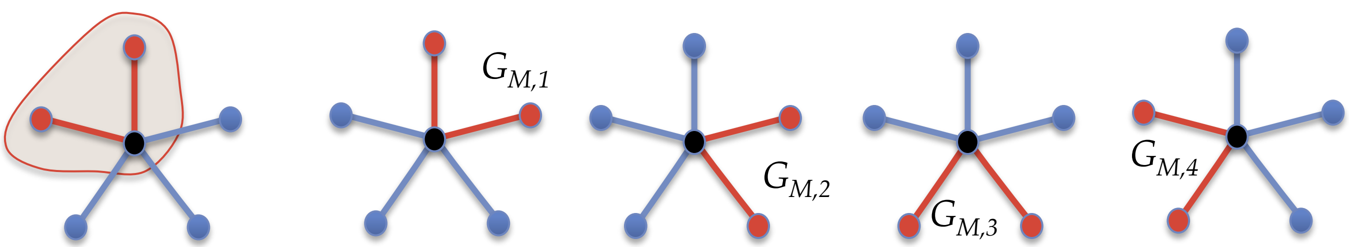
Genus 0



Genus 2



- Symmetry



Problem of intrinsic symmetries

Future plans

- Extension to full matching
- Maximum reuse of G_M for the correspondence computation

- Dynamic mesh registration 4D (3D + *t*)
- geometric + dynamic features
- Registration speed up by using Spatial segmentation -> registration of segments

Acknowledgements

For assistance in comparison of Plansac method to our landmark transfer technique, we would like to thank Art Tevs and the authors of Plansac paper [TBW*11] Alexander Berner, Michael Wand, Ivo Ihrke, and Hans-Peter Seidel.

Would like to thank Frederic Cordier for assistance in implementation.

This work has been supported by the French national project SHARED (Shape Analysis and Registration of People Using Dynamic Data, No.10-CHEX-014-01).

References

- [BMS*11] P. Bosea, A. Maheshwaria, C. Shub, S. Wuhrer, A survey of geodesic paths on 3D surfaces, Computational Geometry - Theory and Applications, Volume 44, Issue 9, Pages 486–498, November 2011.
- J.S.B. Mitchell, D.-M. Mount, and C.-H. Papadimitriou. The Discrete Geodesic Problem, SIAM Jounal of Computation, 16:647--668, 1987.
- [RTG00] RUBNER Y., TOMASI C., GUIBAS L. J.: The earth mover's distance as a metric for image retrieval. *Int. J. Comput. Vision 40*, 2 (2000), 99–121.
- [LH05] Marius Leordeanu, Martial Hebert: A Spectral Technique for Correspondence Problems Using Pairwise Constraints. ICCV 2005: 1482-1489.

References

- ISO/IEC FCD 19774 -- Humanoid animation, Feature points for the human body, http://h-anim.org/Specifications/H-Anim200x/ISO_ IEC_FCD_19774/FeaturePoints.html
- [SMT03] H. Seo, N. Magnenat-Thalmann, An automatic modeling of human bodies from sizing parameters, Proc. ACM symposium on Interactive 3D graphics, pp.19-26, 2003.
- [CZ08] W. Chang, M. Zwicker, Automatic Registration for Articulated Shapes, Computer Graphics Forum (Proceedings of SGP 2008), 1459-1468, 2008.
- [HAWG08] Q.-X. Huang, B. Adams, M. Wicke, L. J. Guibas, Non-Rigid Registration Under Isometric Deformations, Proc. of the Symposium on Geometry Processing, pp.1449-1457, 2008.
- [TBW*09] A. Tevs, M. Bokeloh, M. Wand, A. Schilling, H.-P. Seidel, Isometric Registration of Ambiguous and Partial Data, Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR '09), 2009.
- [TBW*11] A. Tevs, A. Berner, M. Wand, I. Ihrke, H.-P. Seidel, Intrinsic Shape Matching by Planned Landmark Sampling", Eurographics, 2011
- [WWG*10] Chaohui Wang ; Yang Wang ; Xianfeng Gu ; Samaras, D. ; Paragios, N., Dense Non-rigid Surface Registration Using High-Order Graph Matching, Proc. IEEE Computer Vision and Pattern Recognition (CVPR), pp. 382- 389, 2010.
- [BWM*11] A. Berner, M. Wand, N. J. Mitra, D. Mewes, H.-P. Seidel, Shape Analysis with Subspace Symmetries, Computer Graphics Forum (Eurographics), 2(30), 2011.
- [Ull76] Ullmann J.R., An Algorithm for Subgraph Isomorphism, Journal of the Association for Computing Machinery, vol. 23, pp. 31-42, 1976.
- MITCHELL, J. S. B.,MOUNT, D. M., AND PAPADIMITRIOU, C. H. 1987.The discrete geodesic problem. SIAM J. of Computing 16(4), 647–668.
- [GJ79] M. Garey, D. Johnson, Computers and Intractability: A Guide to the theory of NP-completeness. W.H. Freeman and Co., San Francisco, Calif., 1979.

?

mykhalchuk@unistra.fr