Lab of Imagery and Vision 4D

POLYTECHNIQUE MONTRÉAL

LE GÉNIE EN PREMIÈRE CLASSE

CHU Sainte-Justine

3D Shape Asymmetry Analysis Using Correspondence Beween Partial Geodesic Curves

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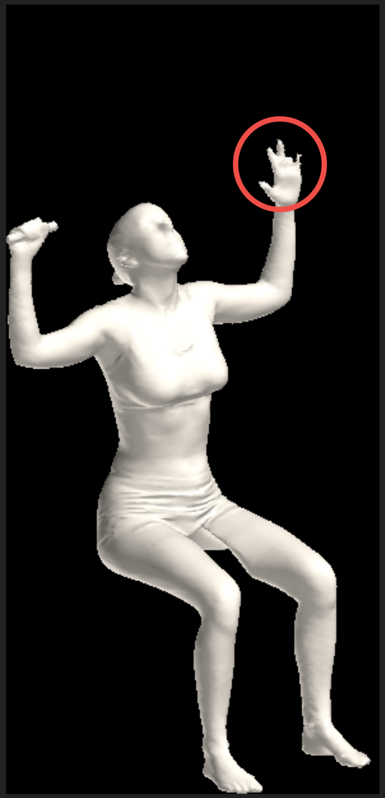
Ola Ahmad, Philippe Debanné, Stefan Parent, Hubert Labelle, Farida Cheriet

In 5th IEEE Global Conference on Signal and Information Processing

Montreal, Nov. 15, 2017

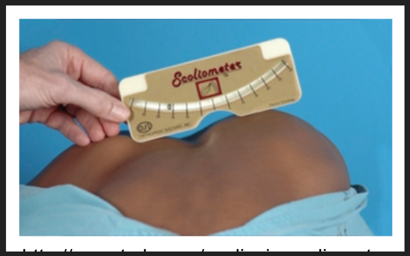
General focus:

- **Intrinsic symmetry of partial shape data**
- **3D shape analysis with local asymmetries**



WHAT DO WE FOCUS ON

Biomedical application:



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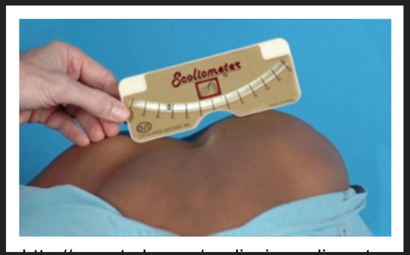

- Scoliosis is a 3D Musculoskeletal deformations that affect the shape of the torso.

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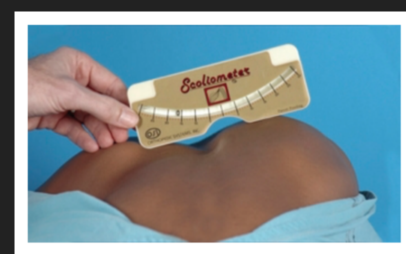

- Scoliosis is a 3D Musculoskeletal deformations that affect the shape of the torso.
- 1 in 25 people have mild scoliosis deformations.

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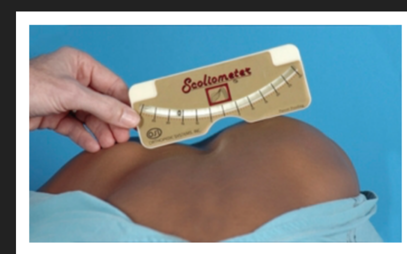
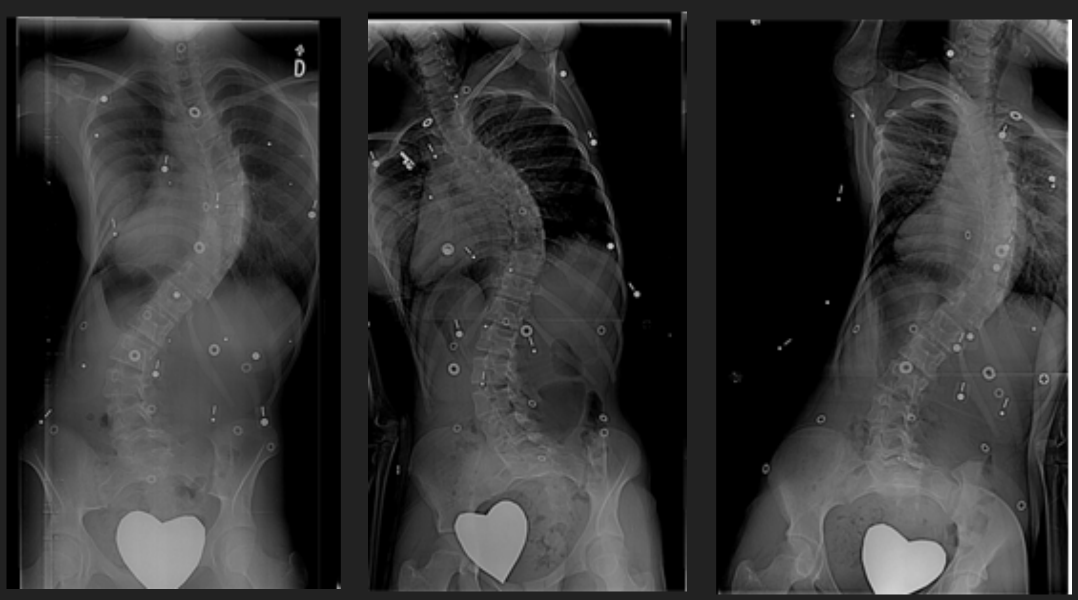


- Scoliosis is a 3D Musculoskeletal deformations that affect the shape of the torso.
- 1 in 25 people have mild scoliosis deformations.
- 1 in 200 adolescents have scoliosis that progress to require either bracing or surgical treatment.

HOW TO PREDICT THE SURGERY FOR SCOLIOSIS

Traditional treatement:
radiographic measurements



- Scan the shape in three different poses: neutral standing, left and right bending.
- The spine curve mobility under different poses can help predicting the best surgical strategy.

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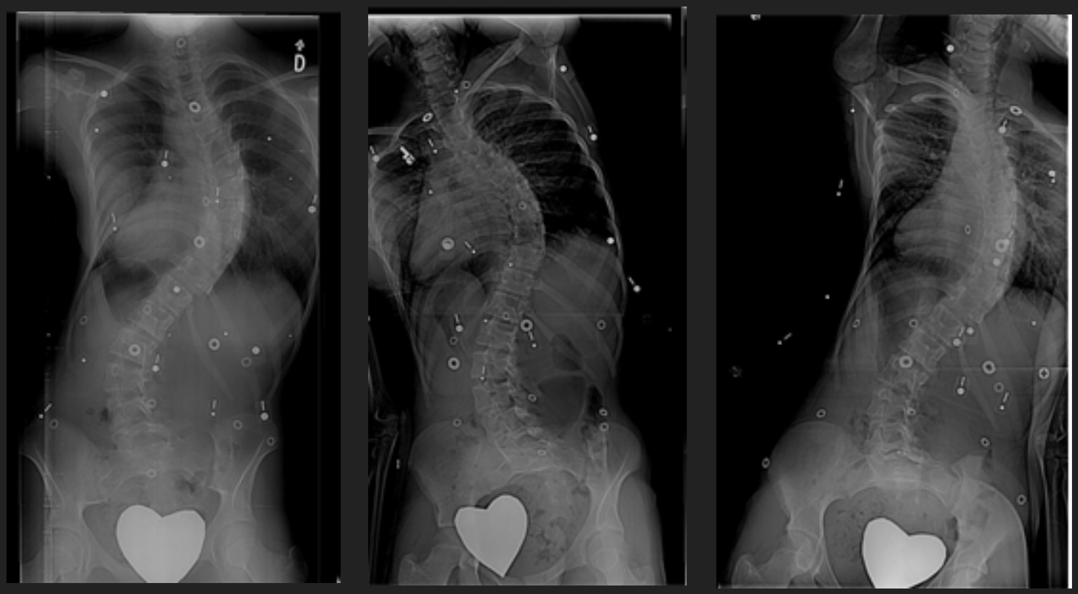

How to consider the asthetic corrections?

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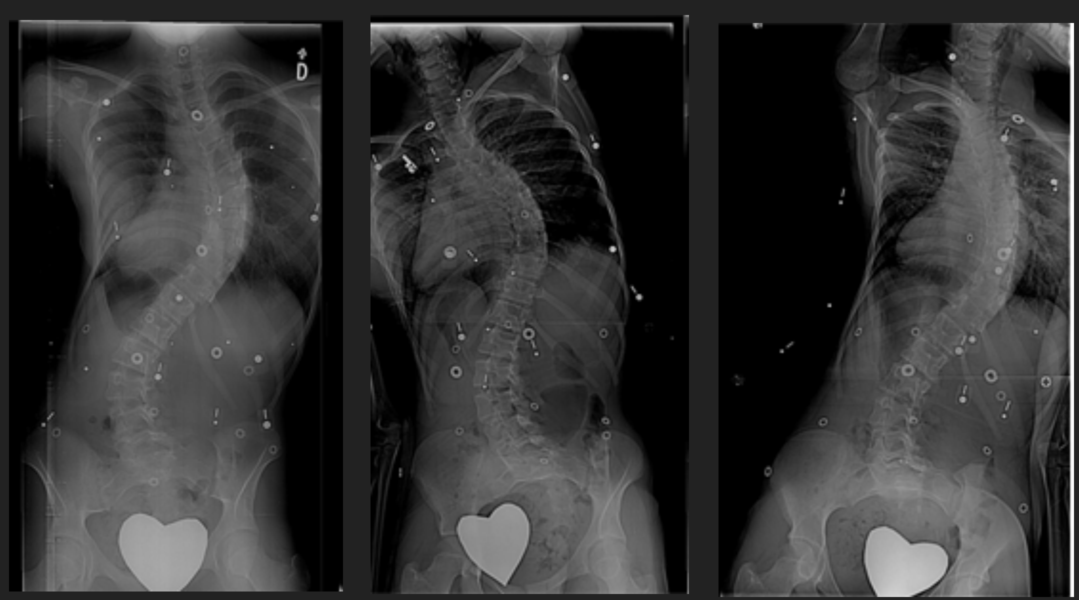
HOW TO PREDICT THE SURGERY FOR SCOLIOSIS

Traditional treatement: radiographic measurements

Improvement: topographic + radiographic measurements



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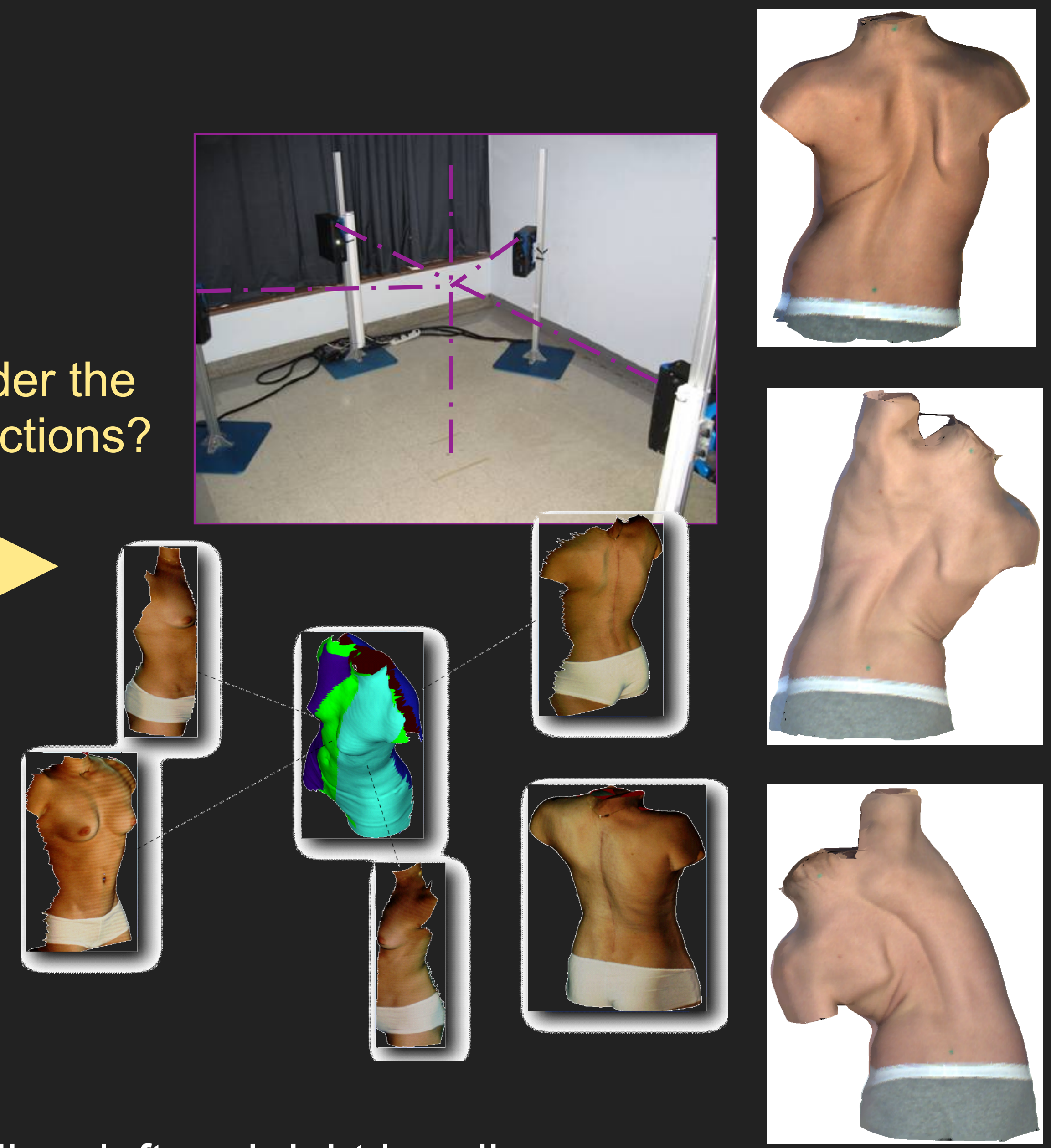

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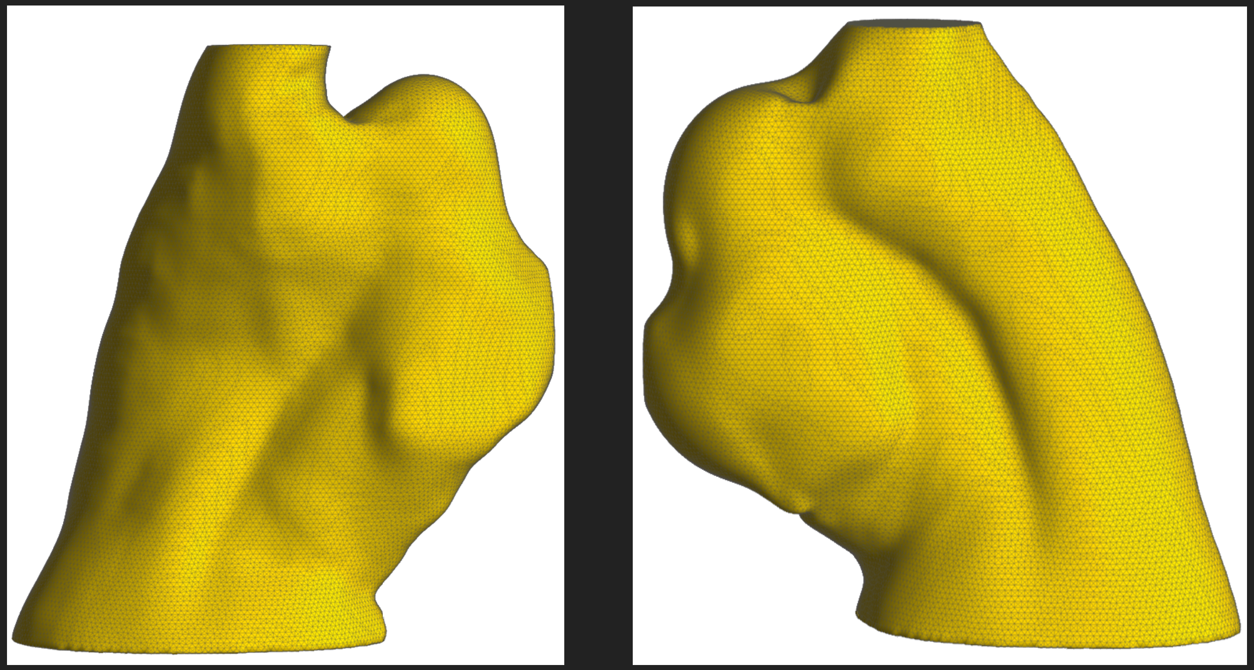
Main challenges:

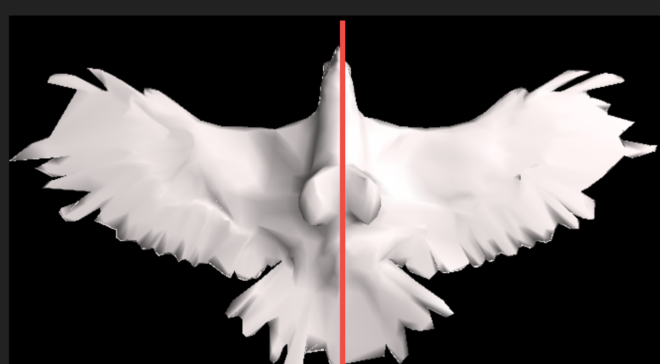
- Truncated parts of the body.
- Non-rigid deformations.

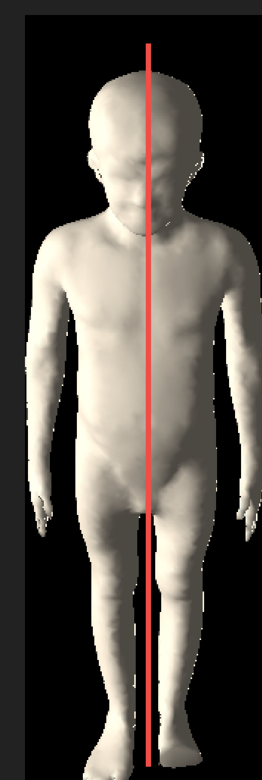


How can we analyse the 3D shape asymmetry of the deformable scoliotic torsos under pose changes?

MOTIVATION

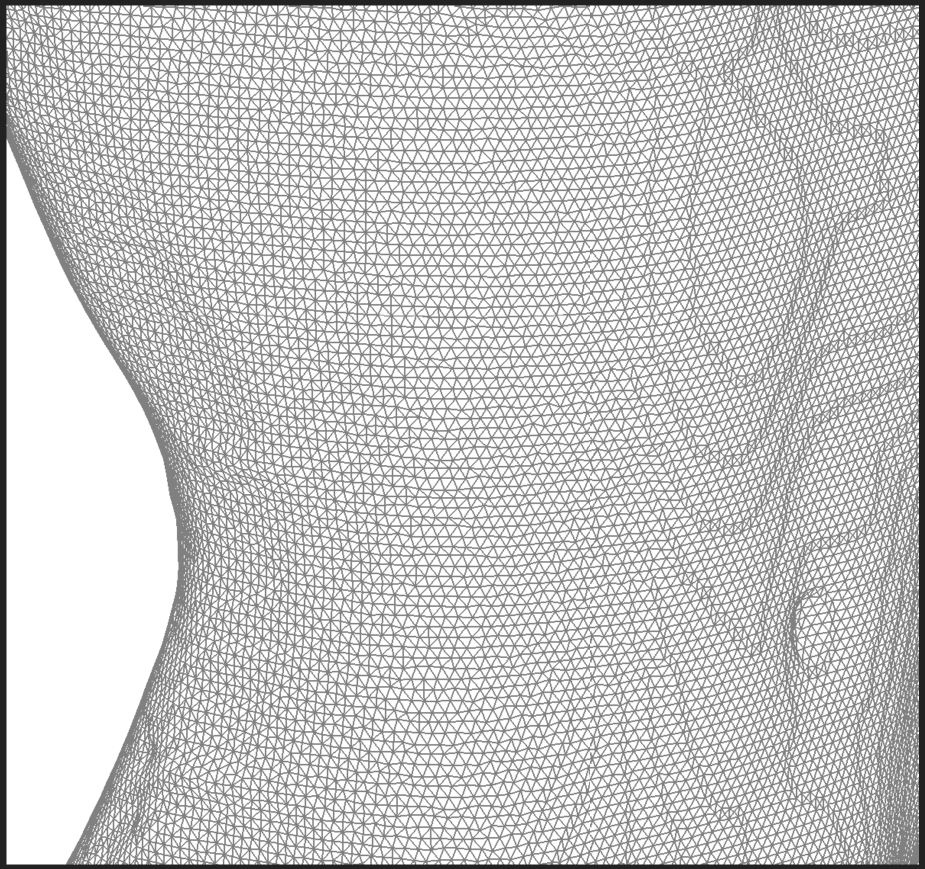
- Most natural shapes have a degree of symmetry.
- The Detection of the global symmetry allows analyzing the local differences between corresponding parts (organs).





1. Detection of symmetry plane and medial curve

- 3D Mesh modelling: connected graph model



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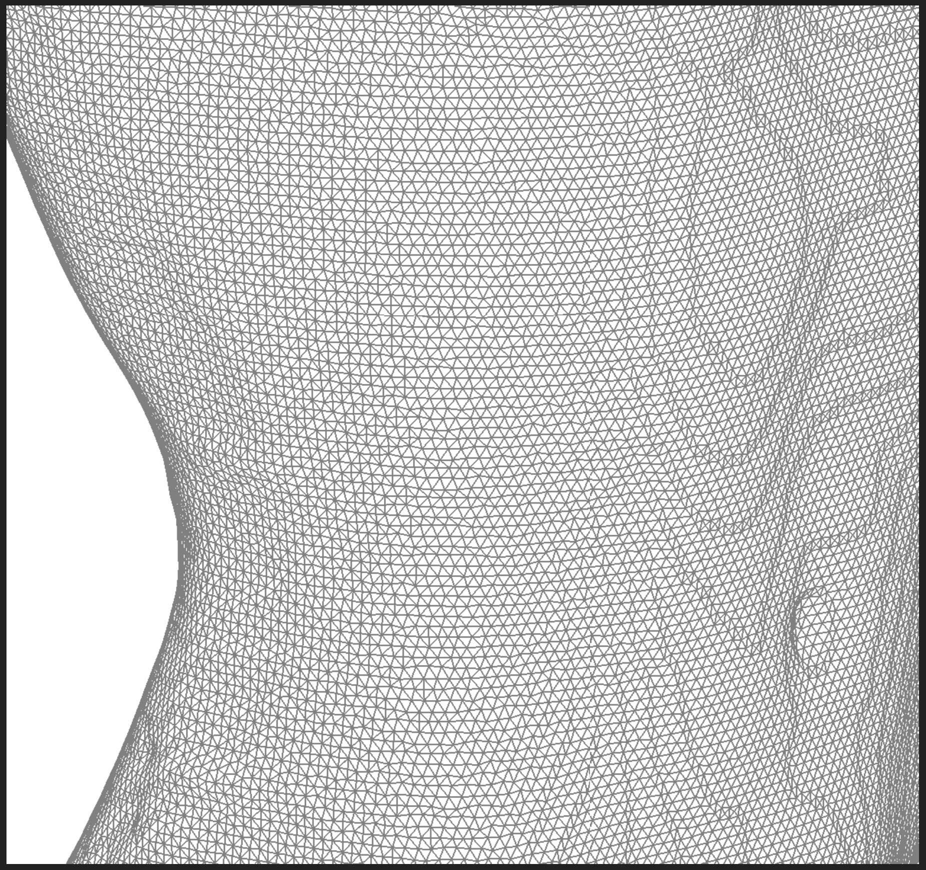

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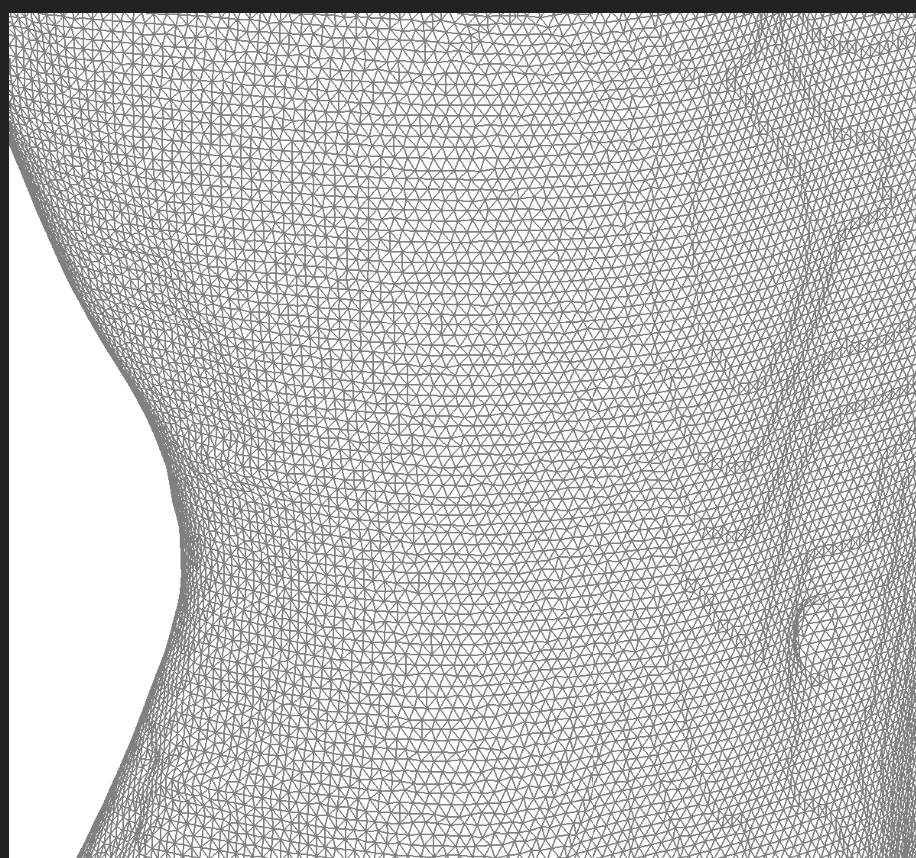
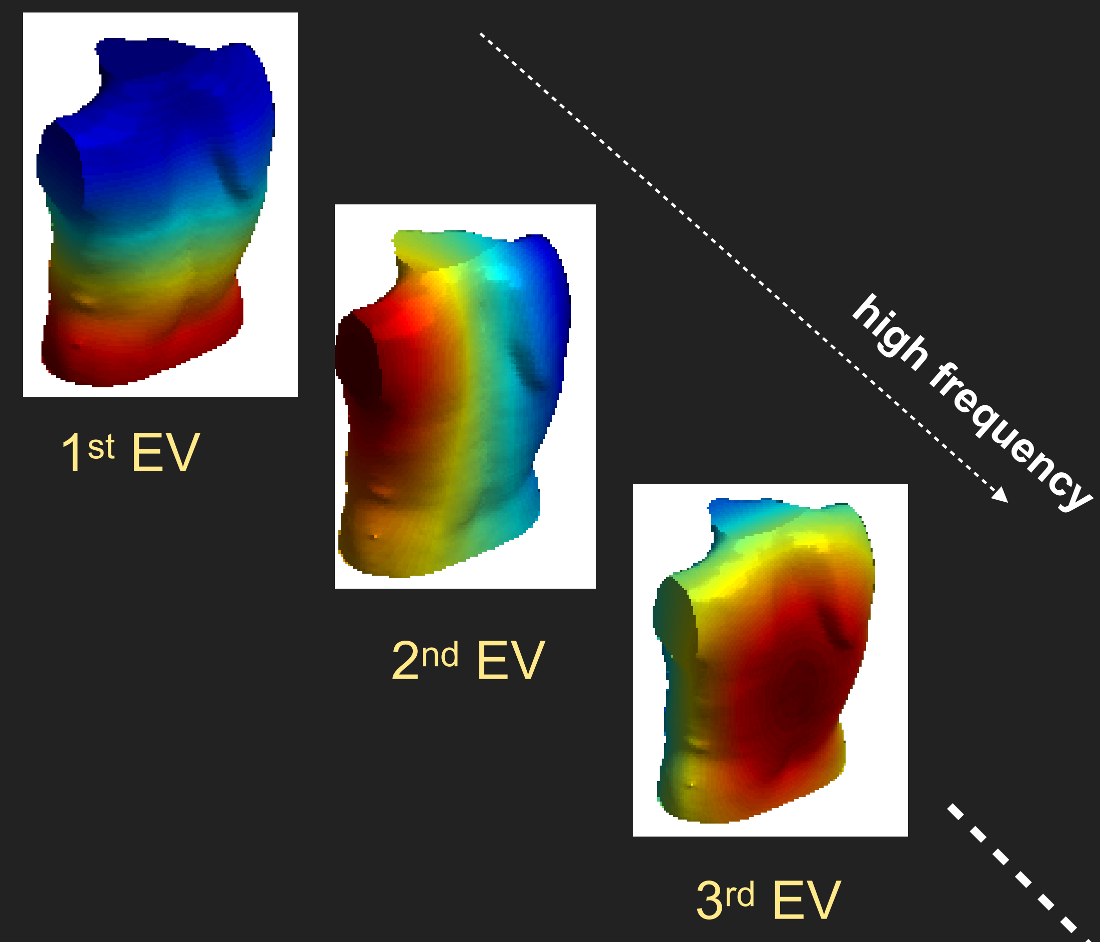
- 3D Mesh modelling: connected graph model
- Spectral decomposition of a graph Laplacian

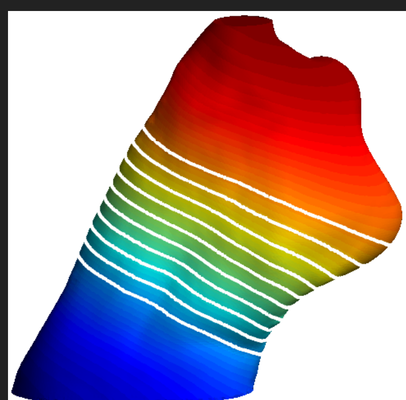


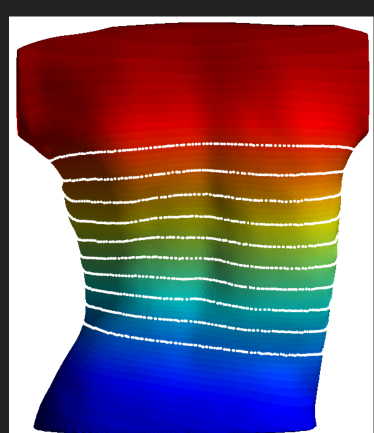


1. **Detection of symmetry plane and medial curve**

PROPOSED APPROACH

1. Detection of symmetry plane and medial curve





Fiedler vector (FV) analysis: level set function on the mesh data

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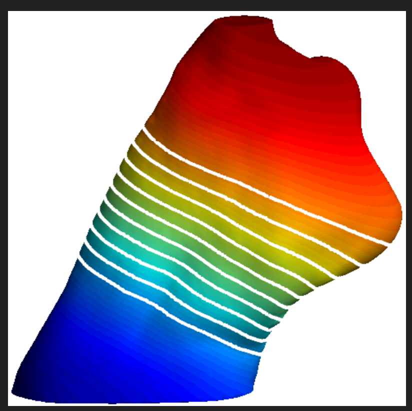

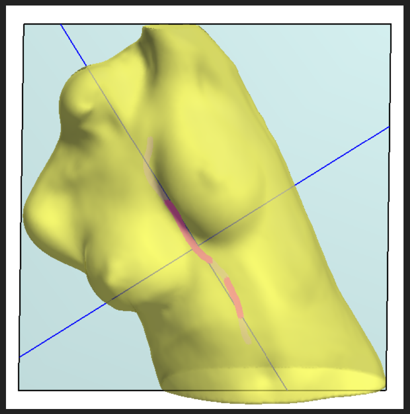

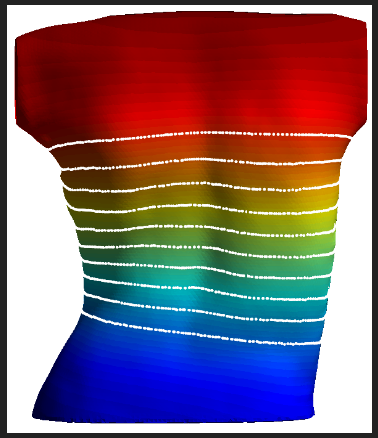

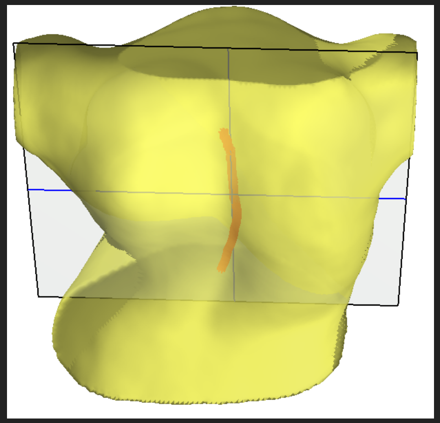

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PCA of the level set centroid points

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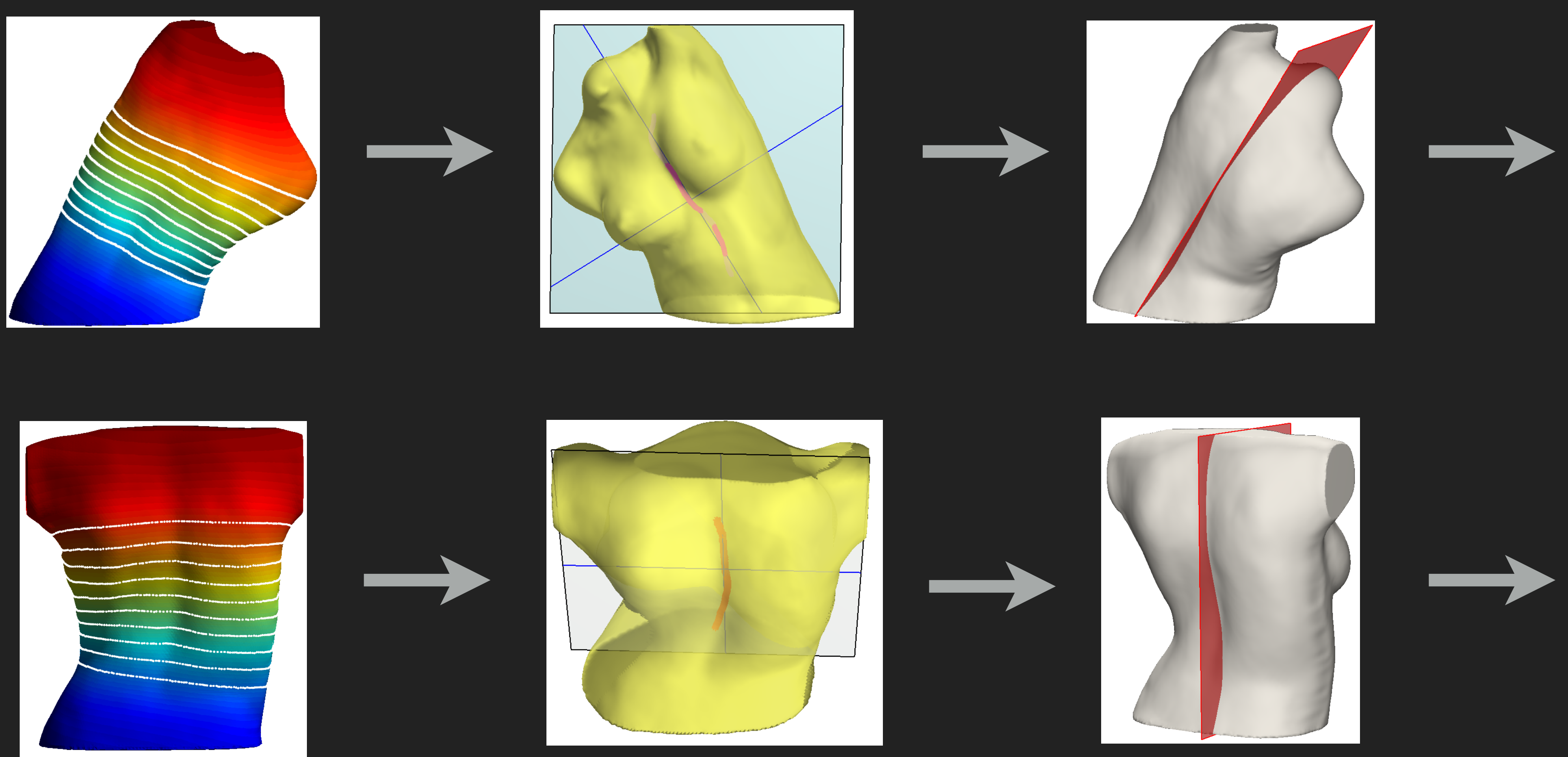

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Global symmetry of the shape

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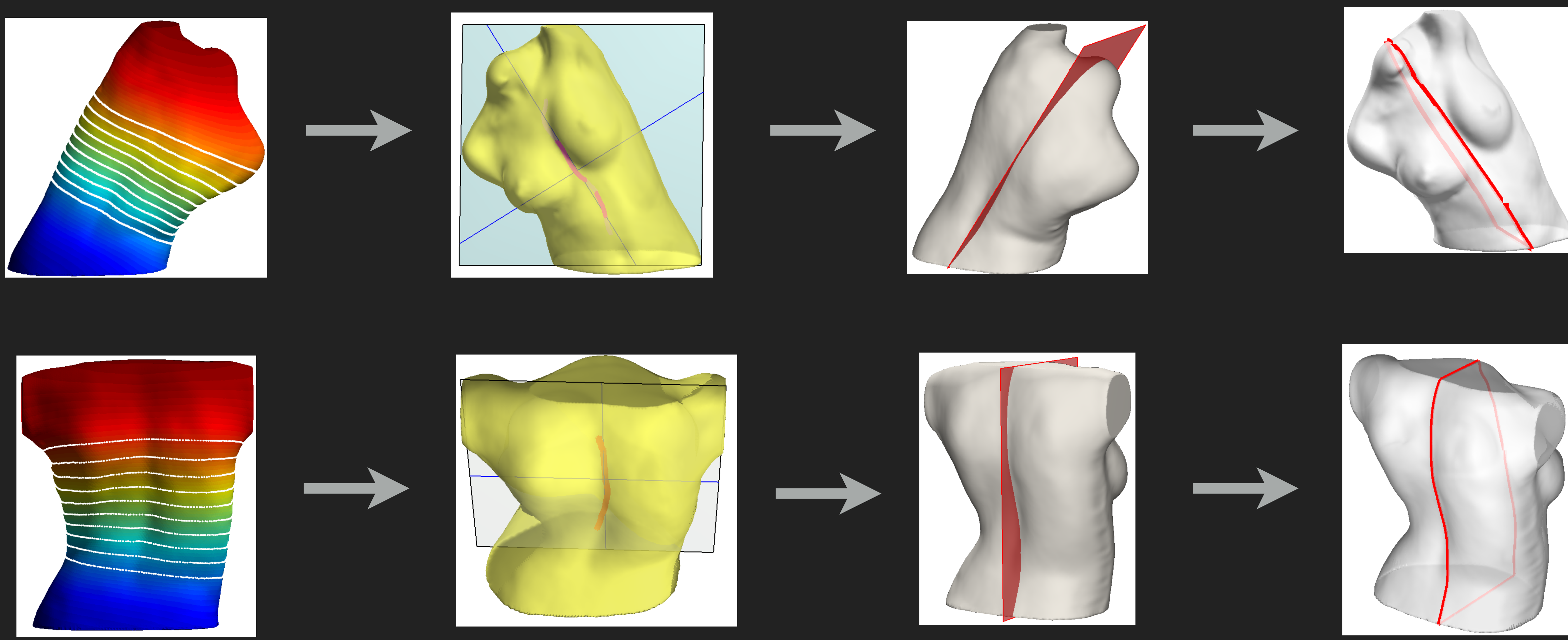

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Medial curve

2. **Detection of reflectional geodesic curves**

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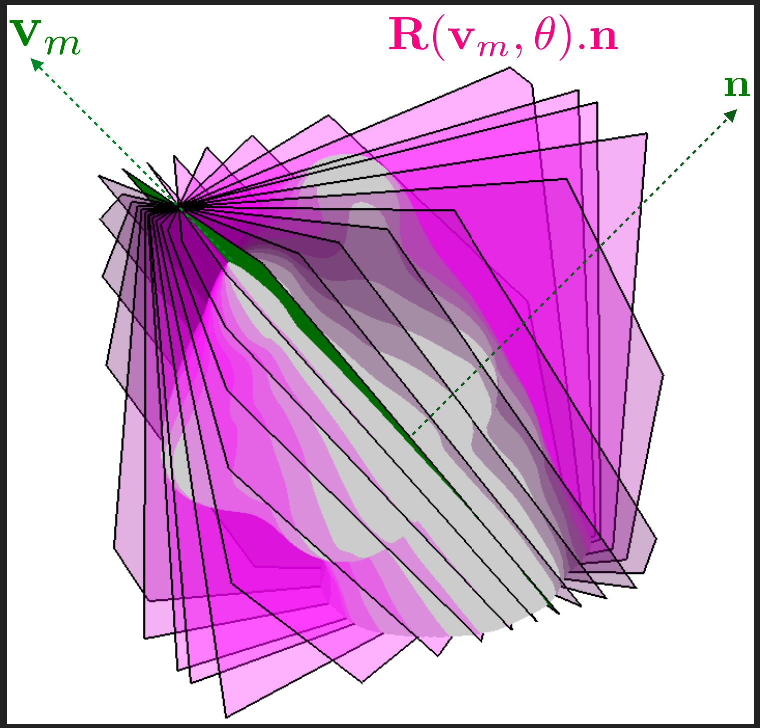

$$\mathbf{R}(\mathbf{v}_m, \theta) = \mathbf{I}_3 + \sin\theta \mathbf{A}(\mathbf{v}_m) + (1 - \cos\theta)\mathbf{A}^2(\mathbf{v}_m)$$

$$\mathbf{A}(\mathbf{v}_m) = \begin{bmatrix} 0 & -\mathbf{v}_m(3) & \mathbf{v}_m(2) \\ \mathbf{v}_m(3) & 0 & -\mathbf{v}_m(1) \\ -\mathbf{v}_m(2) & \mathbf{v}_m(1) & 0 \end{bmatrix}$$

$$\theta \in (0, \pi)$$

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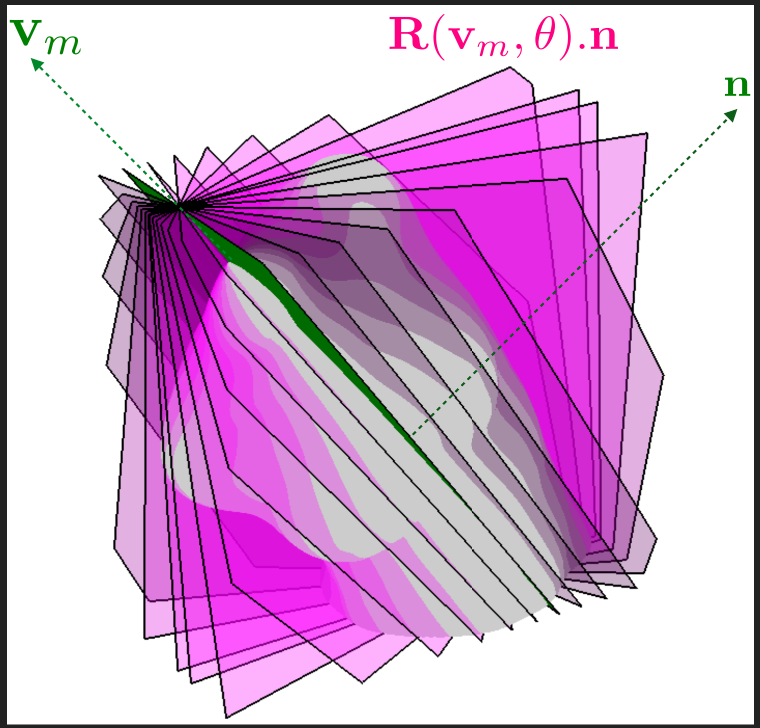

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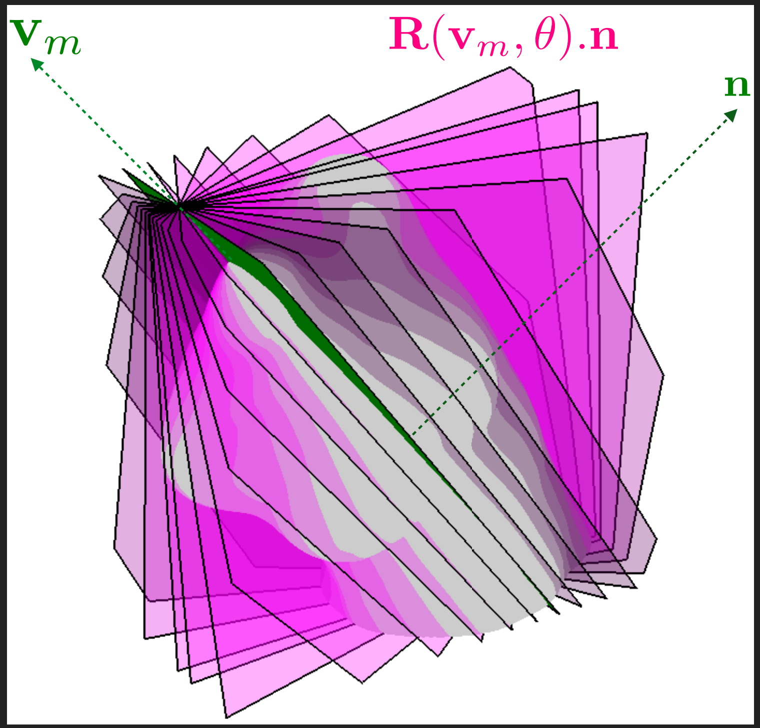

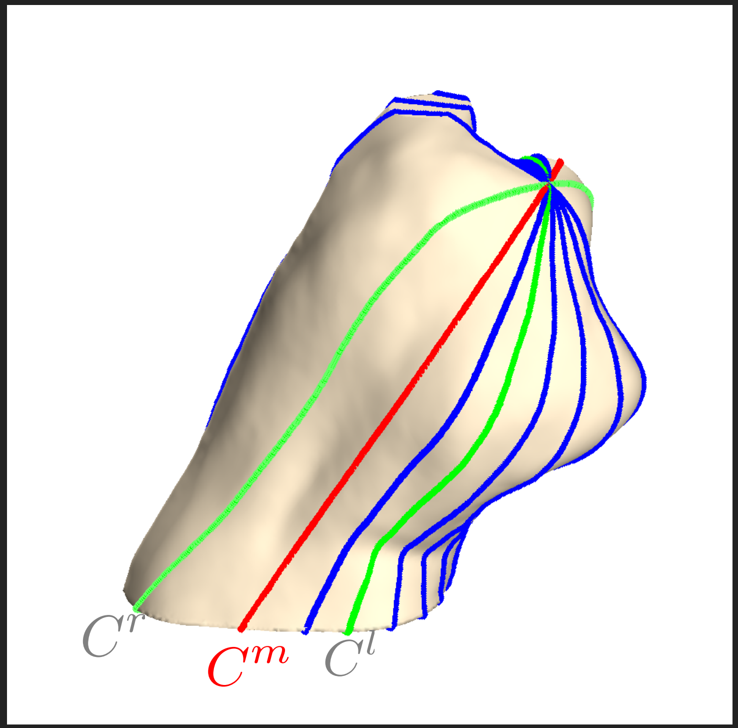

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$$\mathcal{C}^l = \operatorname{argmin}_{\{\mathcal{C}^l_1, .., \mathcal{C}^l_k, .., \mathcal{C}^l_I\}} \|d^{m-r} - d^{m-l}_k\|^2$$

$$d^{m-r} = \|\mathcal{C}^m - \mathcal{C}^r \circ c^r\|^2$$

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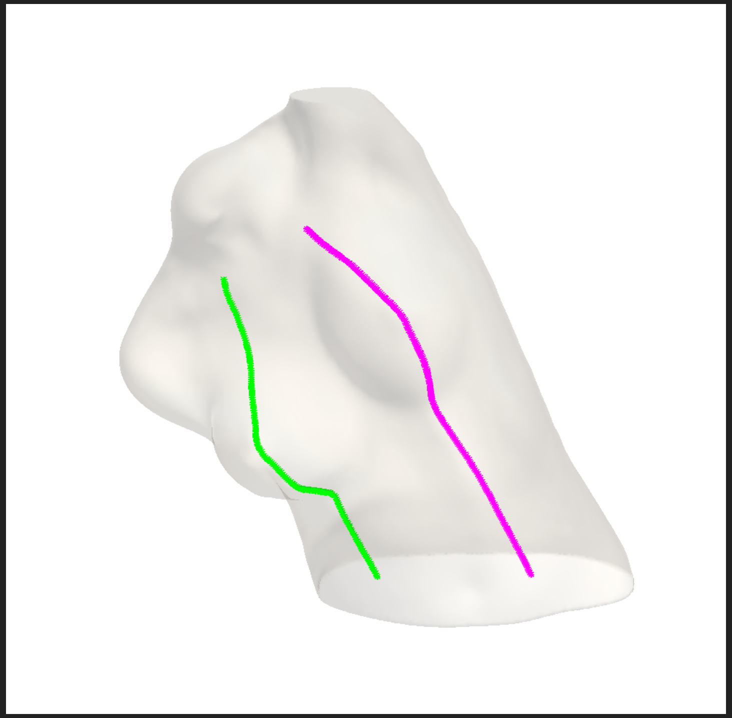

Reflective partial curves

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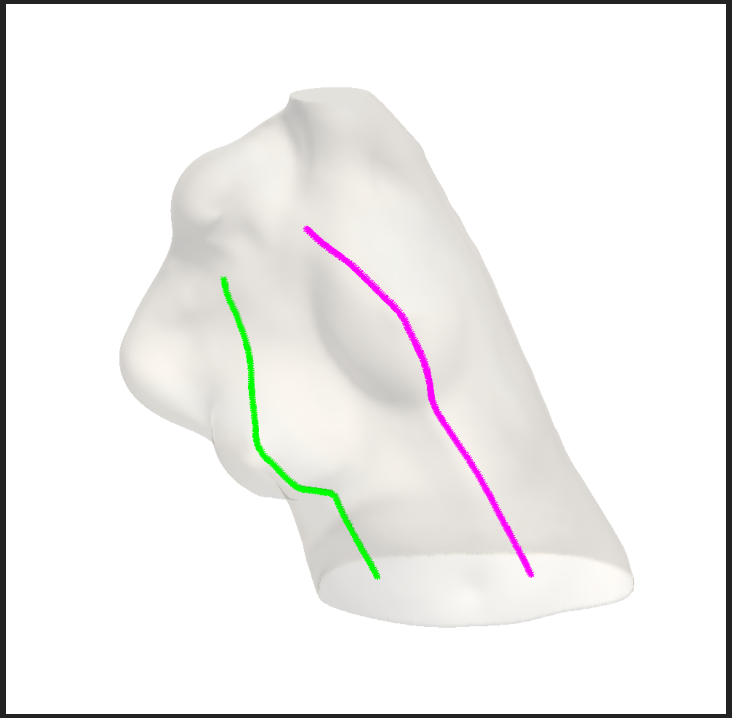

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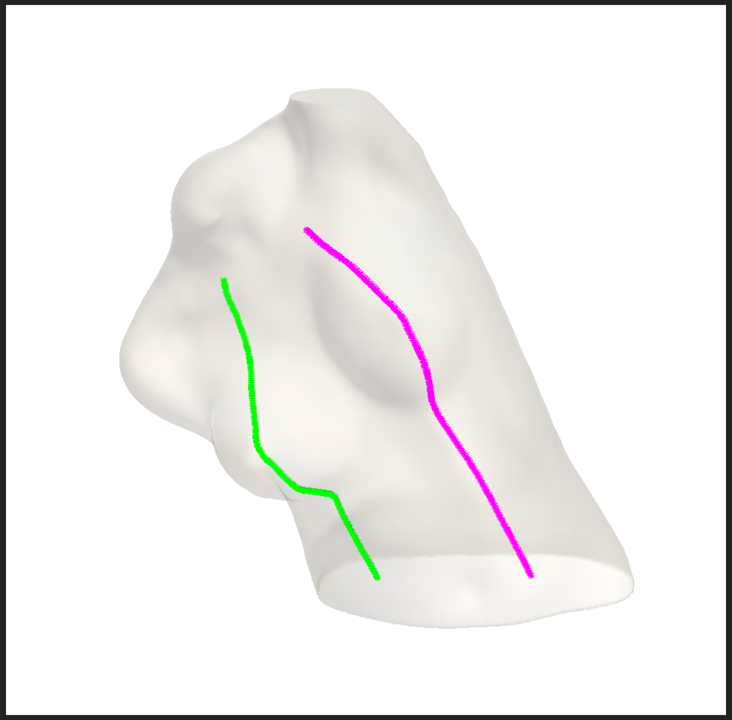

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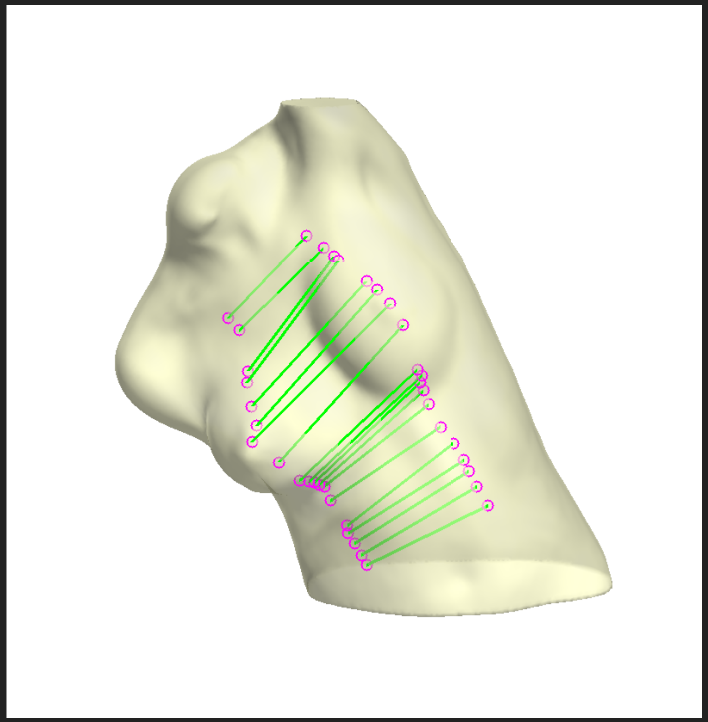
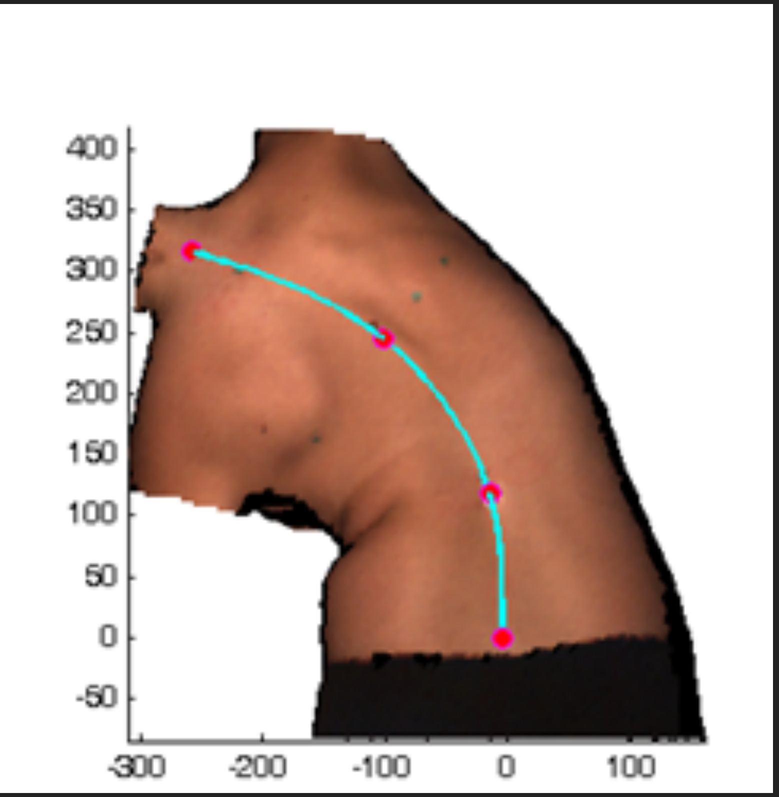


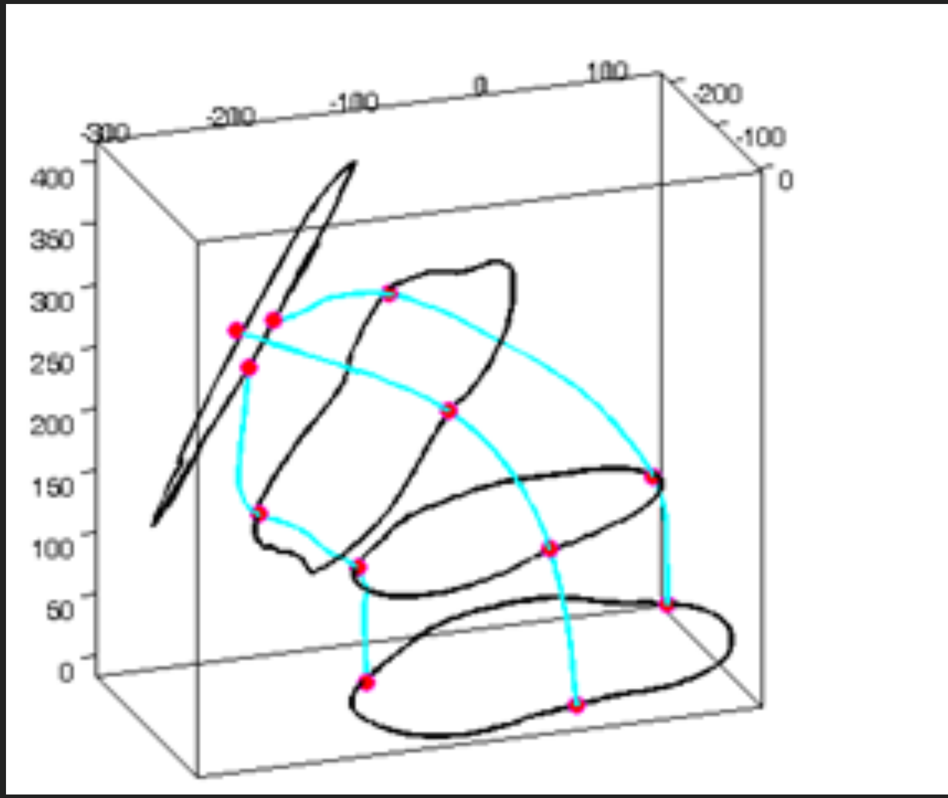
non-rigid alignement

CPD Algorithm

A. Myronenko and X. Song, "Point set registration: Coherent point drift," IEEE Transactions on Pattern Analysis and Machine Intelligence , vol. 32, no. 12, pp. 2262–2275, 2010

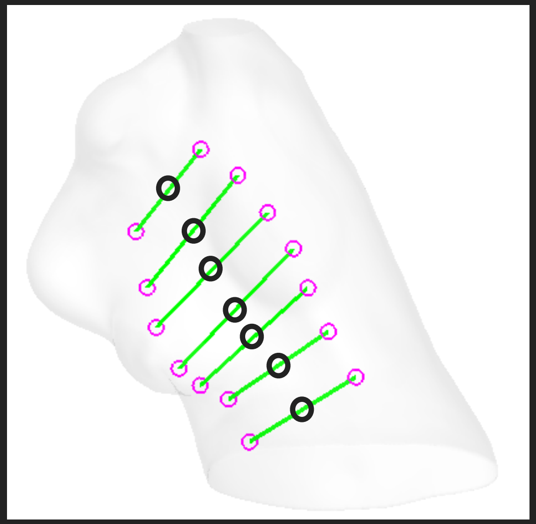
Application:





Intrinsic contour levels (cross-sections) from which indices of asymmetry can be extracted.

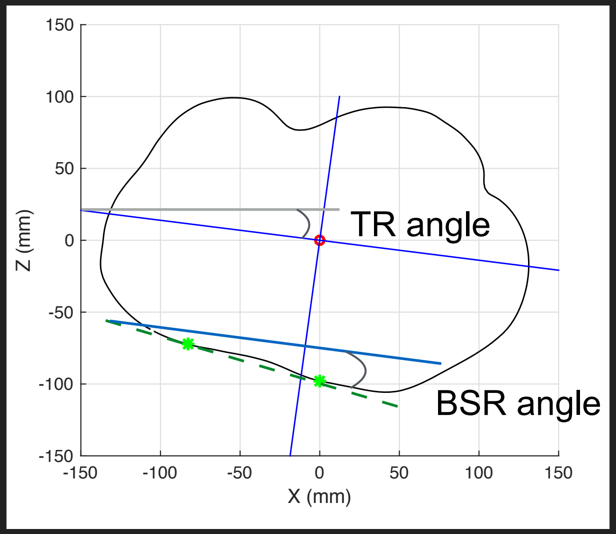
Extraction of intrinsic shape contours of the deformable human torsos

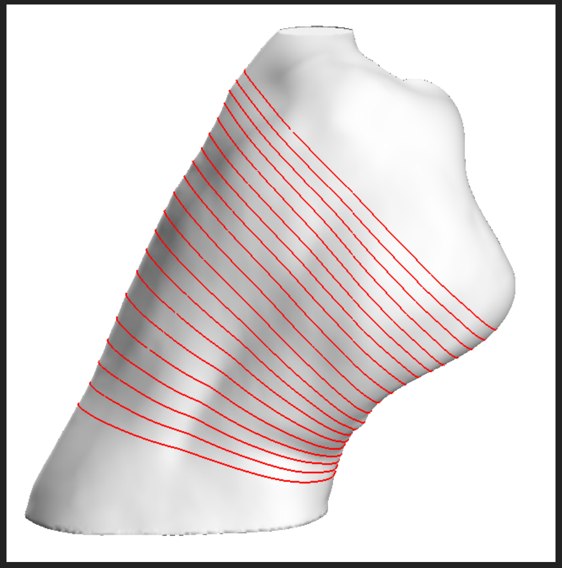


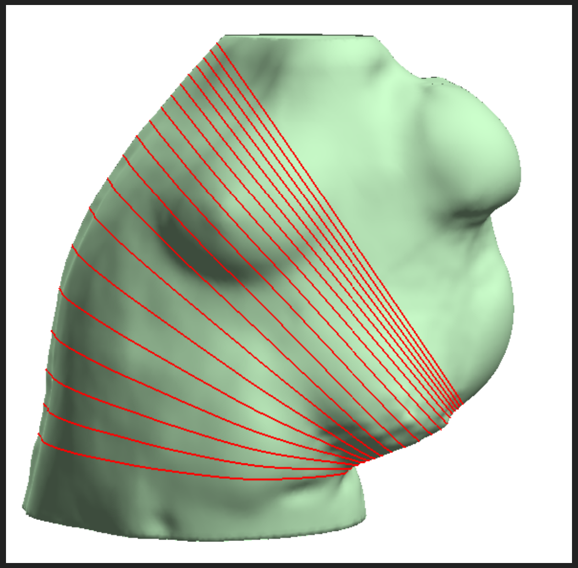
Two corresponding points on the anterior side

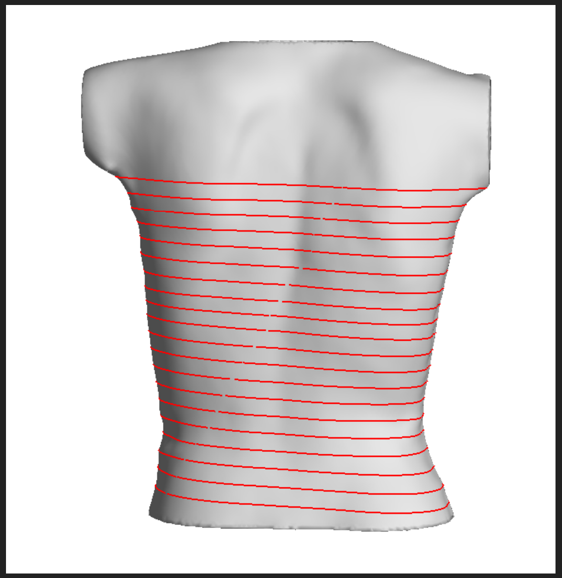
+

middle point on the back side









Philippe Debanné, Ola Ahmad, Stefan Parent, Hubert Labelle, and Farida Cheriet, "A Novel Automatic Method to Evaluate Scoliotic Trunk Shape Changes in Different Postures," International Conference Image Processing and Recognition, LNCS, vol. 10317, pp. 455-462, 2017.

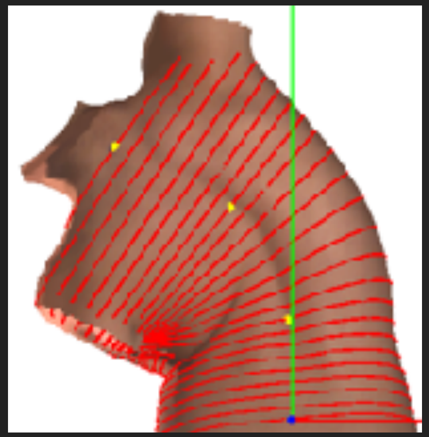
Comparision between the proposed and baseline approaches

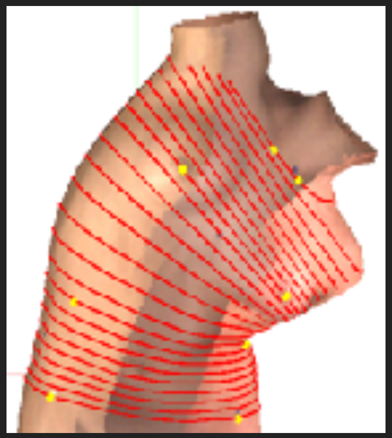
- Dataset:

15 scoliotic torsos each undergores different pose.

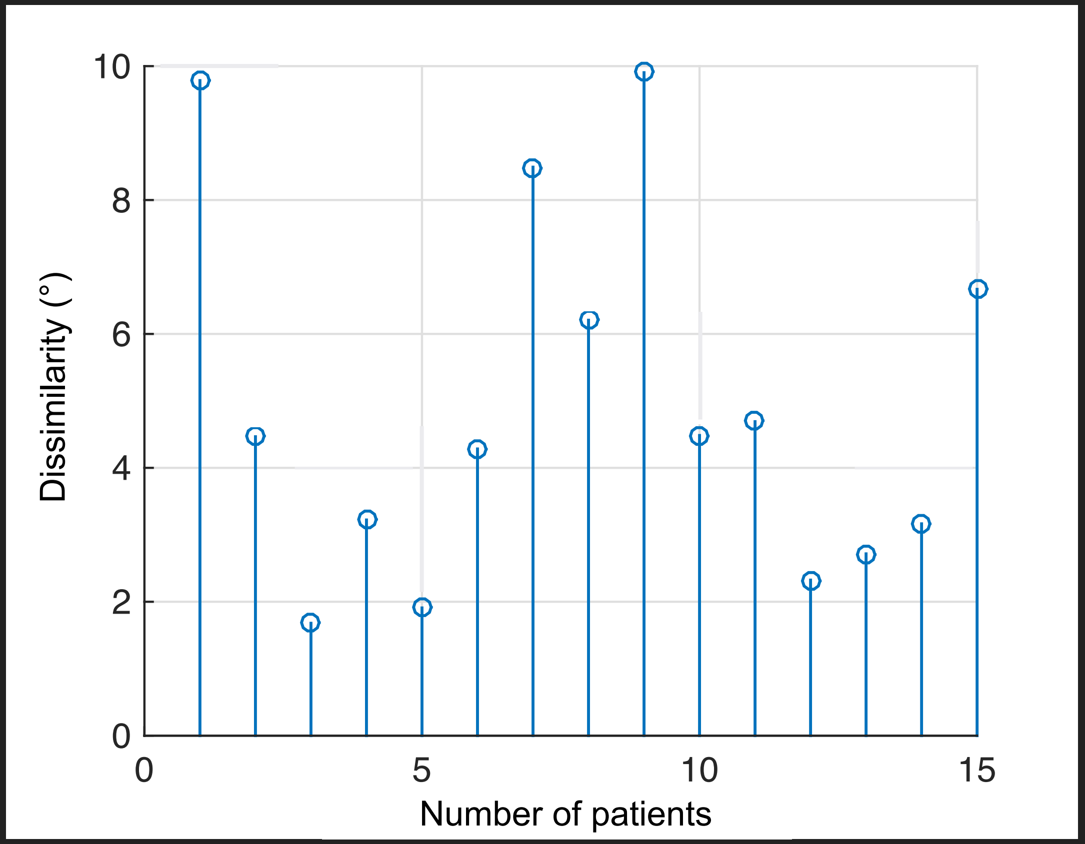
- Baseline approach:

Semi-automatic based on landmarkes.





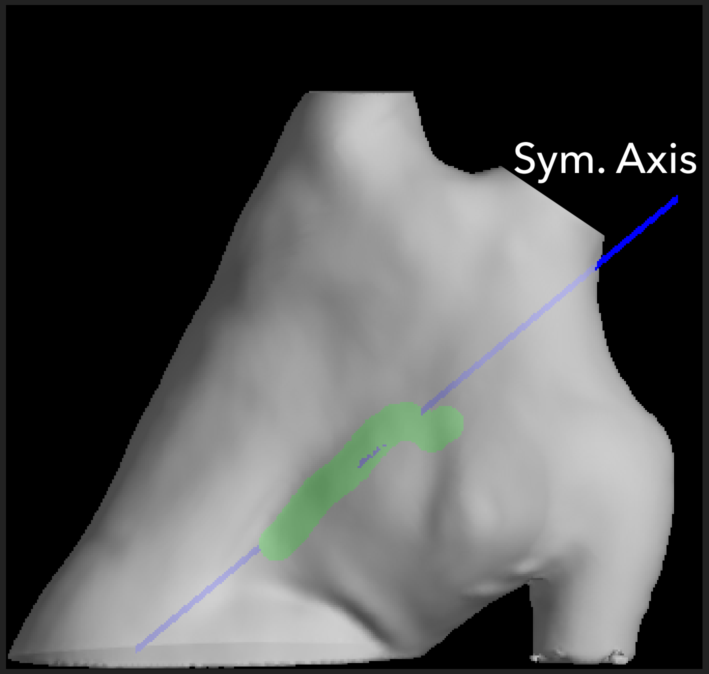
Philippe Debanné, Valérie Pazos, Hubert Labelle, and Farida Cheriet, "Evaluation of reducibility of trunk asymmetry in lateral bending," Stud Health Technol Inform , vol. 158, pp. 72–77, 2010.

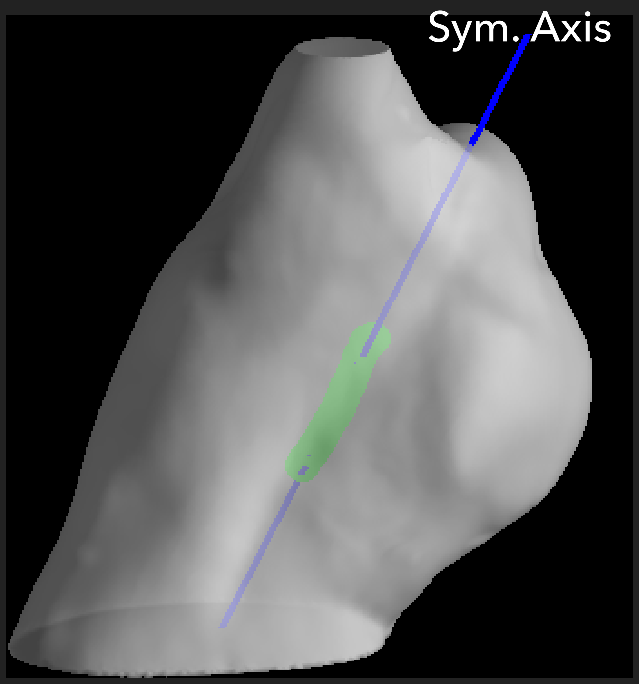


Dissimilarity criteria: $|\bar{\theta} - \bar{\theta}_b|$

$$\bar{\theta} = \frac{1}{\#levels} \sum_{\#levels} TR$$

Challenging examples:





Failure in the global symmetry detection under extreme deformations

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- We simplified the analysis of the 3D deformable torso shapes to the matching between geodesic curves in the reflective regions.

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Possible Future improvements:

- Learn a model on the partial data to find the global symmetry of the shape robust to pose changes and extreme deformations.
- Incorporate fingerprint features to enhance point correspondence between partial geodesics.

THANK YOU