ACIVS 2016

Breast Shape Parametrization through Planar Projections

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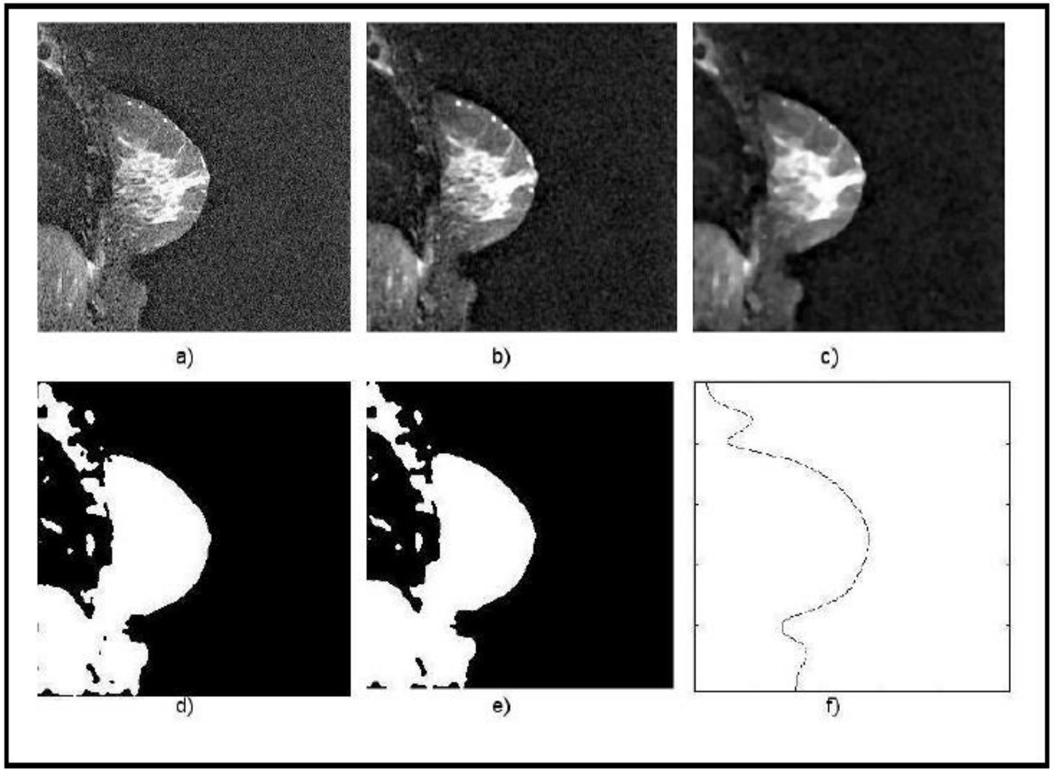
Contents

- Our **goal**: find a small set of parameters to describe breast shape.

- **Why**: In plastic surgery, this give the possibility to do objective measure of patient breast and allows to use objective criteria to evaluate the results of a reconstruction.

Previous work



- Nuclear Magnetic Resonances (NMR) to get breast slices
- Find each slice contour for breast model reconstruction
- Reduce dimensionality using PCA

Previous work

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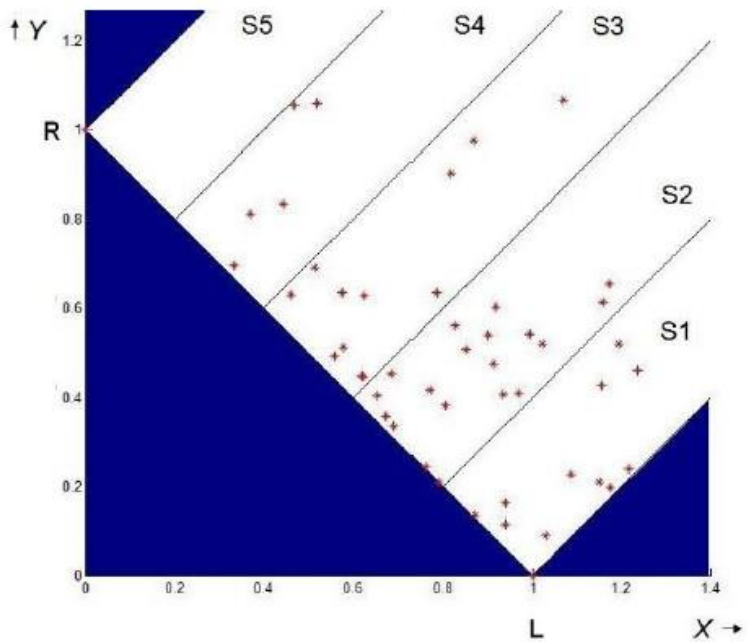
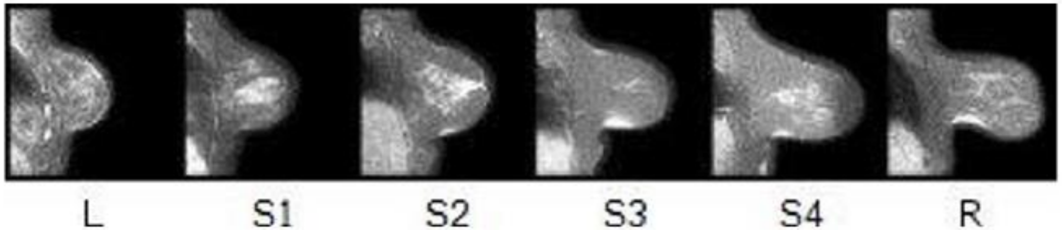




- The results, assessed by the breast specialist, were good but…
- …the NMR is slow and is a cost for the hospital.

Outline

1. Acquisition with low-cost scanner
2. Planar projection in 2D of 3D models
3. Geometrical landmarks extraction
4. Thin-Plate Spline to estimate non-linear deformation
5. Principal Component Analysis to obtain the set of parameters

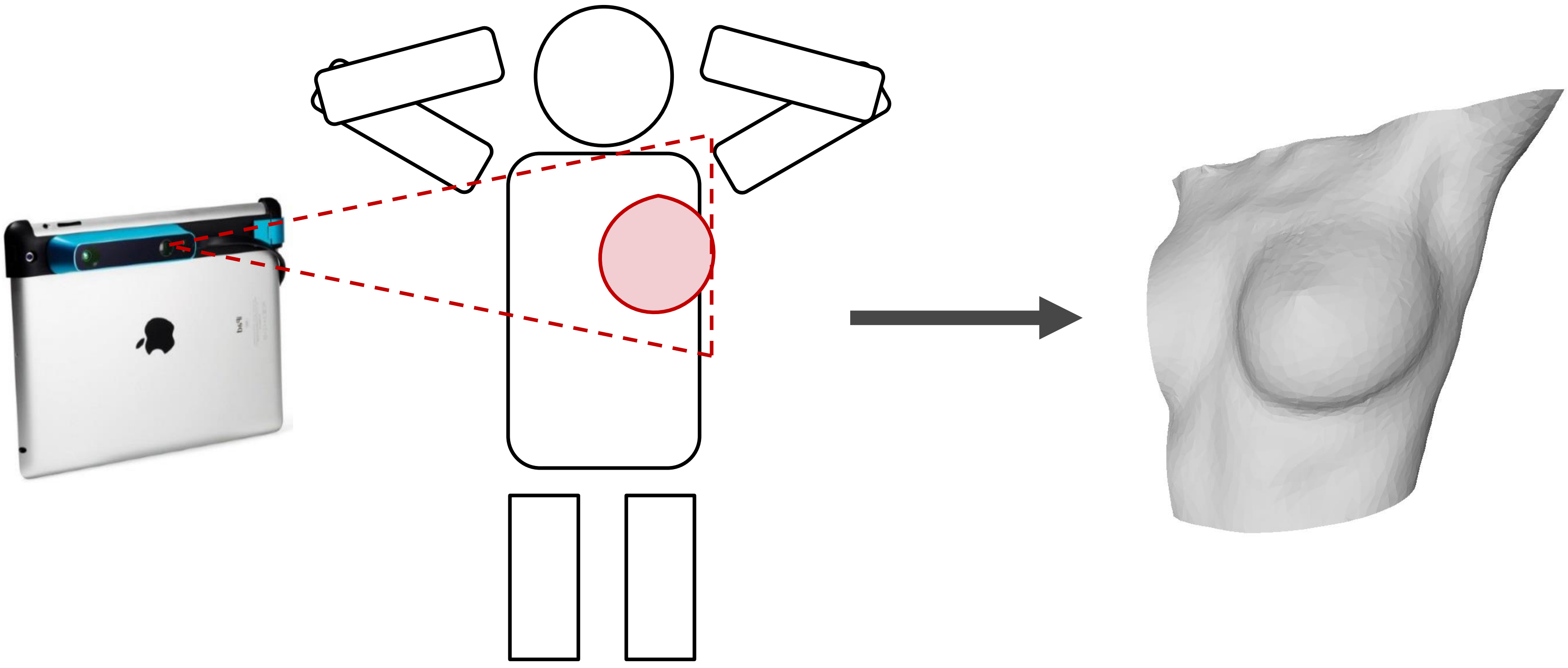
3D Scanner – Structure Sensor

Range	0.4 – 12 m
Max Accuracy	0.5 mm
Technology	Structured Light

It is recommended a distance in the range 0.4 and 3.5 meters. Accuracy is 0.5 mm, but it is gets worse when the volume of scanned area is increased.

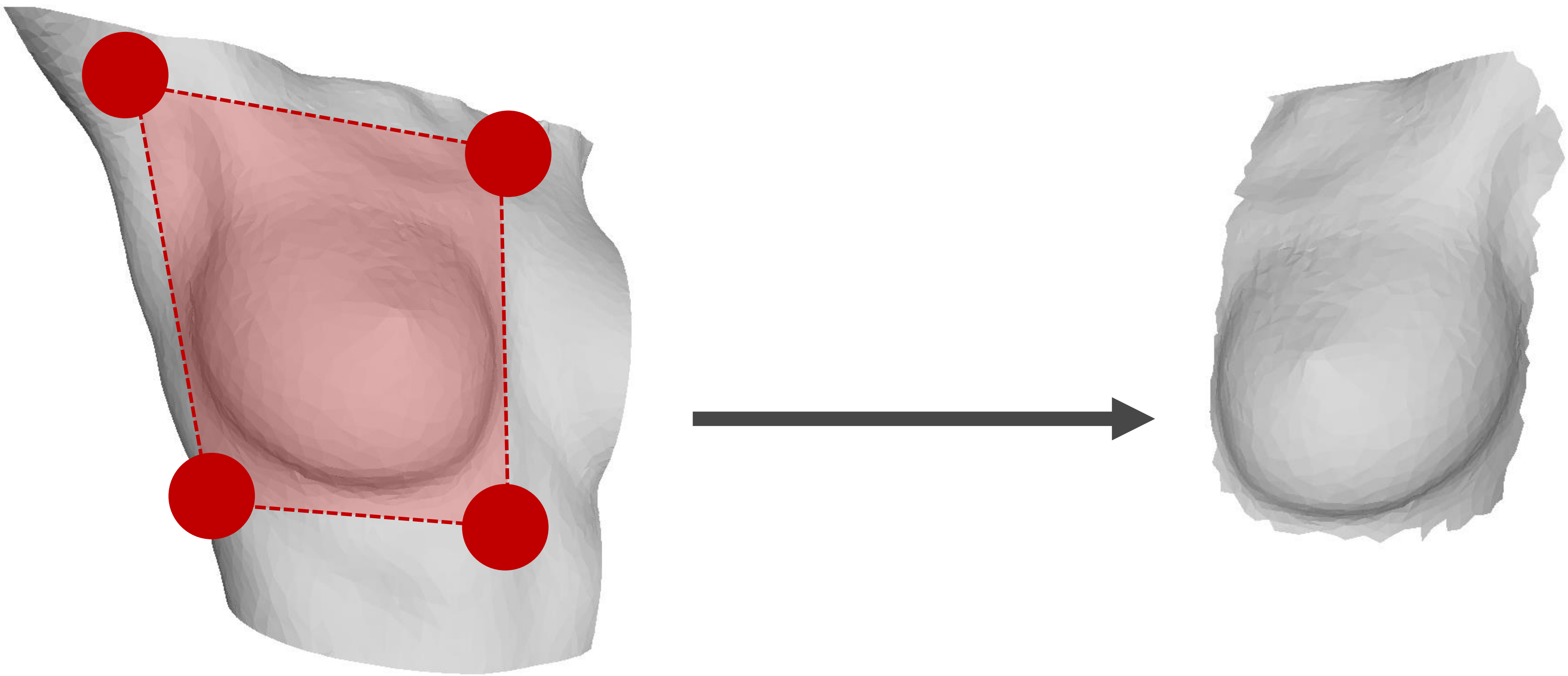
The sensor is not able to acquire RGB color information.

3D Scanner – Acquisition Phase



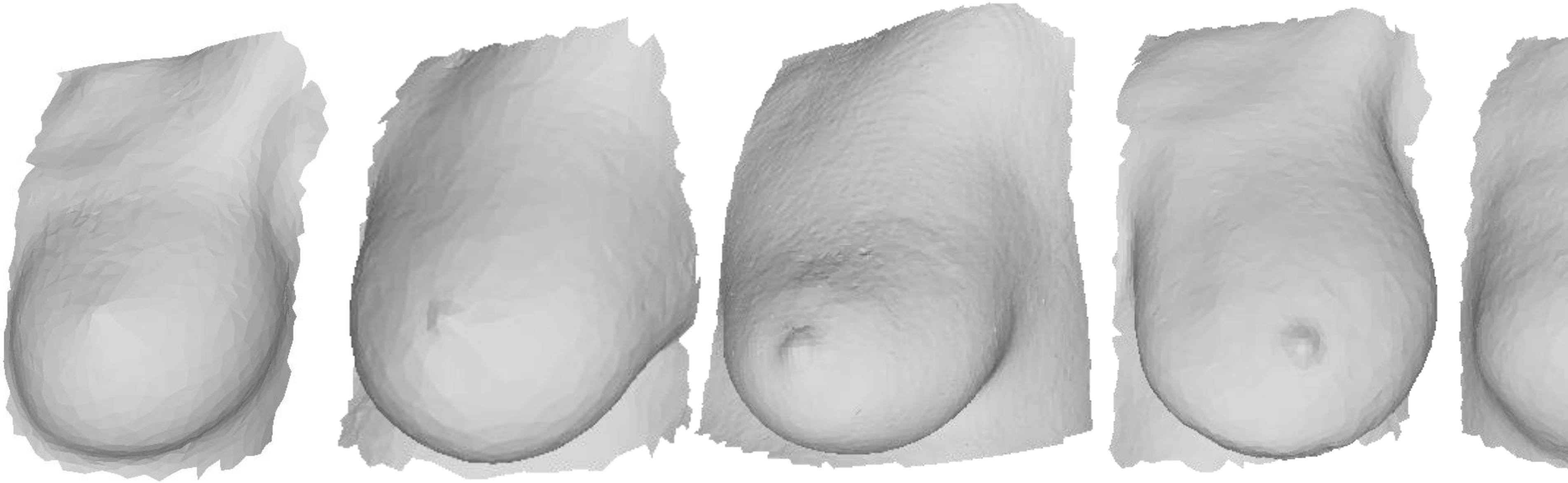
The women volunteers hold the hands behind and above head

Dataset Construction



Cropping and mirroring

Dataset Construction



Our dataset counts 41 + 40 + 3 3D models acquired and processed through the illustrated procedure.

Proposed approach

Planar Projection

Step 1
Alignment

→

Step 2
Projection

→

Step 3
Landmarks Extraction

↓

Parametrization

Step 4
Thin-Plate Spline

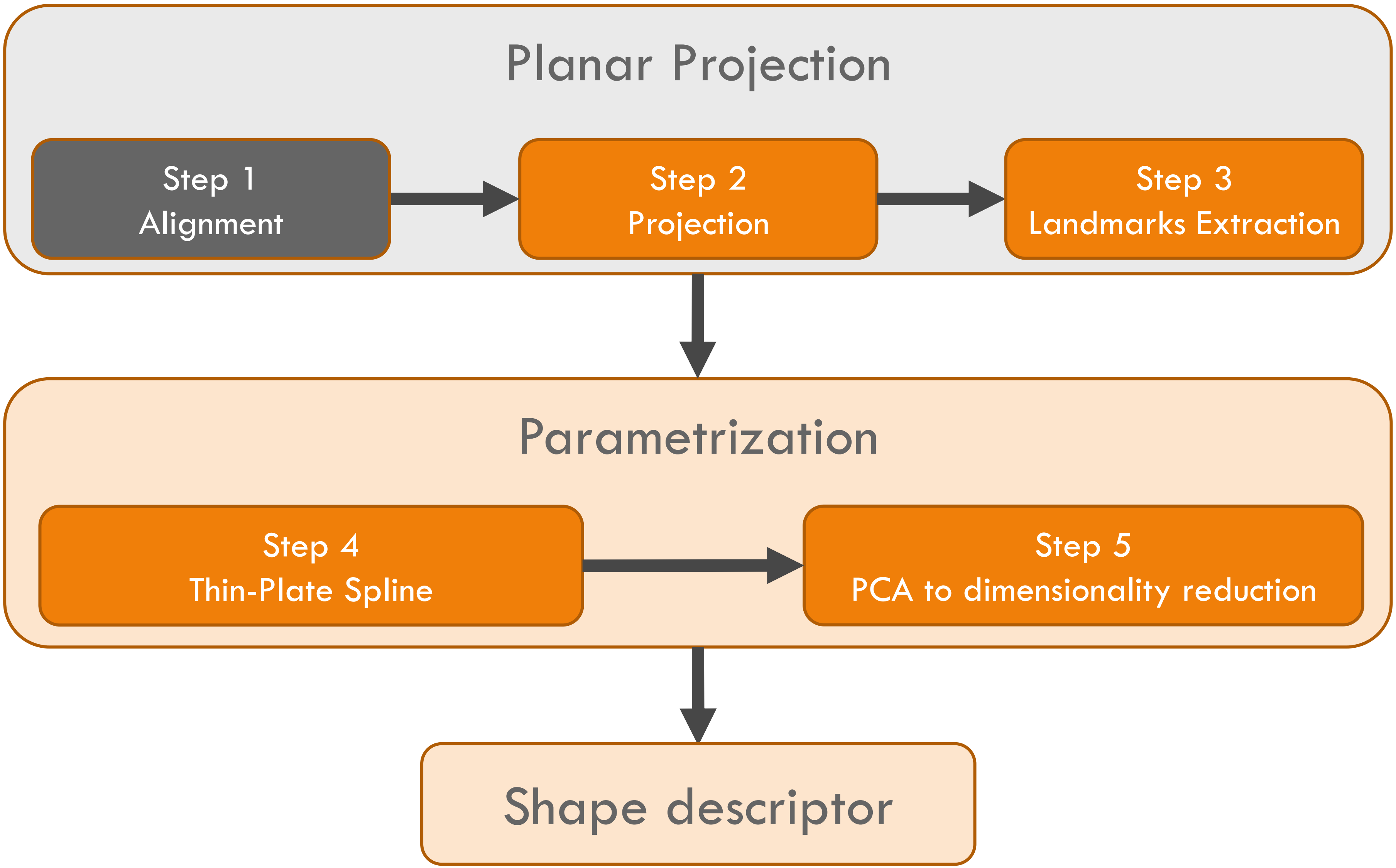
→

Step 5
PCA to dimensionality reduction

↓

Shape descriptor

Proposed approach



Step 1
Alignment

Model alignment

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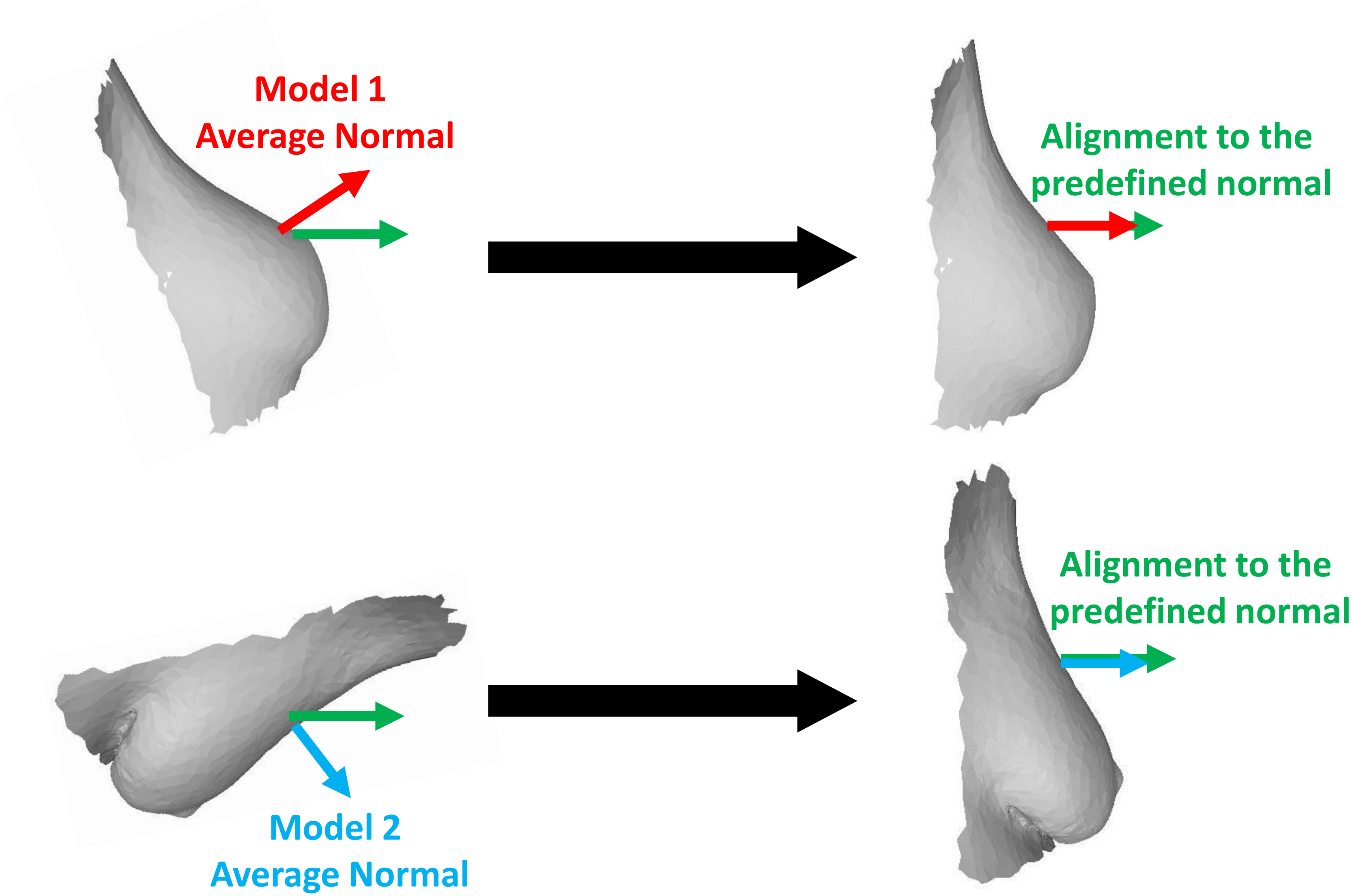


Rodrigues's Formula

Let **a** and **b** two unit vectors in $\mathbb{R}^3$, the rotation matrix to make **a** parallel to **b** is:

$$\mathbf{R} = \mathbf{I} + \mathbf{w} + k\mathbf{w}^2$$

Where:

$$\mathbf{w} = \begin{pmatrix} 0 & -v_z & v_y \\ v_z & 0 & -v_x \\ -v_y & v_x & 0 \end{pmatrix}$$

$$\mathbf{v} = \left(v_x, v_y, v_z\right) = \mathbf{a} \times \mathbf{b}$$

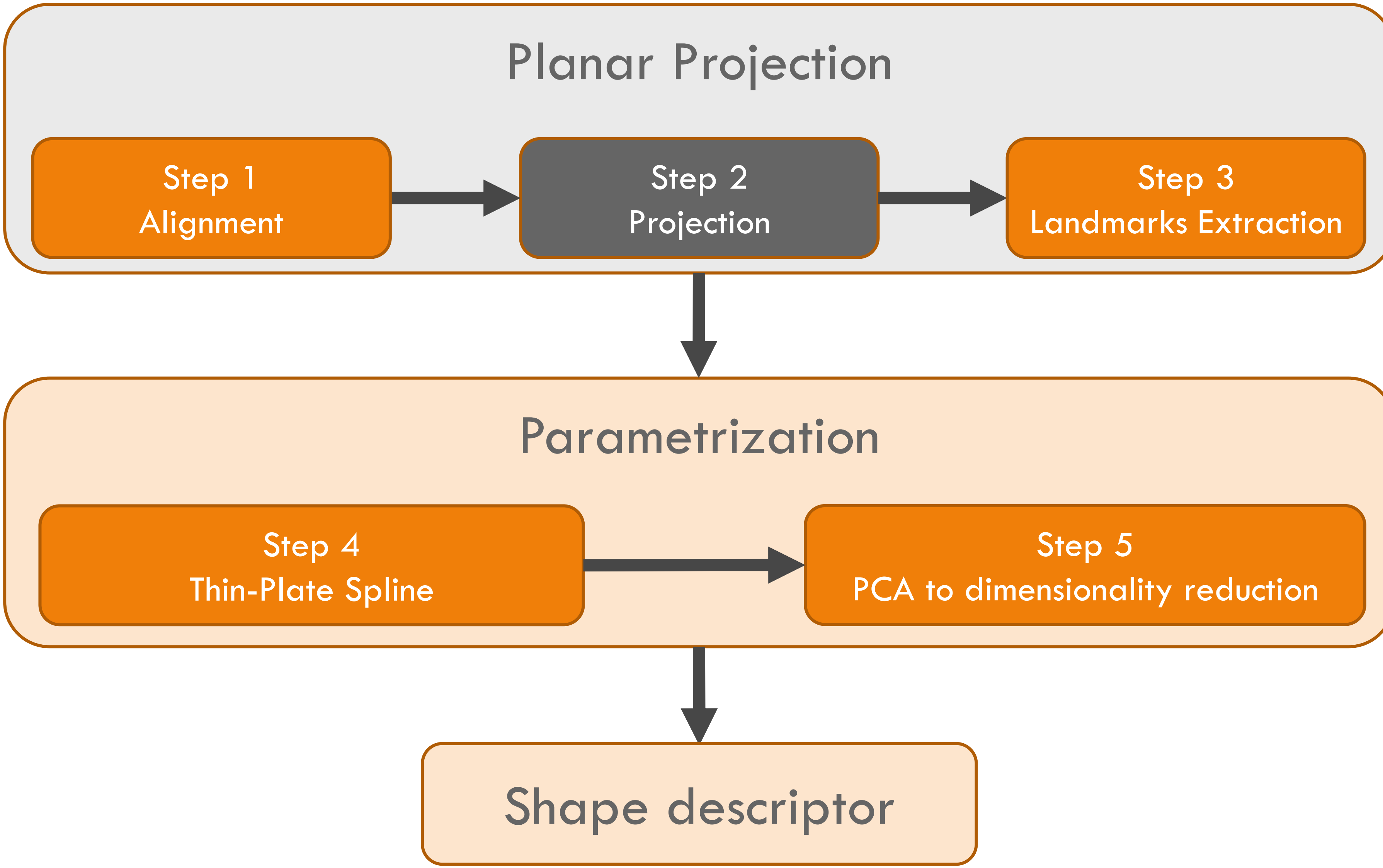
$\mathbf{I}$ is the identiy 3×3 matrix

$$k = \frac{1 - c}{s^2}$$

$$s = \|\mathbf{v}\|$$

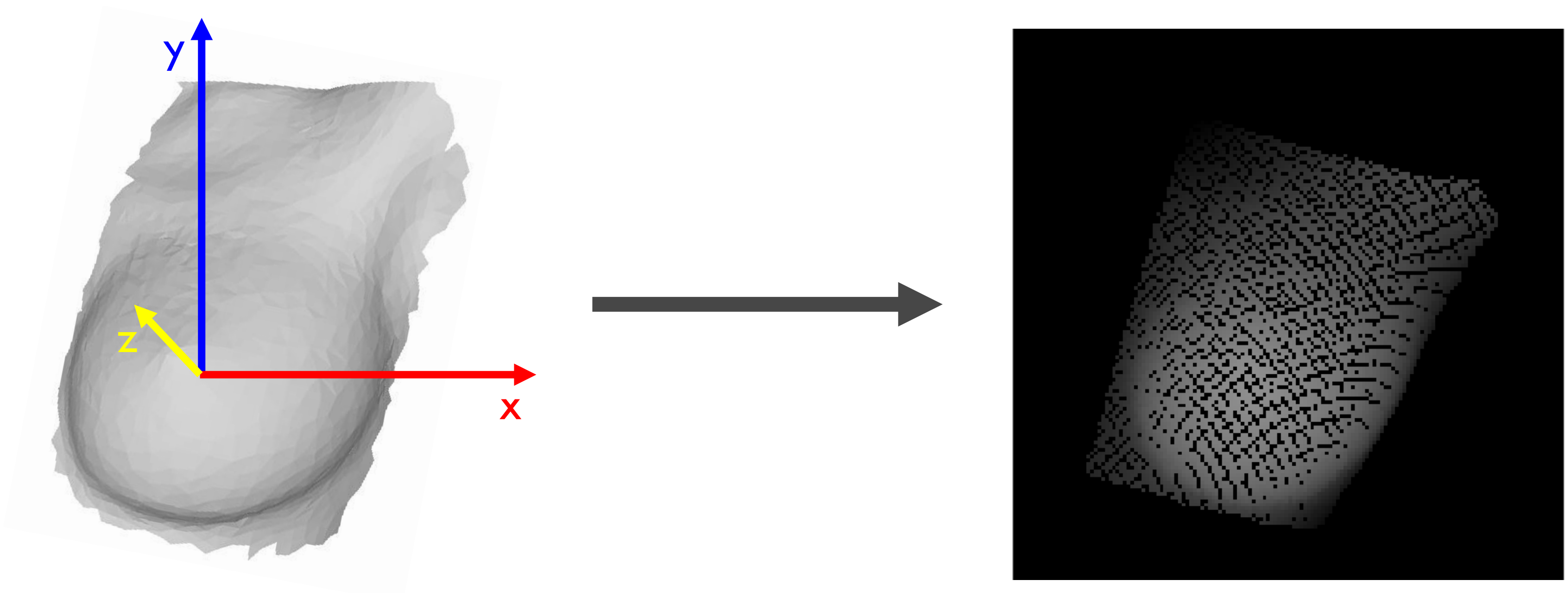
$$c = \mathbf{a} \cdot \mathbf{b}$$

Proposed approach



Projection

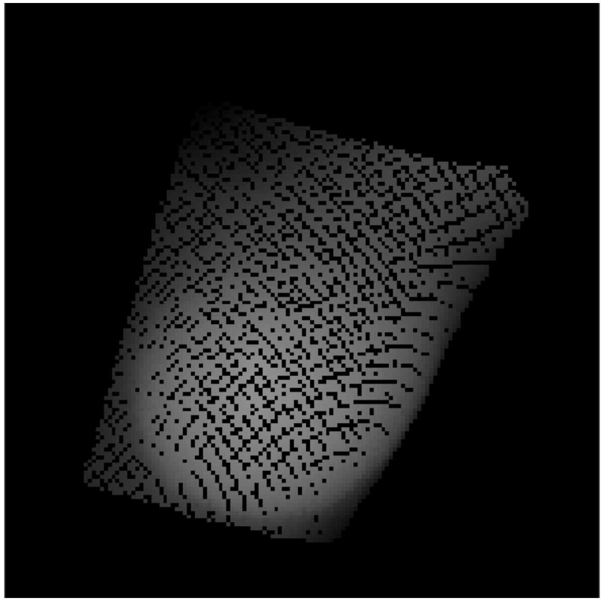
1. Vertices coordinates are properly normalized in [0,1].
2. They are projected on the X-Y plane (along Z).
3. Points are moved in a discrete 2D space.
4. We deal this space as a grey scale image, where the grey level is proportional to the Z coordinate (depth-map).

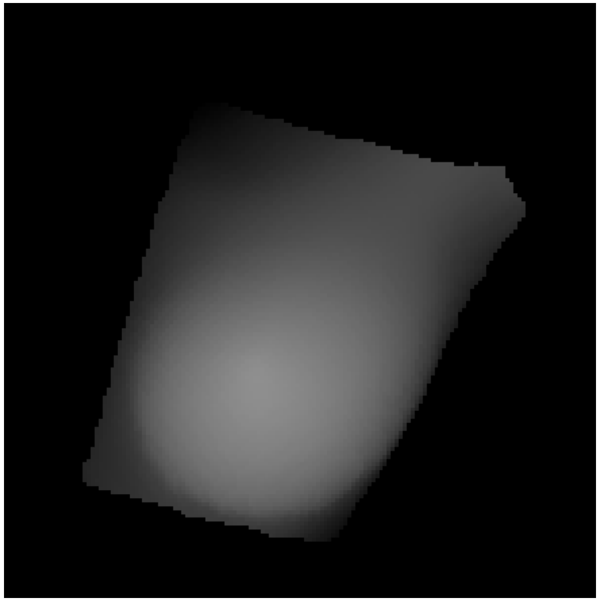


Fill

1. The empty space are filled through morphological closure.

2. A Gaussian filter is used to smooth the map.





Proposed approach

Planar Projection

Step 1
Alignment

→

Step 2
Projection

→

Step 3
Landmarks Extraction

↓

Parametrization

Step 4
Thin-Plate Spline

→

Step 5
PCA to dimensionality reduction

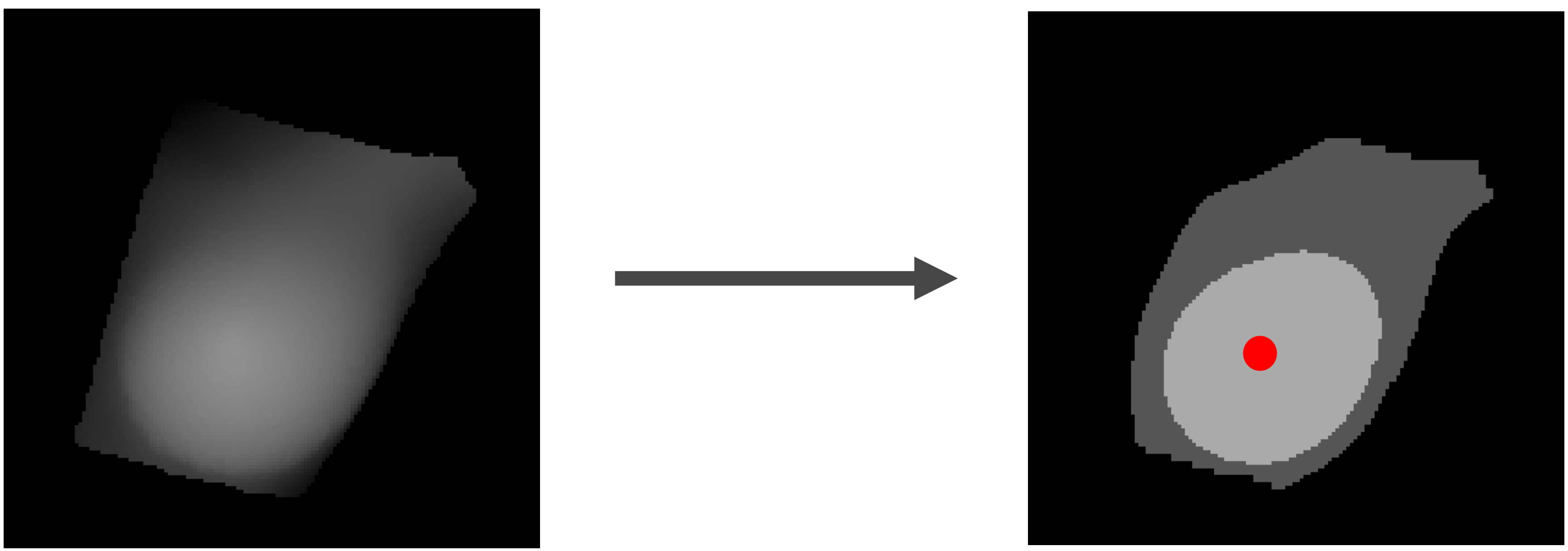
↓

Shape descriptor

Landmarks

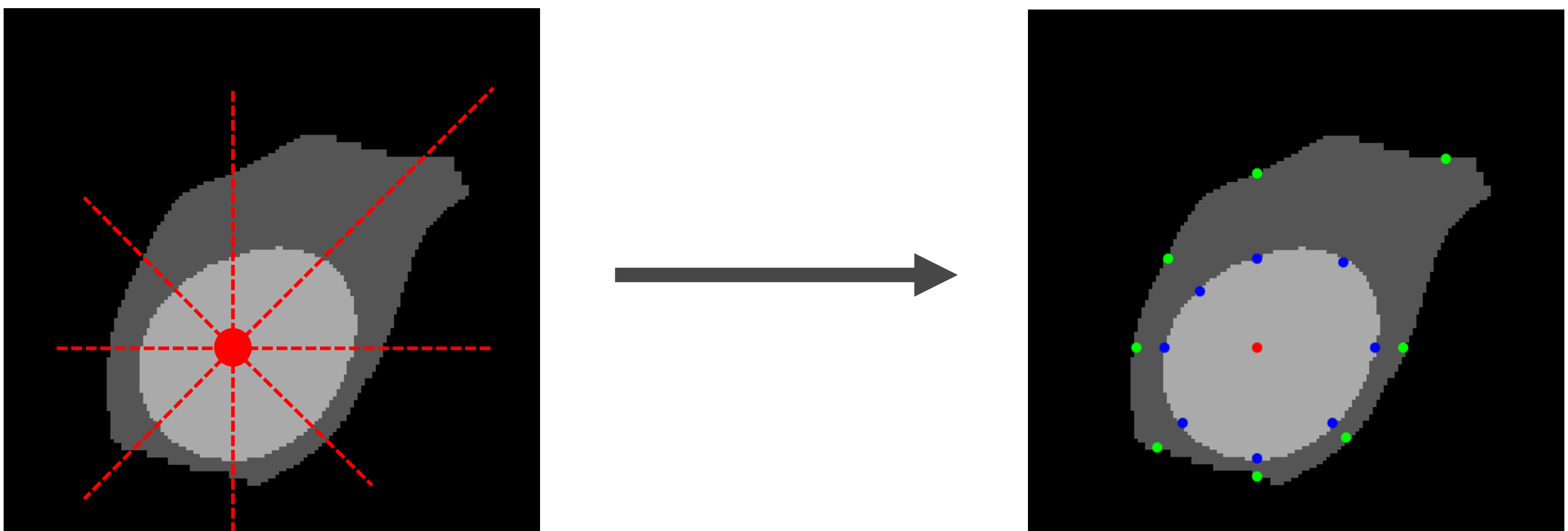
1. The first geometrical landmark is the maximum point.

2. The depth-map is uniformly quantized in 3 level.

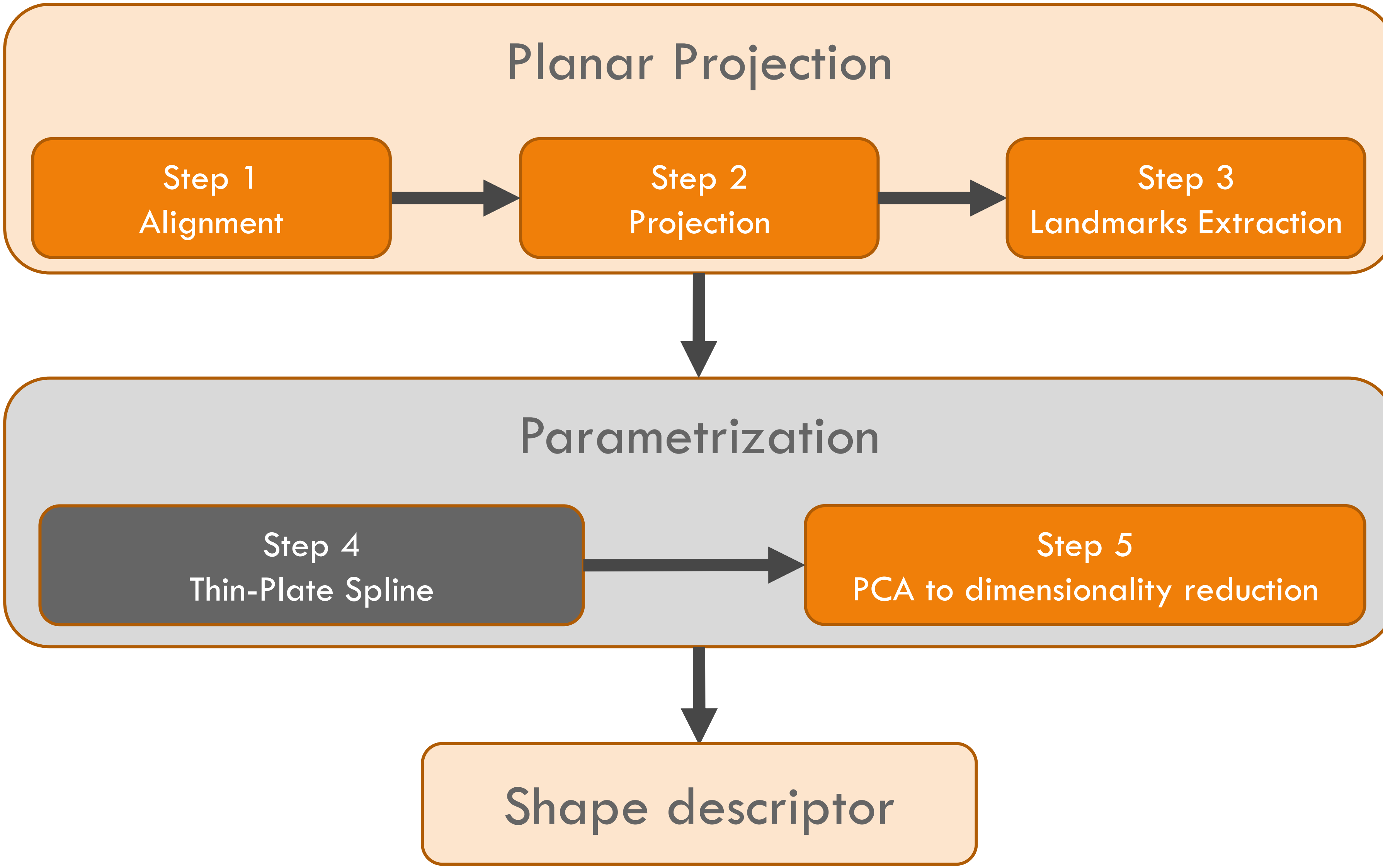


Landmarks

1. The second set of the landmarks is chosen on the first quantization layer boundary.
2. It is the same for the third one.
3. 8 different angels has been considered.



Proposed approach



Thin-Plate Spline

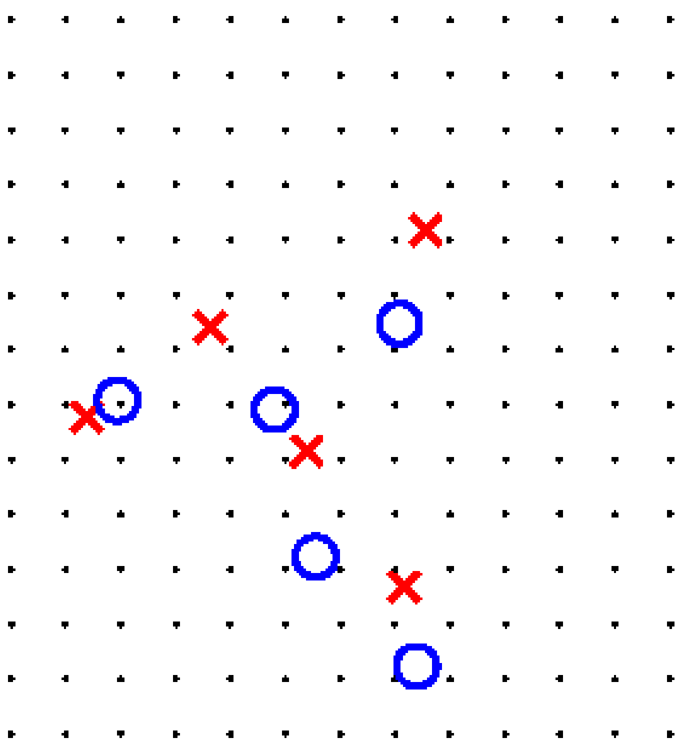
The problem we want to solve by using TPS is the following:

Let $P = \{p_1, p_2, \dots, p_n\}$ and $Q = \{q_1, q_2, \dots, q_n\}$ be two set of points, look for the transformation $F: \mathbb{R}^2 \to \mathbb{R}^2$ such that $F(p_i) = q_i$ for $i = 1, 2, \dots, n$

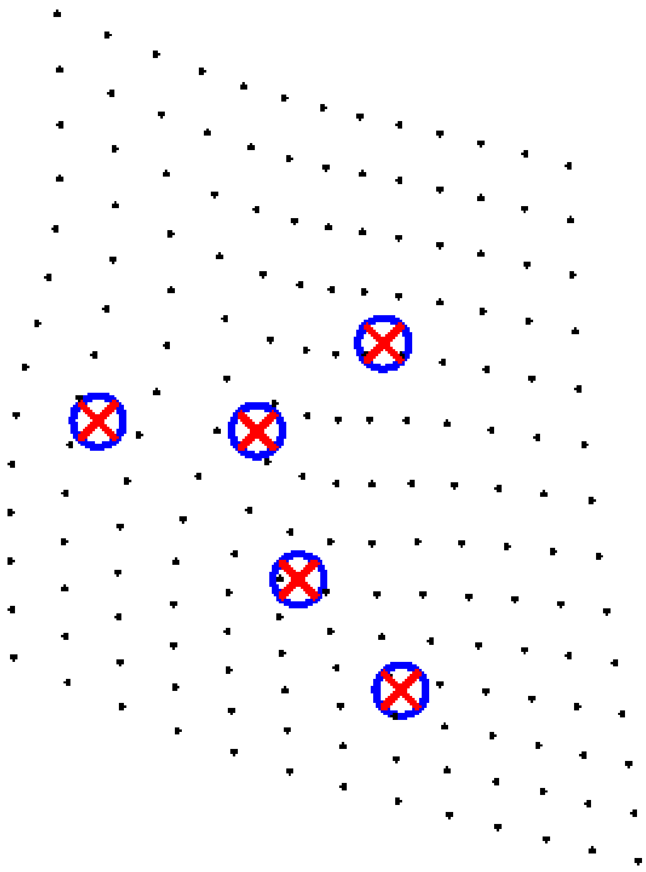
In our scenario P is a set of 17 landmarks of a breast model and Q is the set of 17 reference landmarks.

Thin-Plate Spline

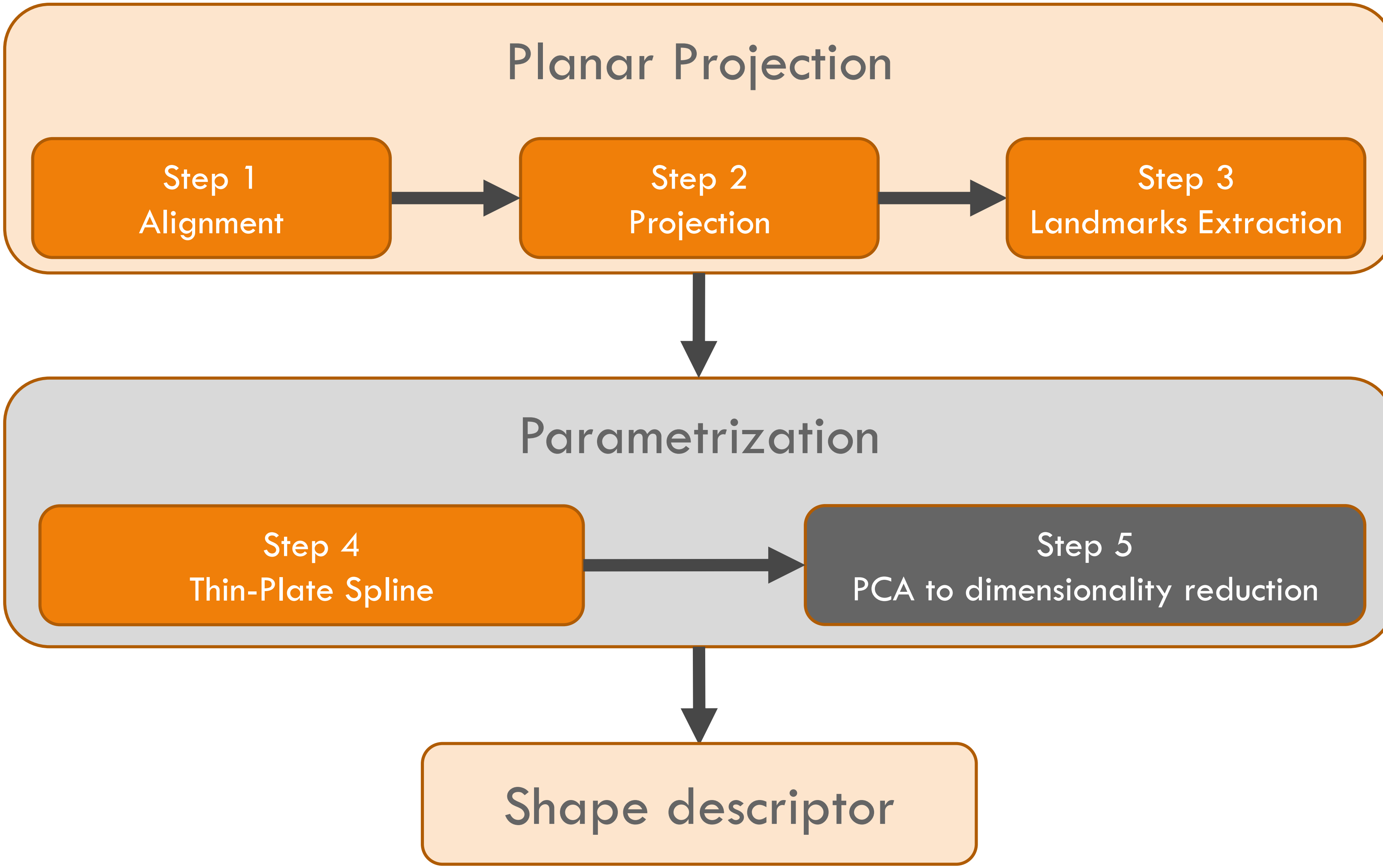
$\times \in P$ $\quad\quad$ $\circ \in Q$



Transformation



Proposed approach



Step 5
PCA

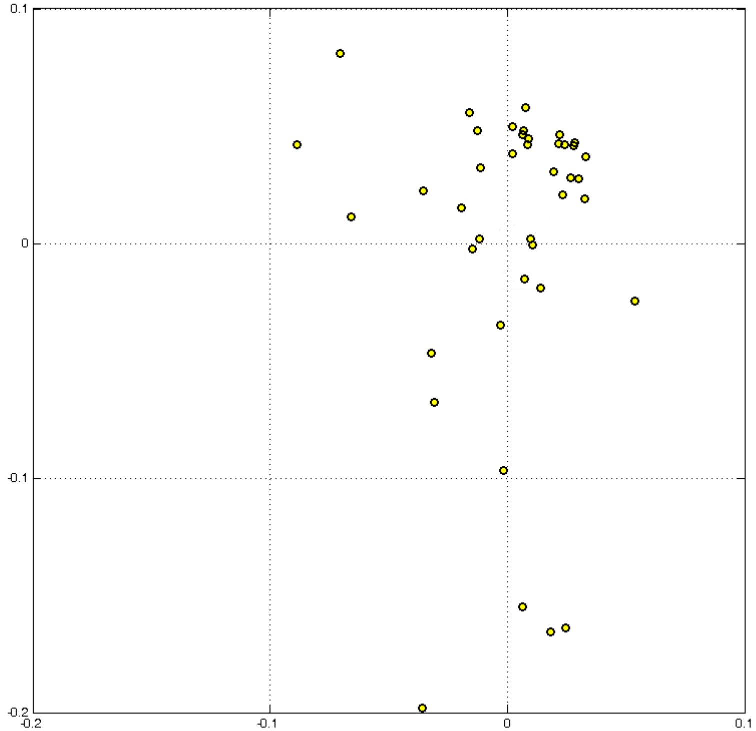
PCA

- We apply PCA on transformation parameters (34 for each breast models).
- The two first principal components which have largest variances can be easily extracted by seeking the largest eigenvalues.

Information	First component	78 %
	Second component	15%

Experiments and Results

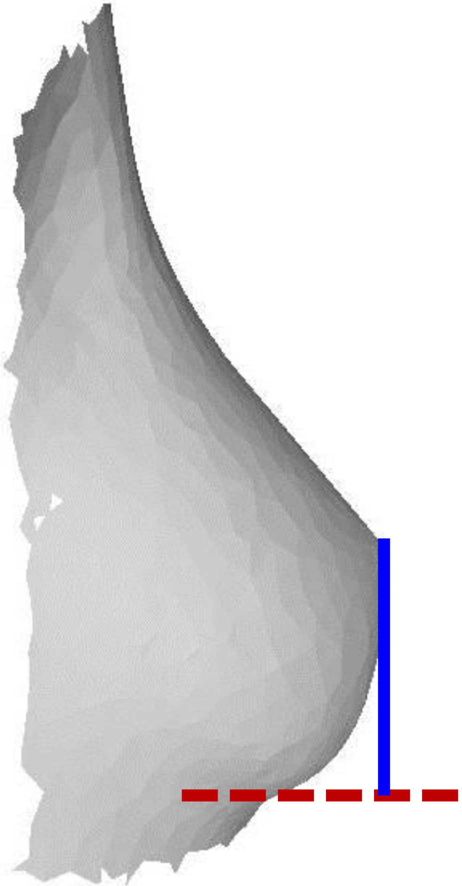
We describe **all the 41 observations** as two-dimensional vectors and plot them in a standard Cartesian coordinate system.



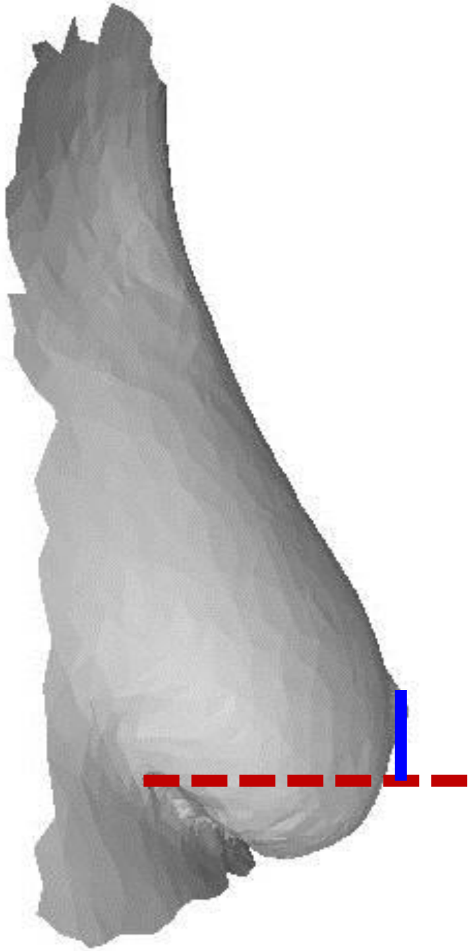
Second component (x axis) seems not related to a particular property.

The first one (y axis) instead, according to breast specialist, captures ptosis and partially the volume.

Ptosis



Normal

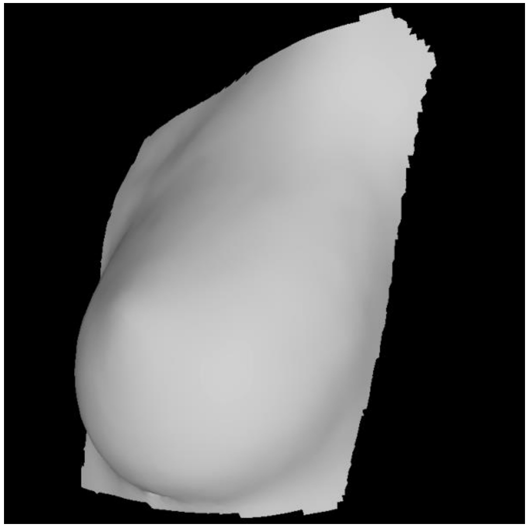


Mild Ptosis

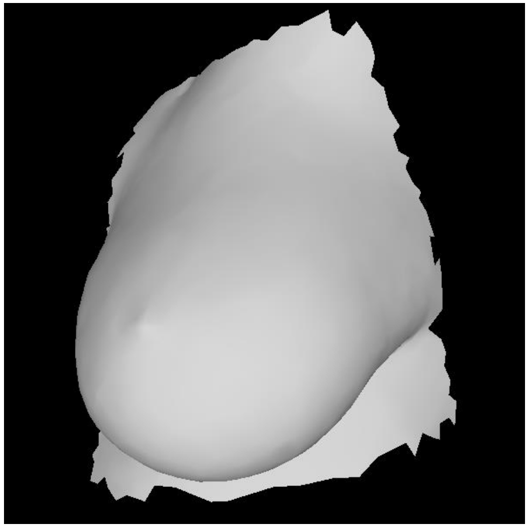
Experiments and Results

$y = -0.198$

$y = -0.047$

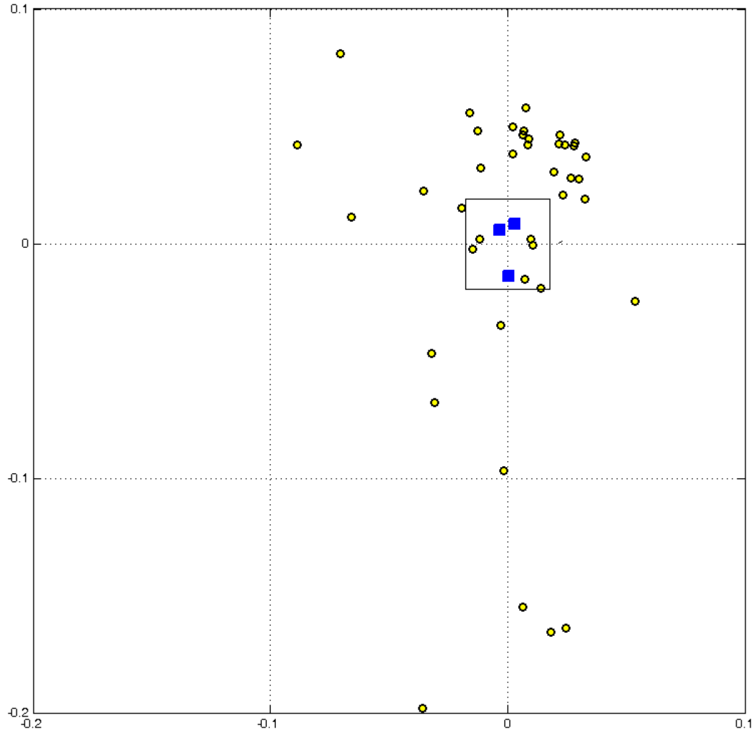


$y = 0.081$



Experiments and Results

To validate our approach **same model** has been acquired 3 times, but by different operators.

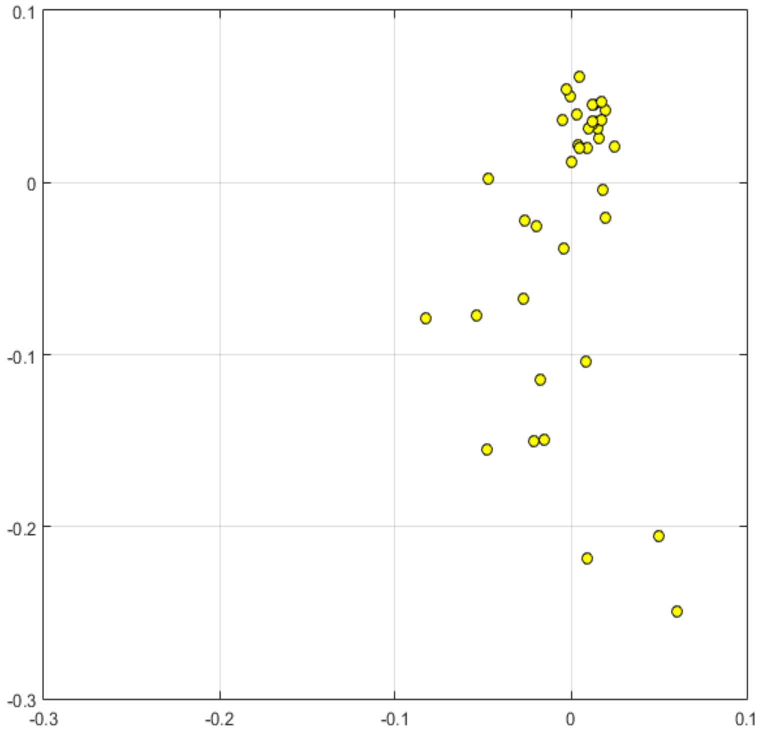


The 3 models have been parametrized using the mathematical model built with the first dataset.

As expected the final representation in the 2D (blue squares) space is quite similar.

Experiments and Results

Finally, as further test, 40 different breast 3D models have been processed.



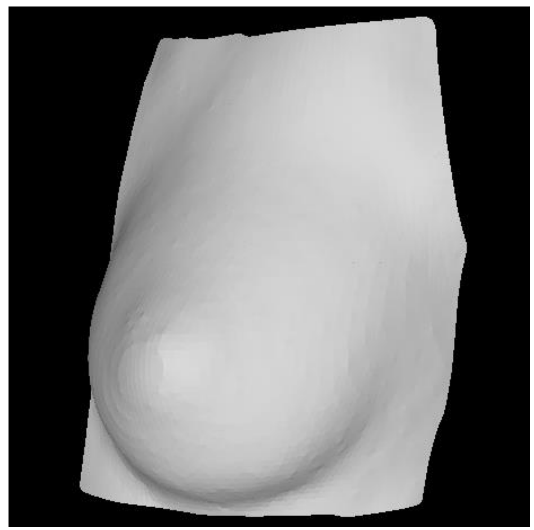
As expected, the 3D models in the 2D parameters space looks coherent.

This confirm that the mathematical model built is valid and can be used on other data.

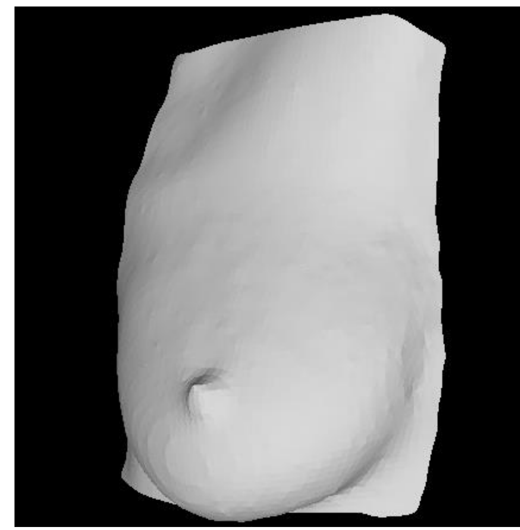
Experiments and Results

$y = -0.249$

$y = -0.067$



$y = 0.061$



Conclusion

- A new approach which exploits low-cost and handheld 3D scanner has been proposed.
- A new dataset with more than 80 3D models has been acquired for proper test.
- Results have been assessed by breast specialist, which claimed that the extracted parameters properly describe a breast shape

Directions for the future

- Change the number and the landmarks position on the breast 3D model.
- Formally describe a clinical procedure for acquisition by 3D scanner.
- Increase the dataset 3D models with new cases.

Thank you for the attention!