Virtual cohort generation of Aortic Valve Stenosis geometries

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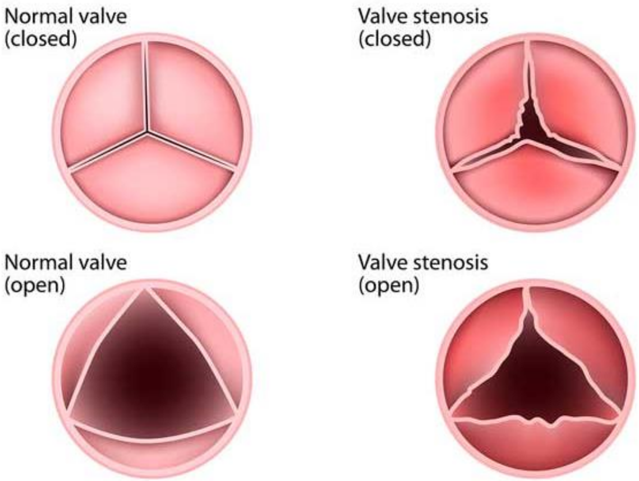
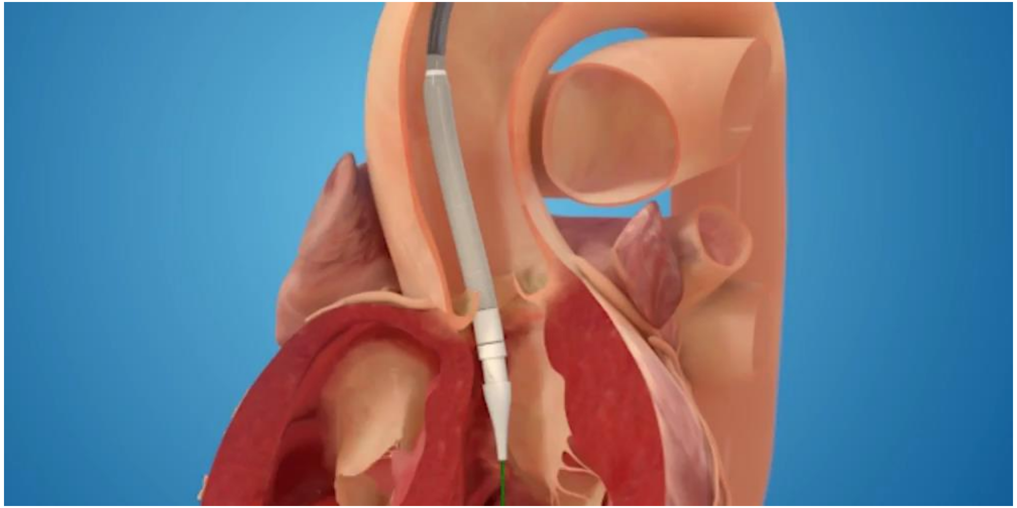
SIMCor

Aortic valve stenosis



Heart-valve-surgery.com (2021)

Transcatheter aortic valve implantation (TAVI)



https://www.medtronic.com

Benefits

- Relief from symptoms
- Increased life expectancy
- Accessible for all patients

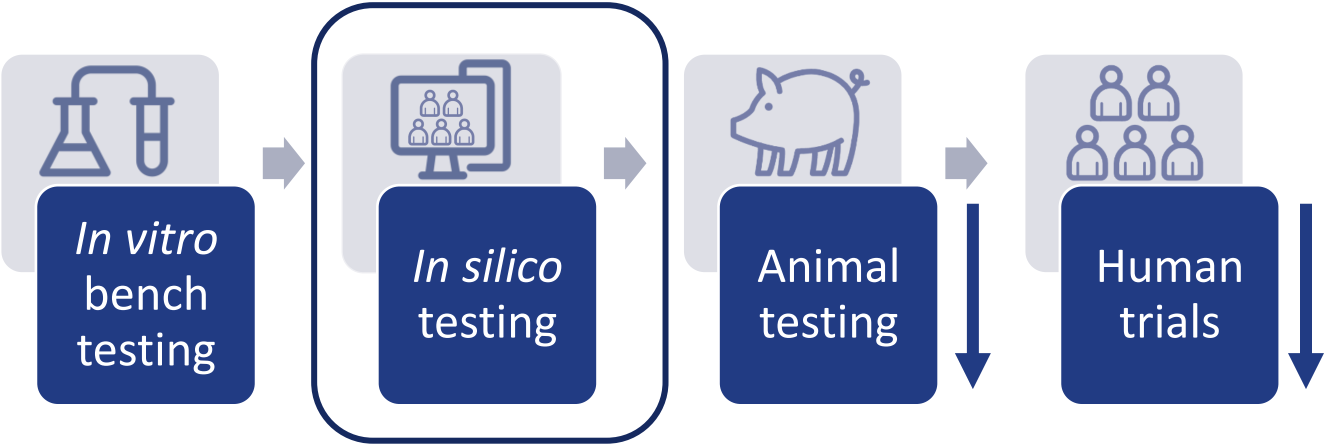
Risks

- Paravalvular leakage
- Thrombosis
- Conduction problems

Developing & testing TAVI devices

In vitro bench testing → Animal testing → Human trials

Developing & testing TAVI devices



The virtual patient

=

+

$Q = Q_{peak-systole}$

$P = 0\ Pa$

+

Geometry

Boundary conditions

Physiological model

The virtual patient

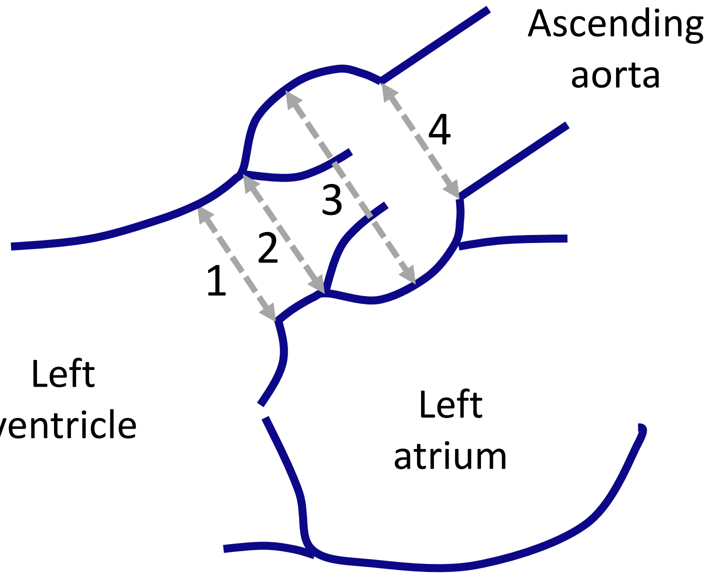
Synthetic geometry

Boundary conditions

Physiological model

Aortic valve geometry

1. LVOT
2. Annulus
3. Sinuses of Valsalva
4. Sinotubular junction



Aortic valve geometry

1. LVOT
2. Annulus
3. Sinuses of Valsalva
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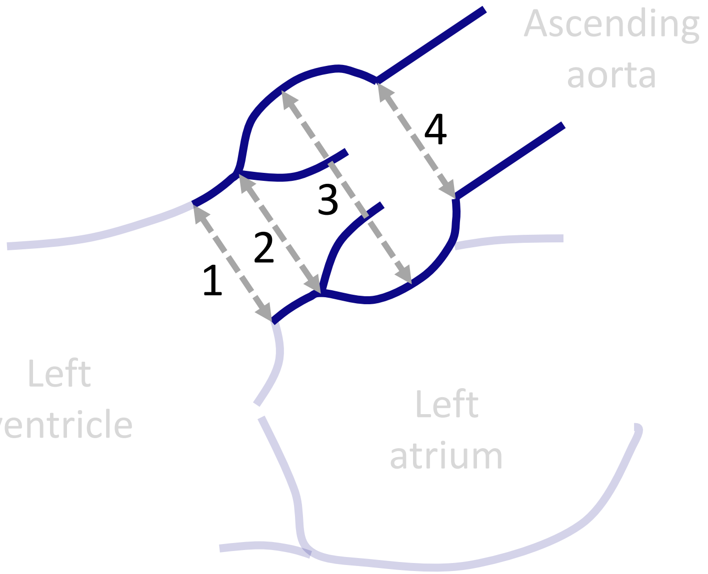
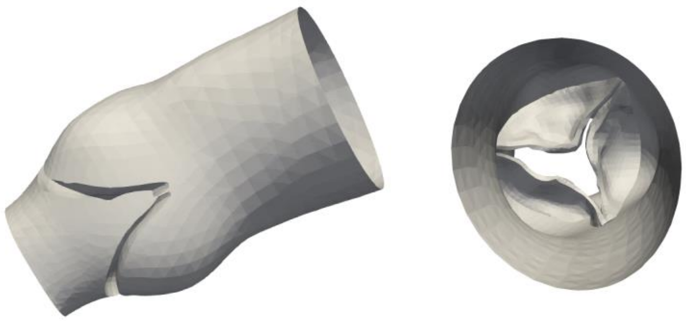
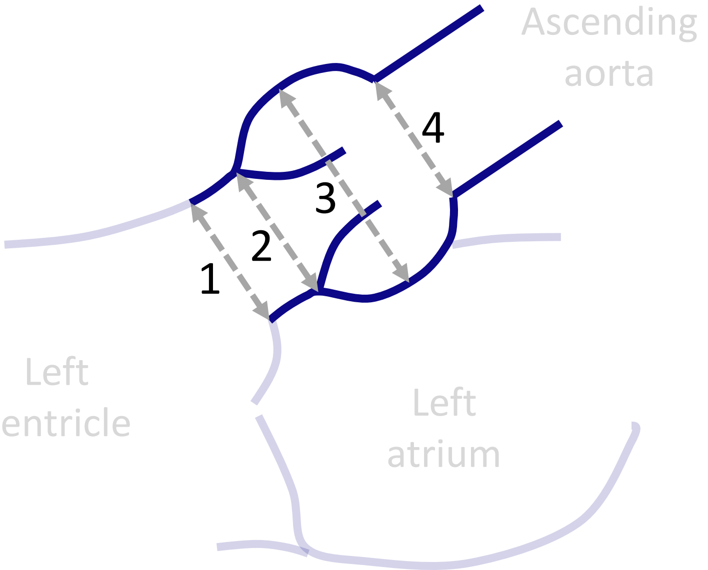


Aortic valve geometry

Real patient data set

- 97 geometries
- Peak-systolic
- Severe stenosis



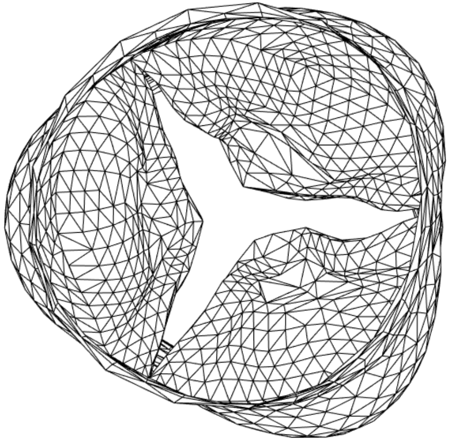


Statistical shape modelling (SSM)

Scores

Shape modes

$$\bar{x} + \sum_{m}^{N} \alpha_m \phi_m = \hat{x} \approx x$$



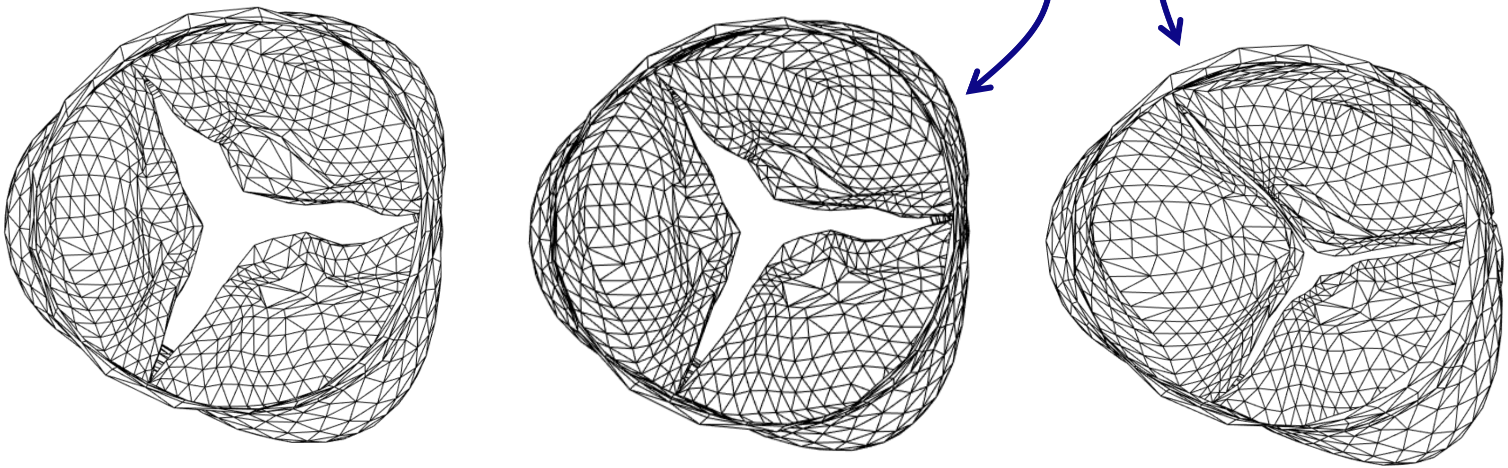
Mean shape

Statistical shape modelling (SSM)

Scores

Shape modes

$$\bar{x} + \sum_{m}^{1} \alpha_{i,m}\phi_m = \hat{x} \approx x$$



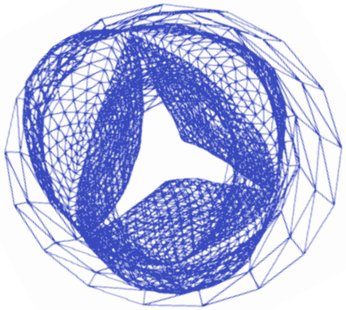
Mean shape

Reconstructed shape

Original shape

Statistical shape modelling (SSM)

Conventional SSM



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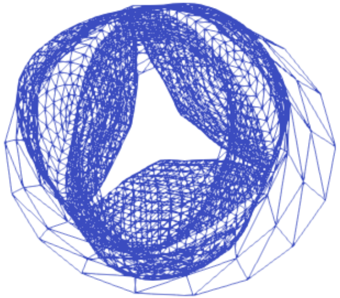
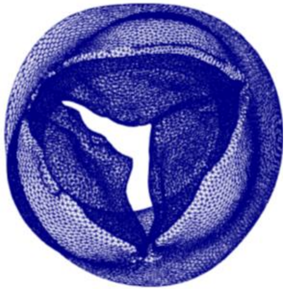


3511 points

3511 points

✗ Inter-patient topology required!

Non-parametric SSM



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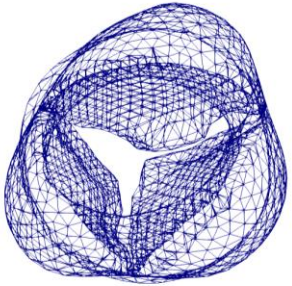


24254 points

4063 points

✓ Applicable to all sets of geometries!

Synthetic geometries with non-parametric SSM

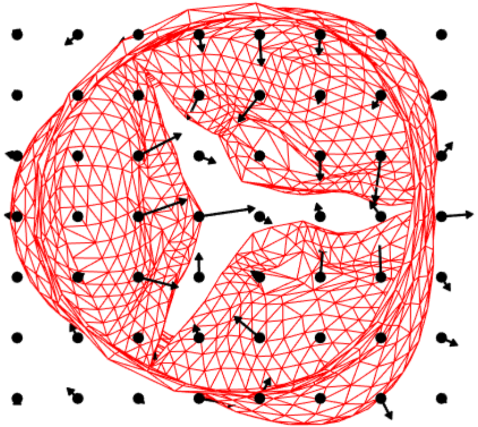
Non-parametric representation → Non-parametric SSM → Generate synthetic geometries → Validate synthetic geometries

Synthetic geometries with non-parametric SSM

Non-parametric representation → Non-parametric SSM → Generate synthetic geometries → Validate synthetic geometries

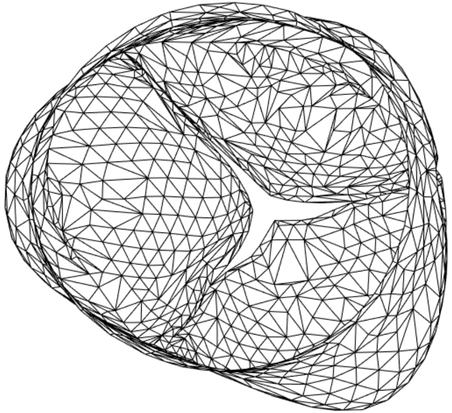
Non-parametric representation

Template $\bar{x}$



Deformetrica

Patient x

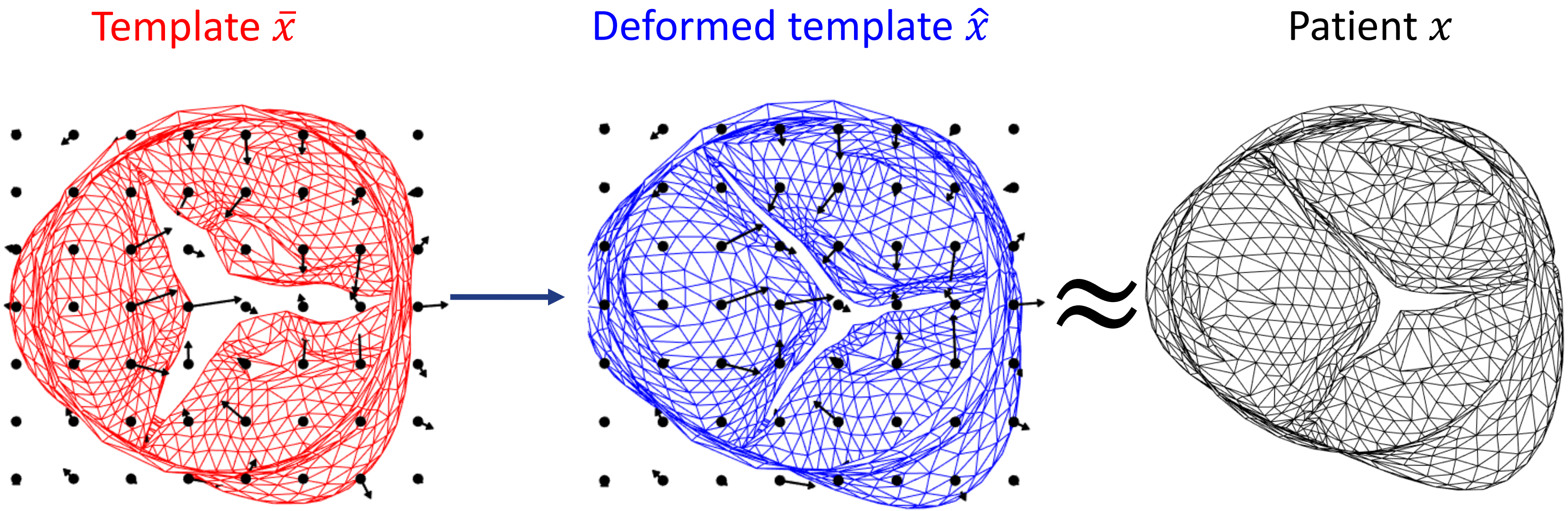


N deformation vectors β_k

$$\bar{x} + \sum_{k}^{N} K(\bar{x}, c_k) \cdot \beta_k$$

Durrleman et al. *NeuroImage* 101 (2014): 35-49.

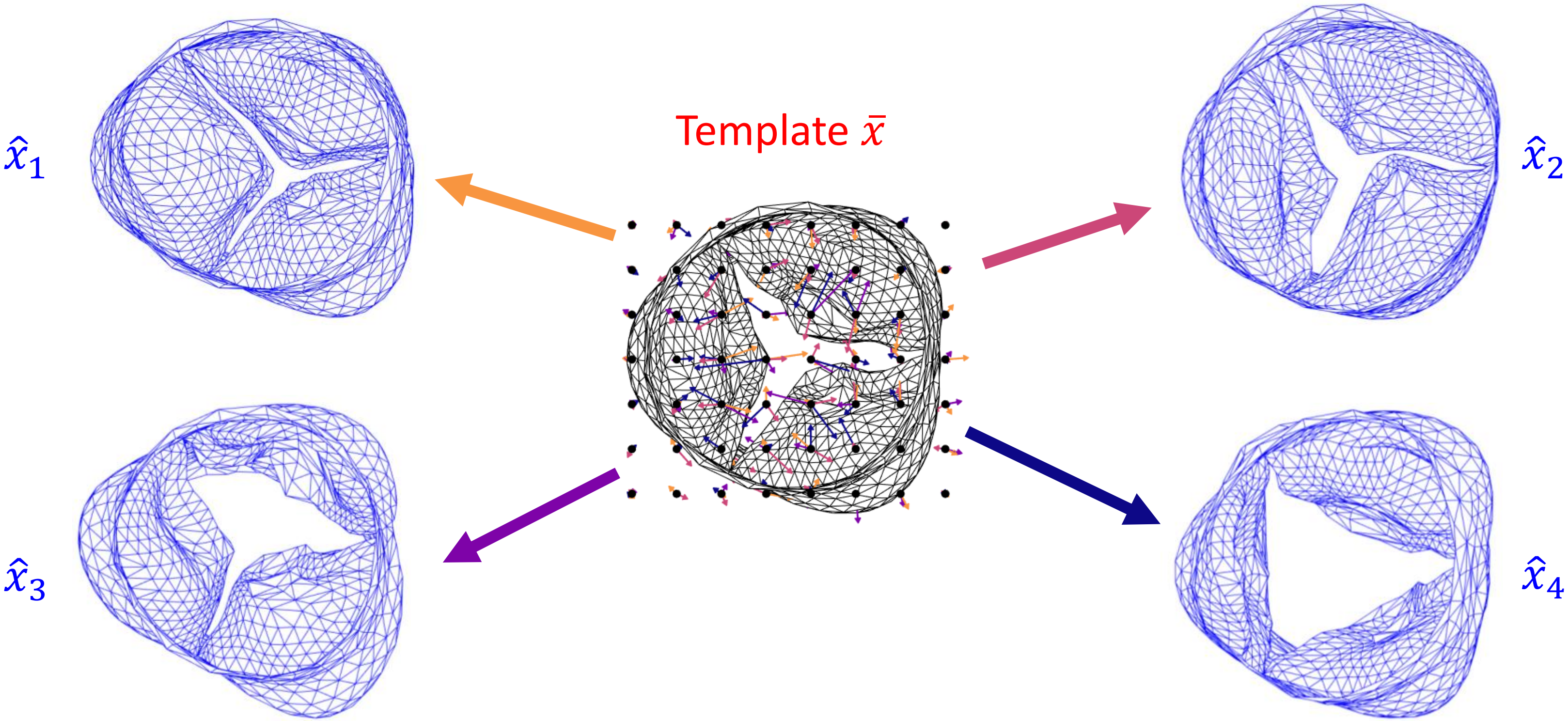
Non-parametric representation



N deformation vectors β_k

$$\bar{x} + \sum_{k}^{N} K(\bar{x}, c_k) \cdot \beta_k = \hat{x} \approx x$$

Non-parametric representation



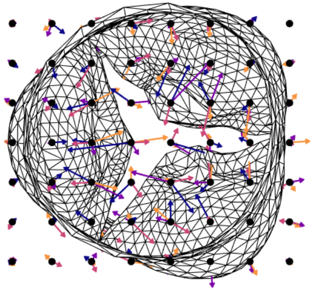
Synthetic geometries with non-parametric SSM

Non-parametric representation ✓

Non-parametric SSM

Generate synthetic geometries

Validate synthetic geometries



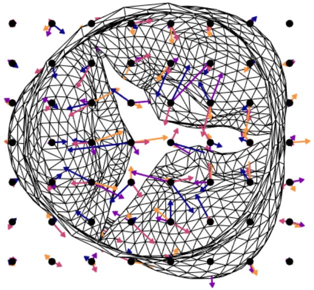
Synthetic geometries with non-parametric SSM

Non-parametric representation

Non-parametric SSM

Generate synthetic geometries

Validate synthetic geometries

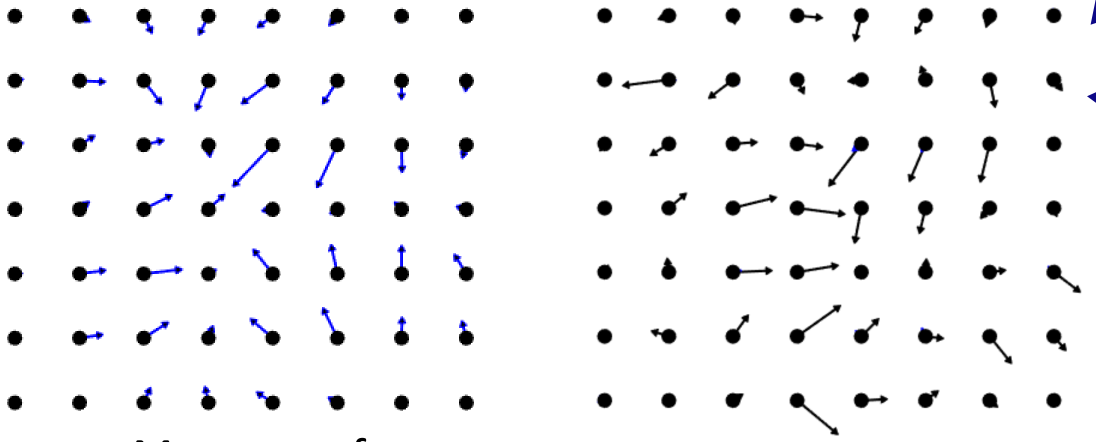


Non-parametric SSM

$$\bar{\beta} + \sum_{m}^{1} \alpha_m \phi_m = \hat{\beta} \approx \beta$$

Scores

Shape modes



Mean set of deformation vectors

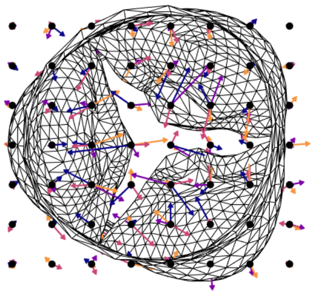
Original deformation vectors

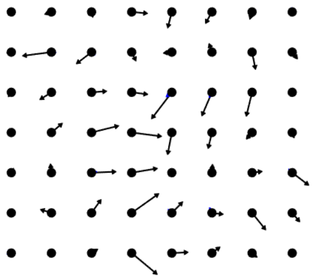
Reconstructed deformation vectors

32 shape modes

Synthetic geometries with non-parametric SSM

1. Non-parametric representation ✓
2. Non-parametric SSM ✓
3. Generate synthetic geometries
4. Validate synthetic geometries





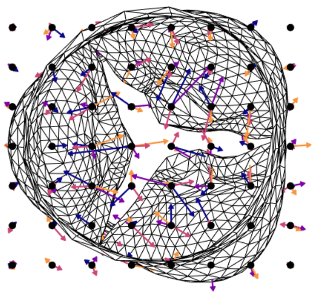
Synthetic geometries with non-parametric SSM

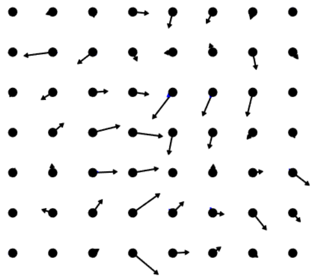
Non-parametric representation

Non-parametric SSM

Generate synthetic geometries

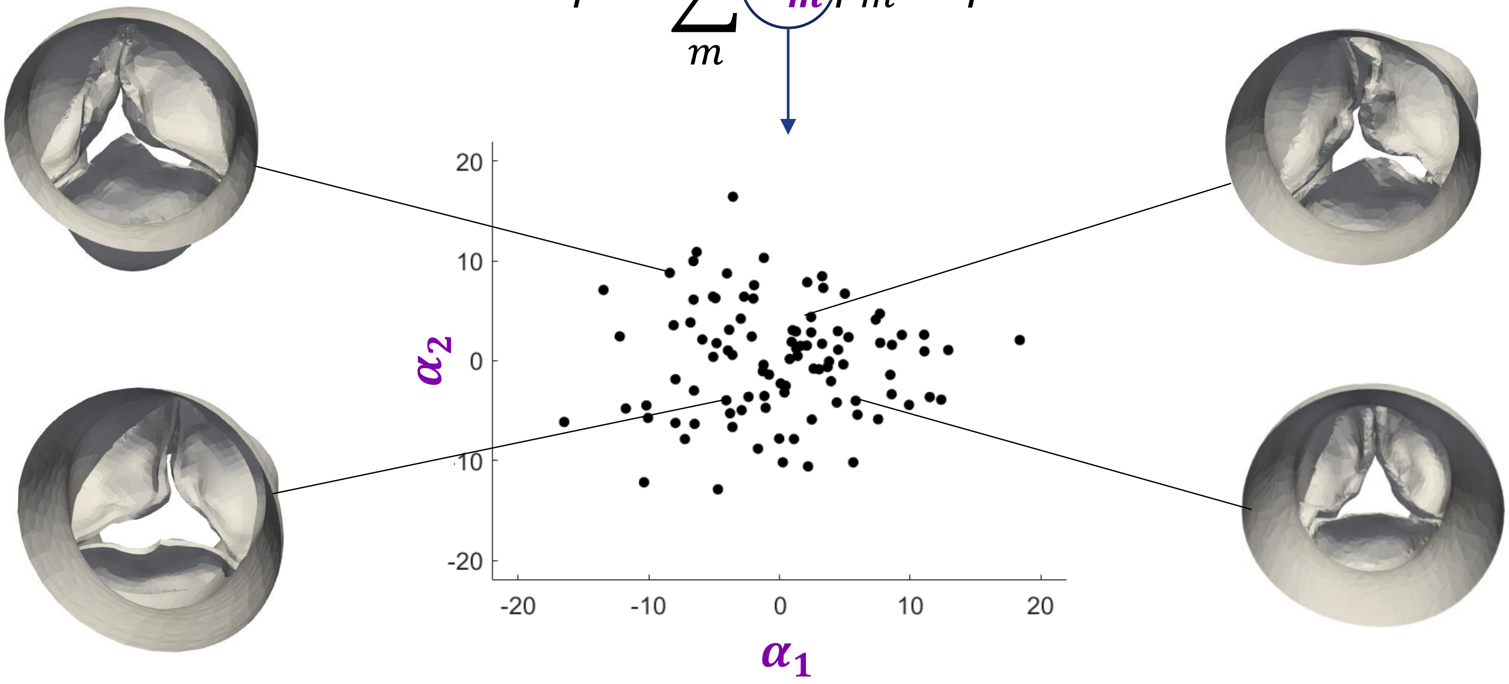
Validate synthetic geometries





Generation of synthetic geometries

$$\bar{\beta} + \sum_{m}^{32} \alpha_m \phi_m = \hat{\beta}$$



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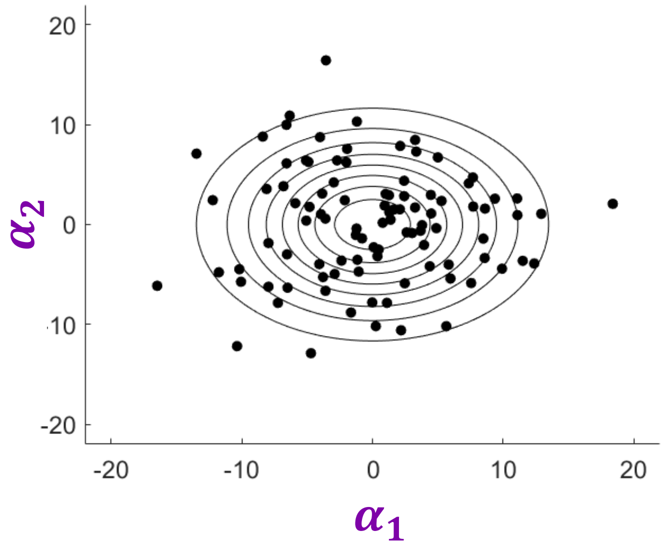
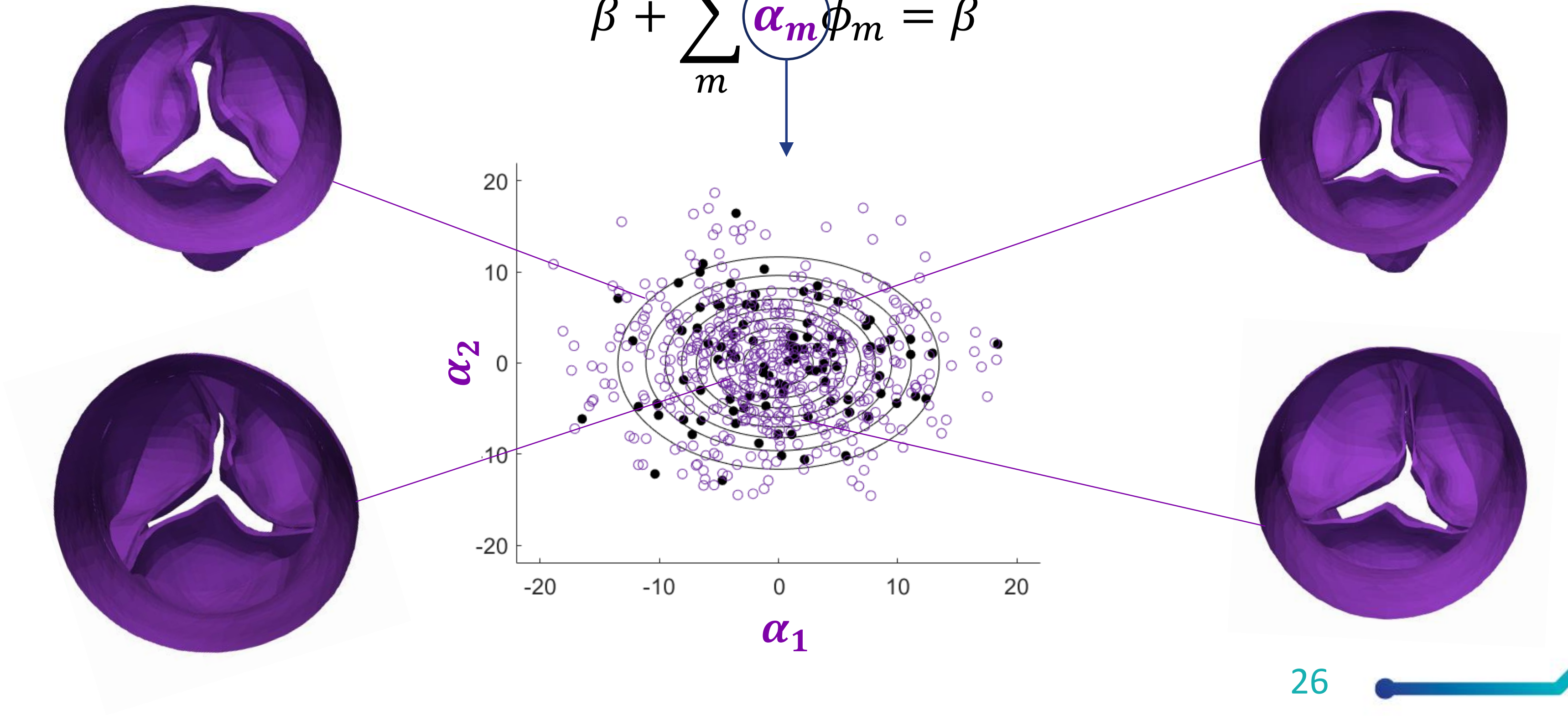


Generation of synthetic geometries

$$\bar{\beta} + \sum_{m}^{32} \alpha_m \phi_m = \hat{\beta}$$



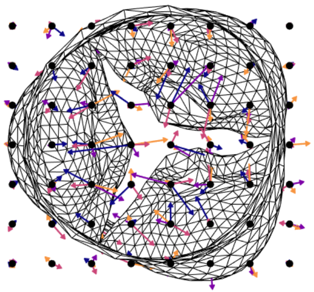
Synthetic geometries with non-parametric SSM

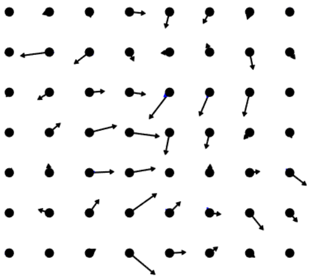
Non-parametric representation

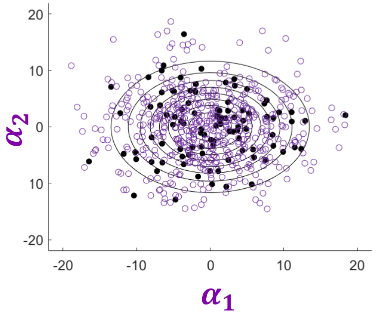
Non-parametric SSM

Generate synthetic geometries

Validate synthetic geometries

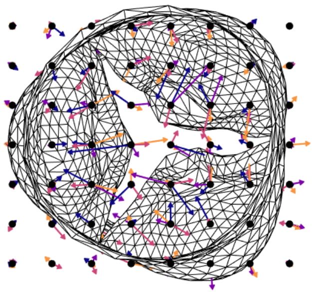


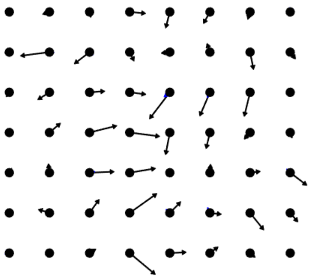


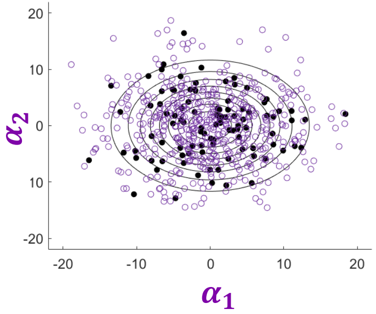


Synthetic geometries with non-parametric SSM

- Non-parametric representation ✓
- Non-parametric SSM ✓
- Generate synthetic geometries ✓
- Validate synthetic geometries

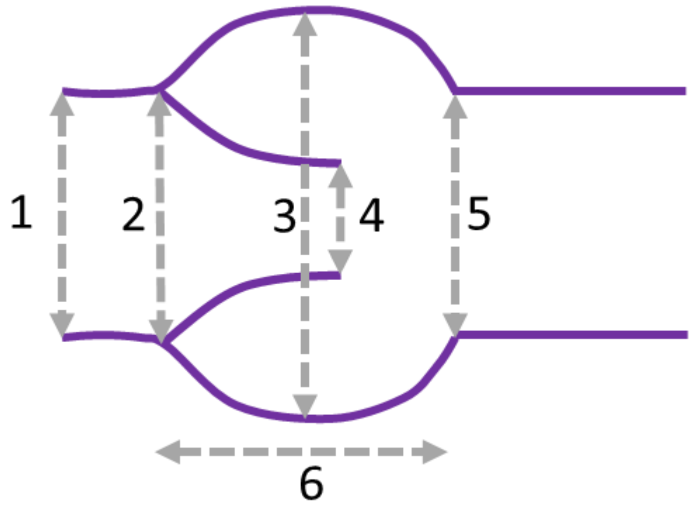






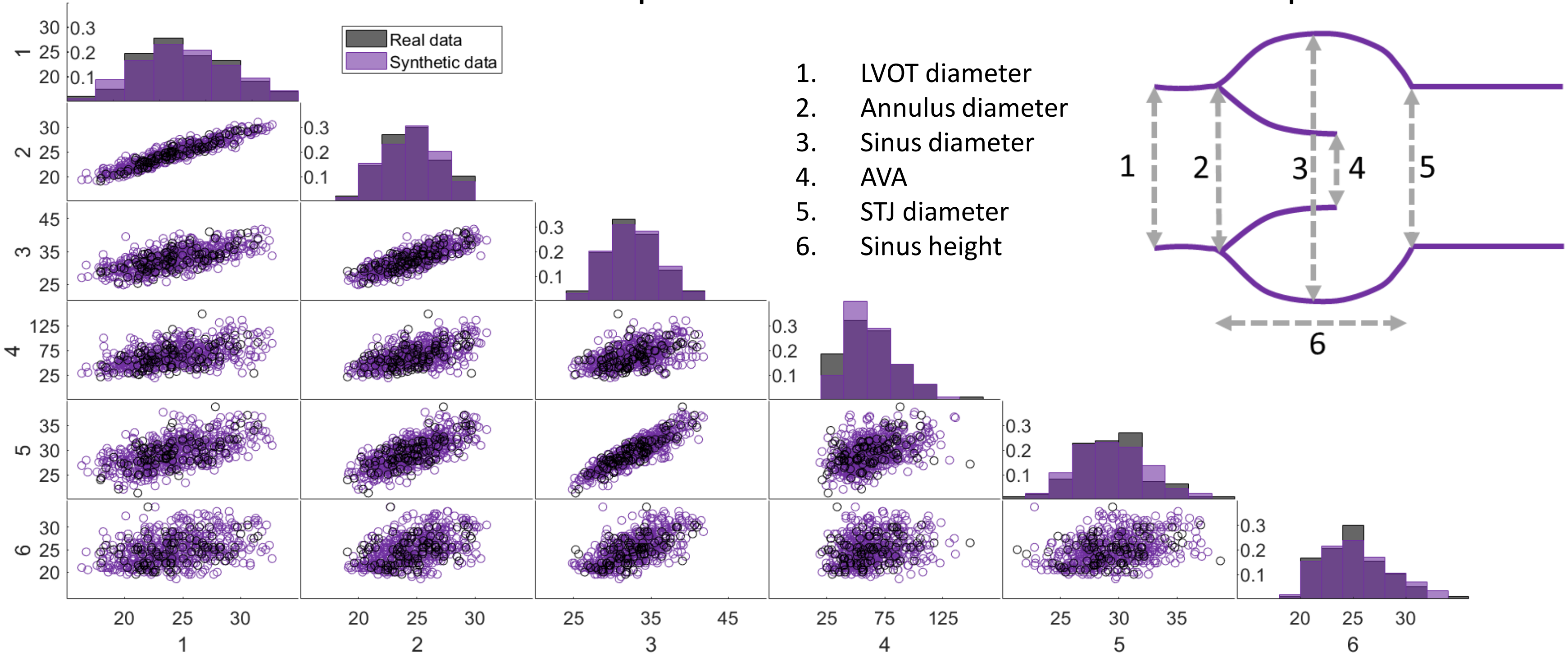
Validation

1. LVOT diameter
2. Annulus diameter
3. Sinus diameter
4. AVA
5. STJ diameter
6. Sinus height



Validation

Non-parametric multivariate ANOVA test: $p = 0.86 > 0.05$



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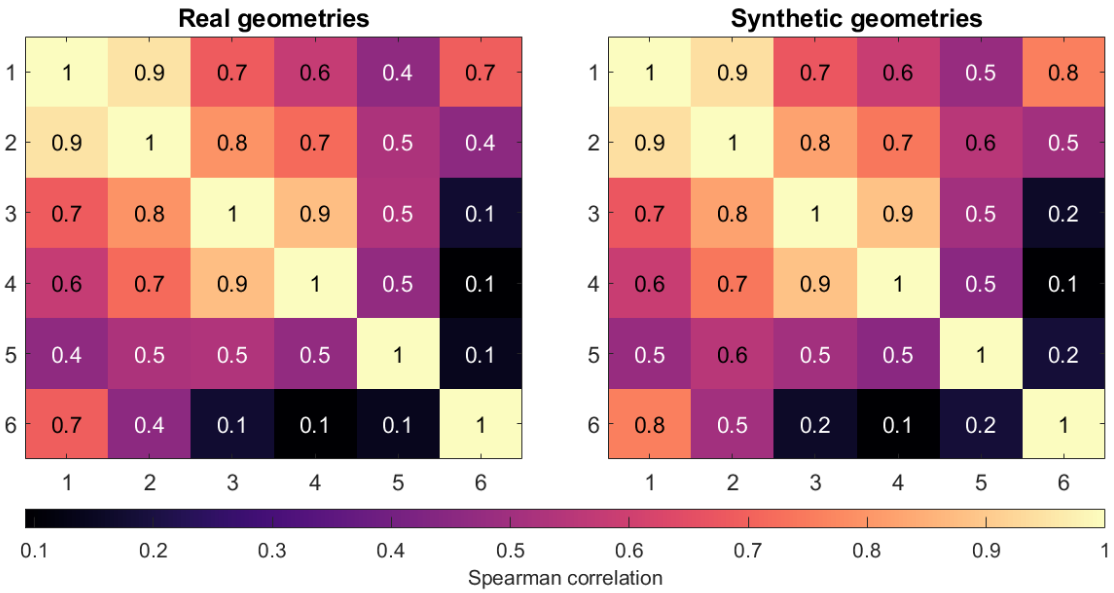
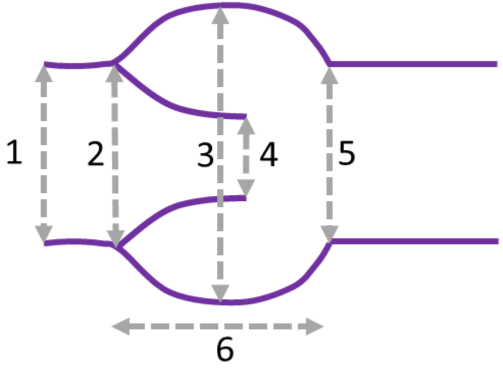
Validation

Non-parametric multivariate ANOVA test: $p = 0.86 > 0.05$





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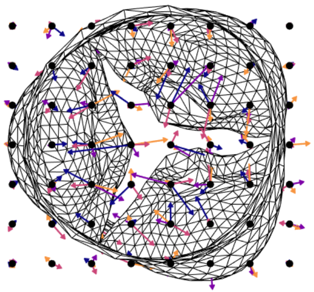
Synthetic geometries with non-parametric SSM

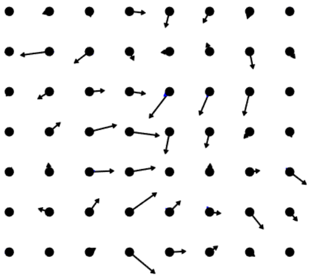
Non-parametric representation

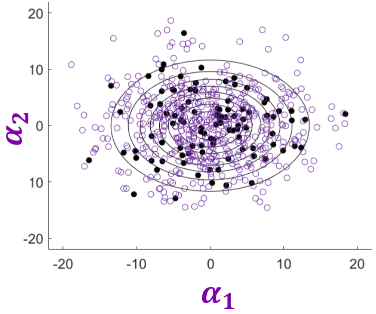
Non-parametric SSM

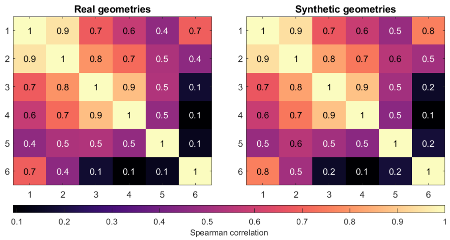
Generate synthetic geometries

Validate synthetic geometries









Virtual cohort generator

SIMCor

Virtual cohort generator to generate synthetic stenosed aortic valve geometries

Enter desired number of virtual cases

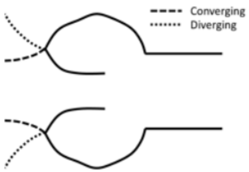
500

Choose template type

Double layer leaflets

Choose desired LVOT shape

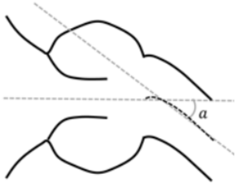
No preference



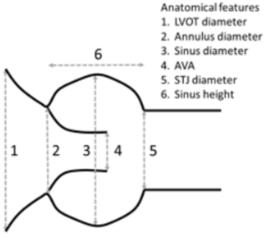
☑ Choose range of angles (a) between LVOT and ascending aorta

Set angle range (between 0 and 70 degrees)

Enter minimum   Enter maximum



☐ Extract anatomical features

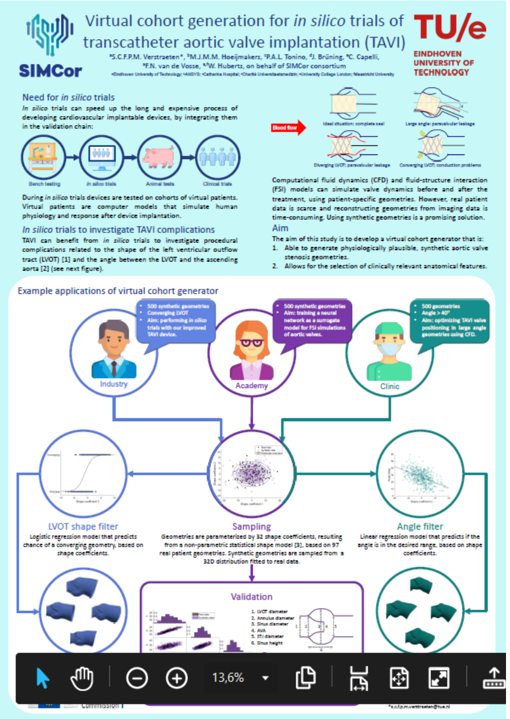


Enter desired number of workers in parallel pool (default 1)

1

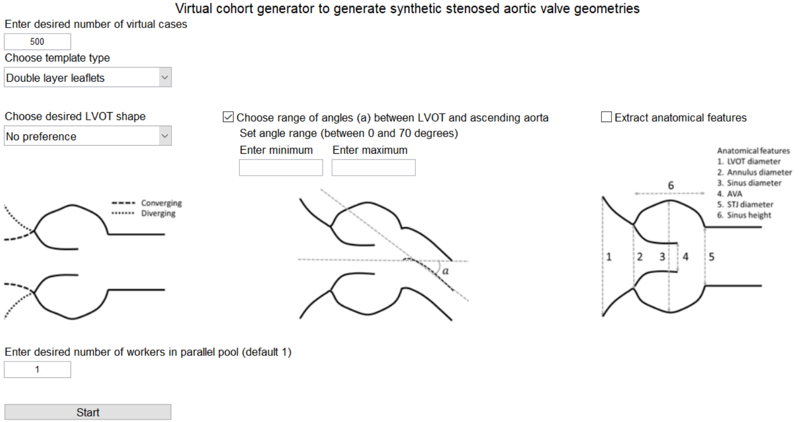
Start

Virtual cohort generator



Poster session III: 12/07 13.15 – 14.15

Scan for poster video



Submitted paper: generation of synthetic aortic valve stenosis geometries for *in silico* trials (Verstraeten et al. 2023)

Special thanks to

Charité
Jan Brüning

University college of London
Claudio Capelli, Jan Bruse

And all other SIMCor partners

Ansys
Martijn Hoeijmakers

Thanks!

Sabine Verstraeten

s.c.f.p.m.verstraeten@tue.nl

Scan for poster video

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