



Virtual cohort generation of Aortic Valve Stenosis geometries

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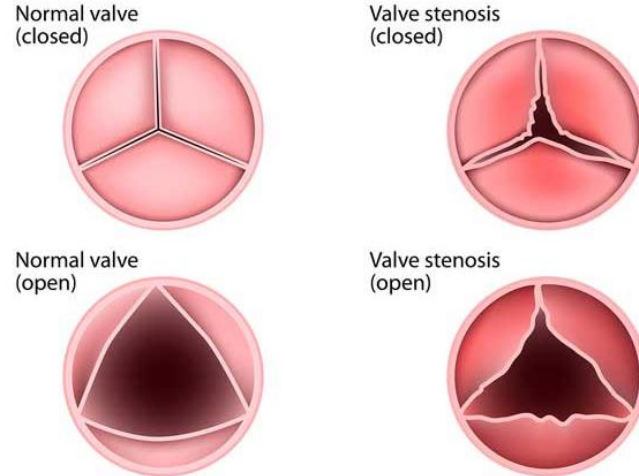
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TECHNOLOGY



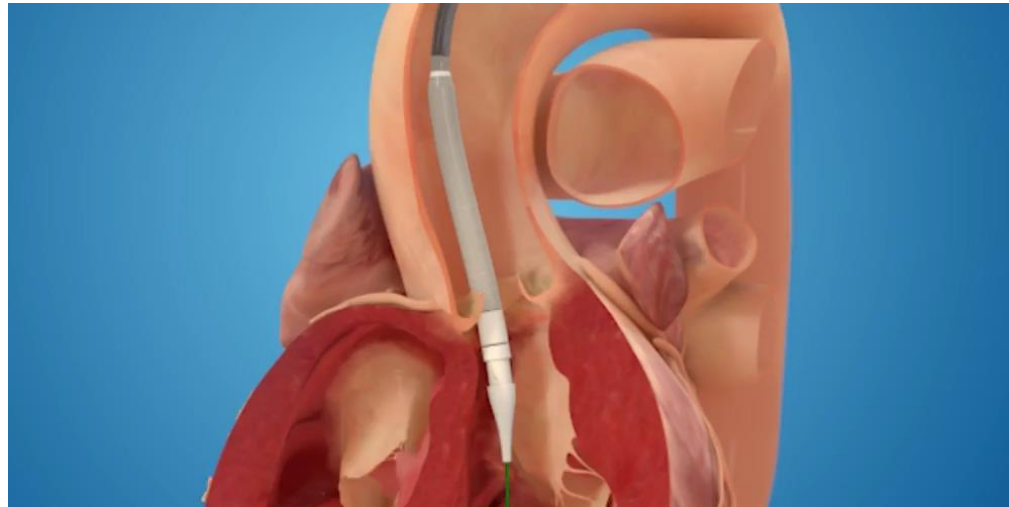
SIMCor

Aortic valve stenosis



Heart-valve-surgery.com (2021)

Transcatheter aortic valve implantation (TAVI)



Benefits

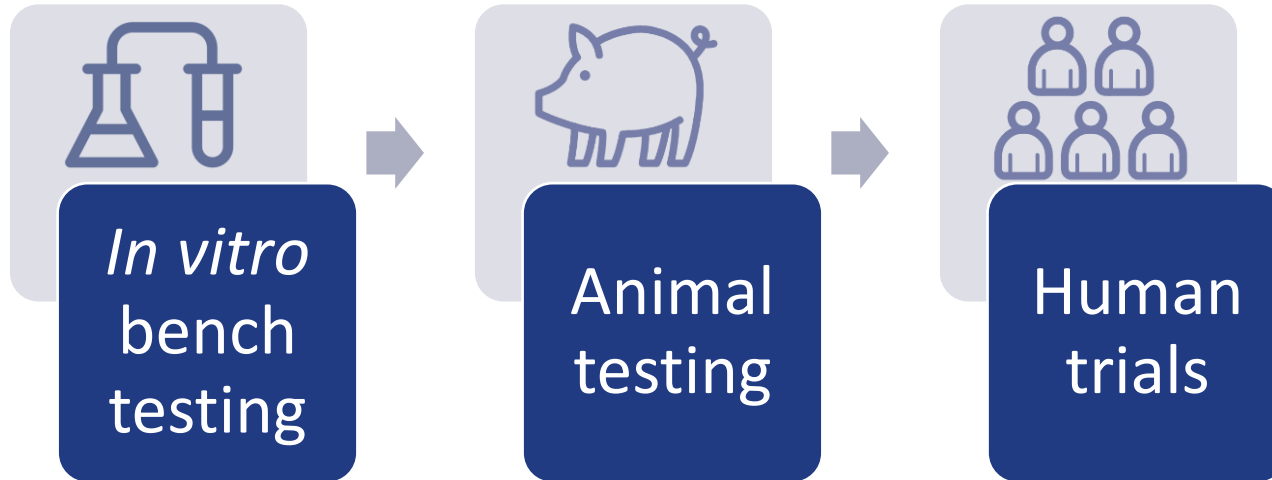
- Relief from symptoms
- Increased life expectancy
- Accessible for all patients



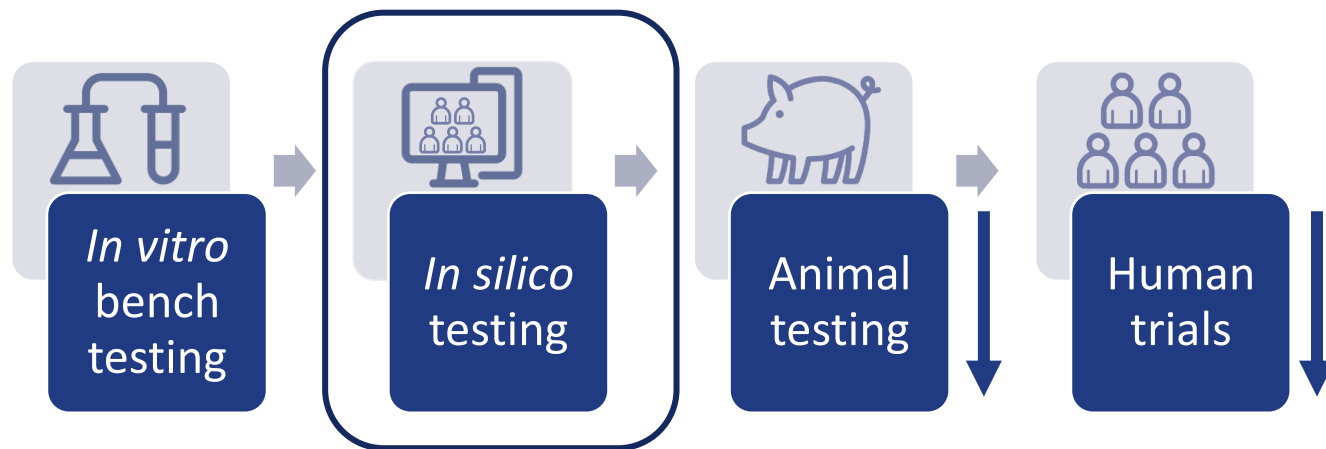
Risks

- Paravalvular leakage
- Thrombosis
- Conduction problems

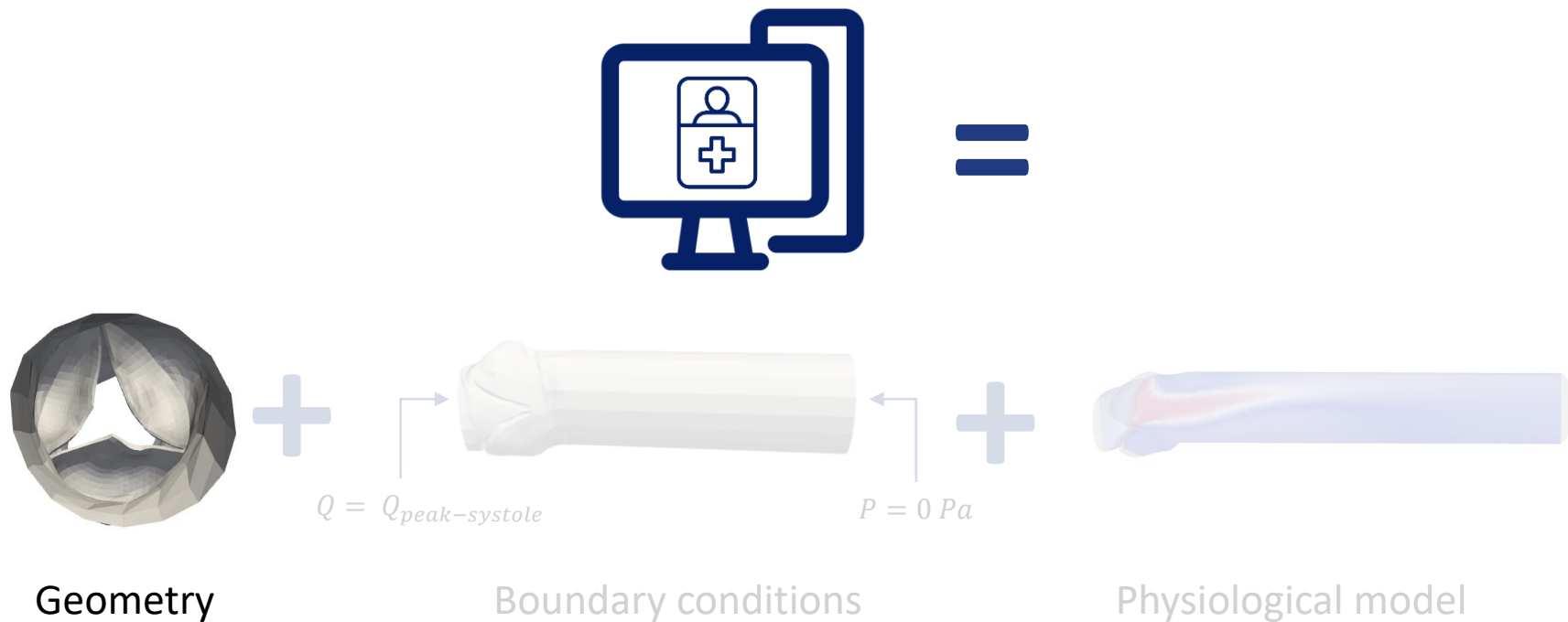
Developing & testing TAVI devices



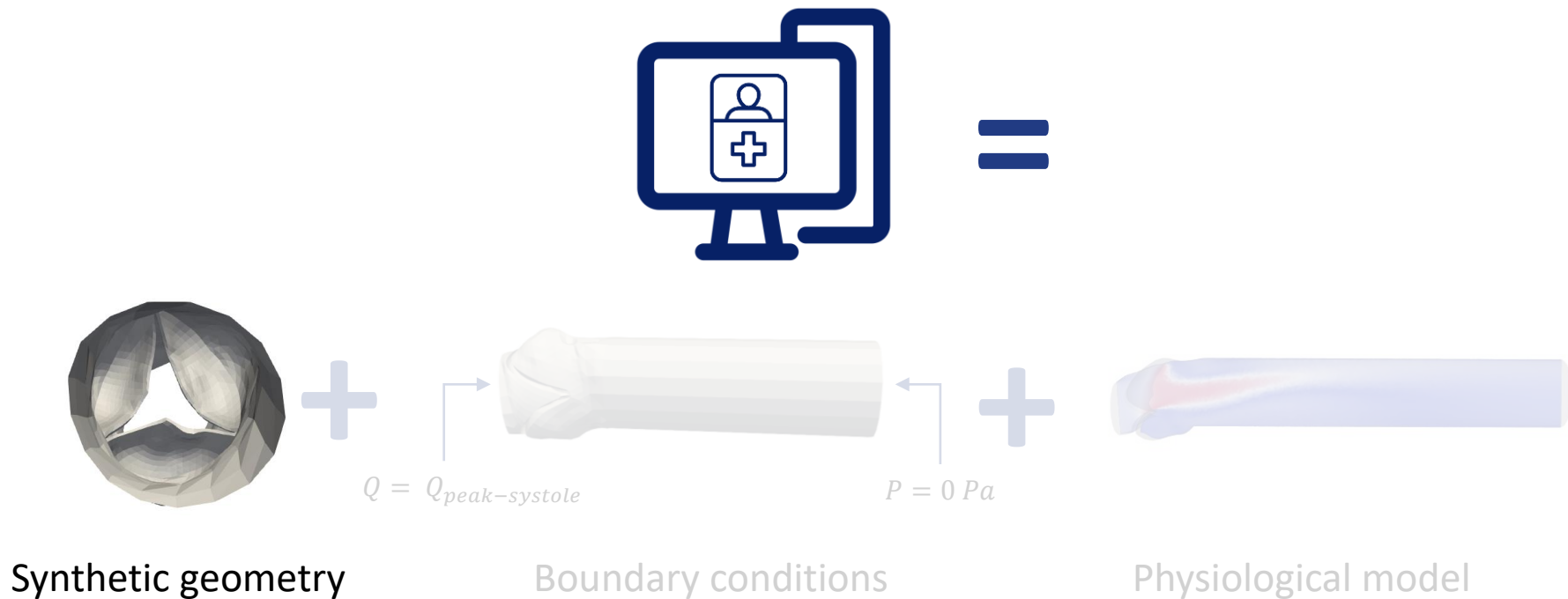
Developing & testing TAVI devices



The virtual patient

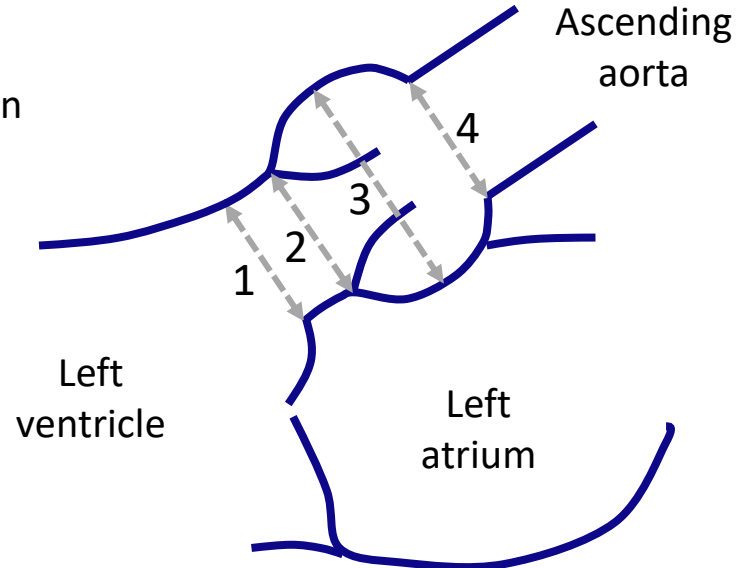


The virtual patient



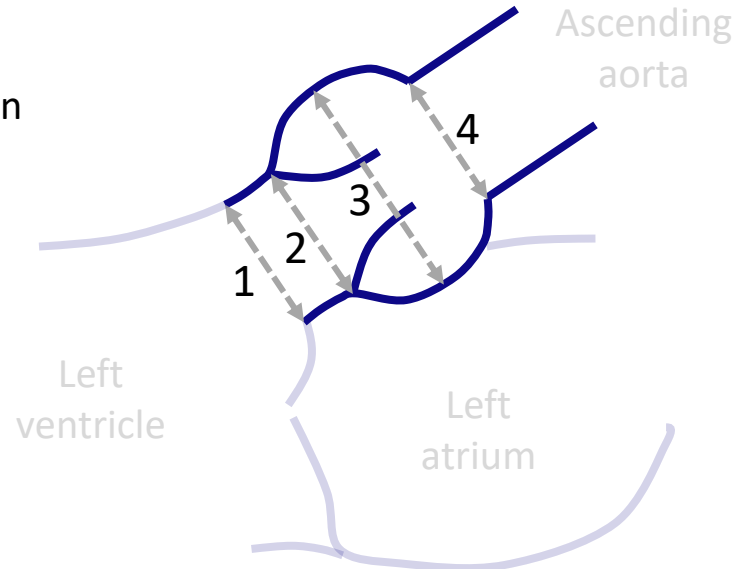
Aortic valve geometry

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



Aortic valve geometry

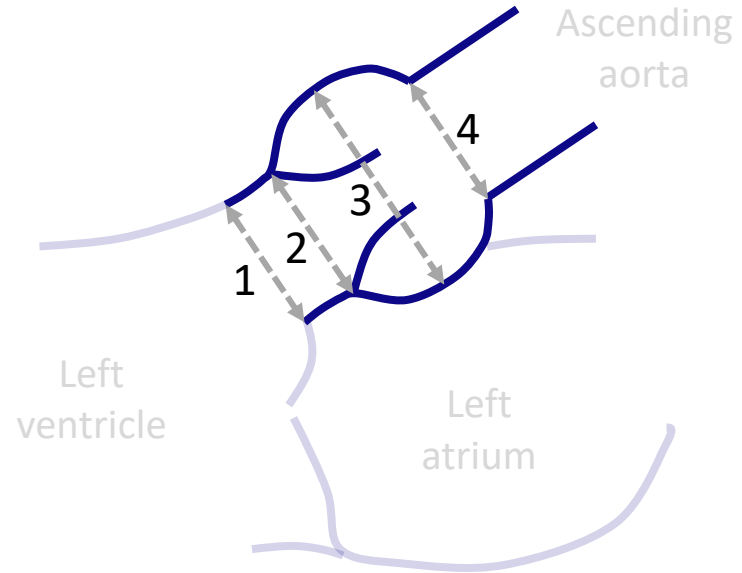
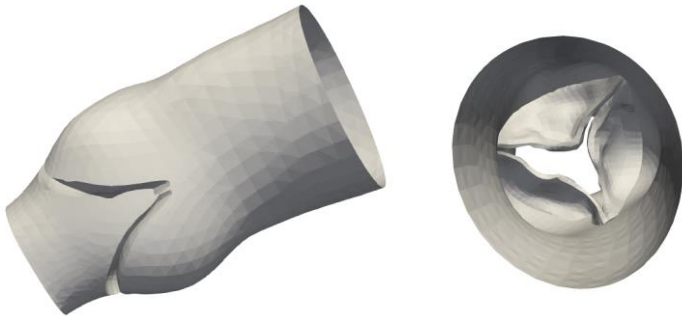
1. LVOT
2. Annulus
3. Sinuses of Valsalva
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Aortic valve geometry

Real patient data set

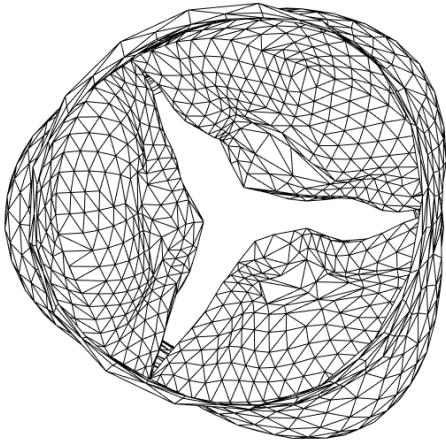
- 97 geometries
- Peak-systolic
- Severe stenosis



Statistical shape modelling (SSM)

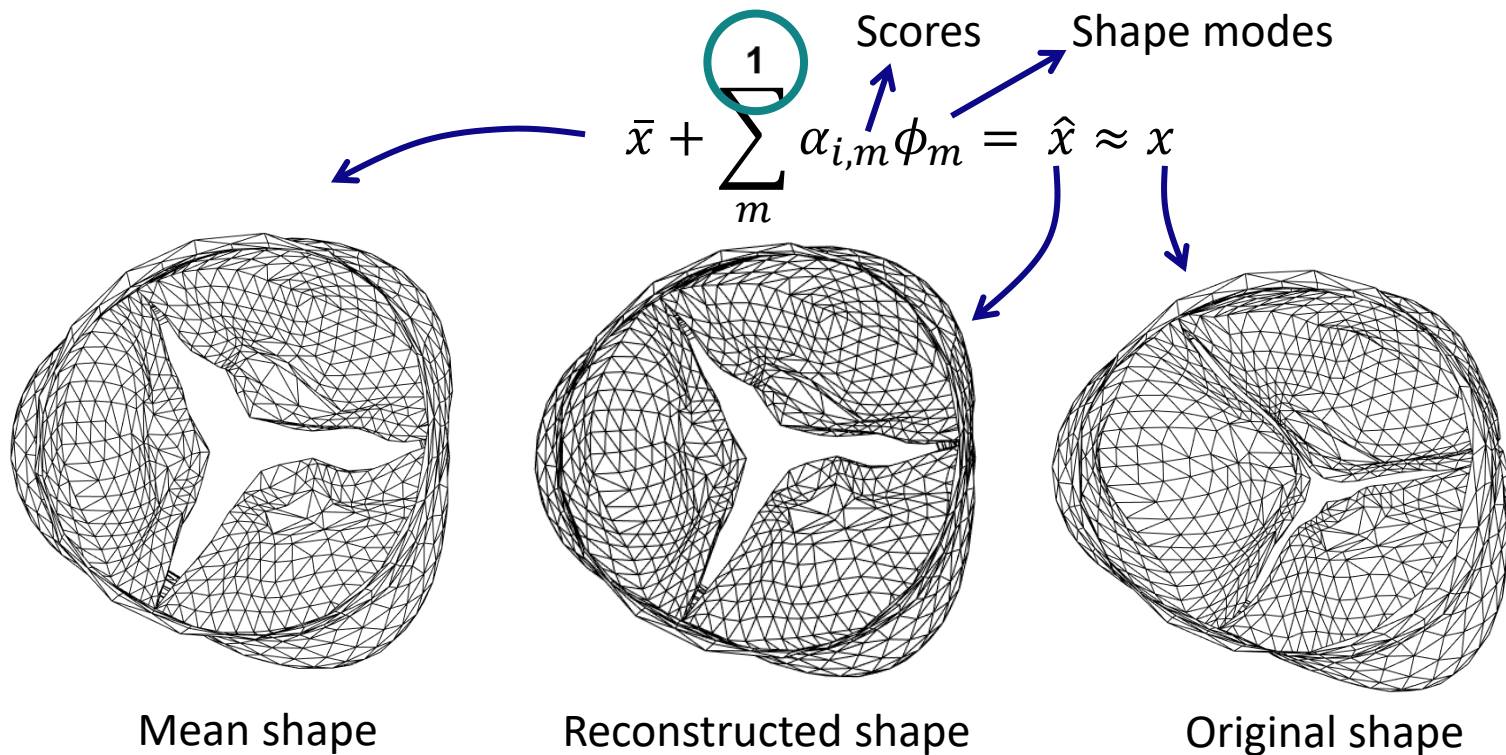
$$\bar{x} + \sum_m^N \alpha_m \phi_m = \hat{x} \approx x$$

Scores α_m Shape modes ϕ_m



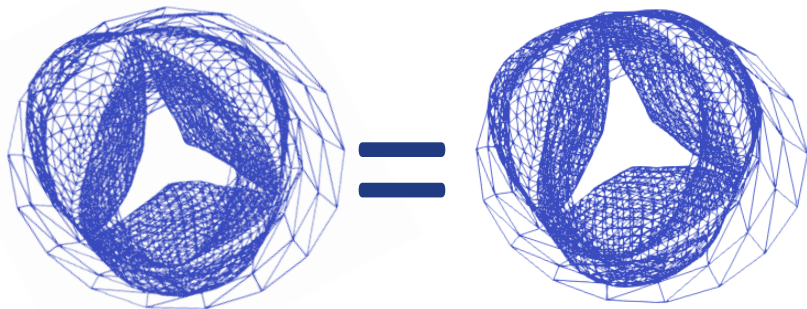
Mean shape

Statistical shape modelling (SSM)



Statistical shape modelling (SSM)

Conventional SSM



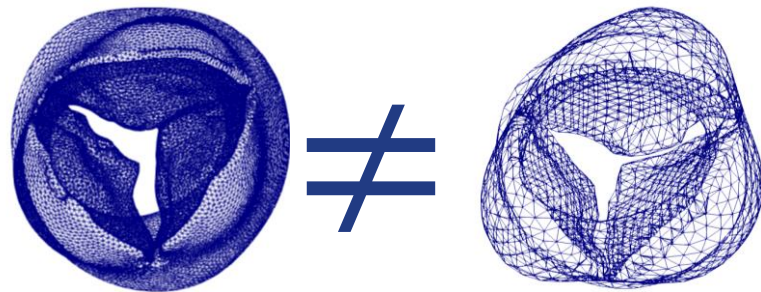
3511 points

3511 points



Inter-patient topology required!

Non-parametric SSM



24254 points

4063 points



Applicable to all sets of geometries!

Synthetic geometries with non-parametric SSM

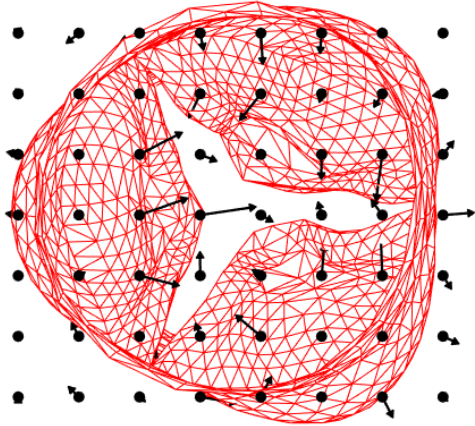


Synthetic geometries with non-parametric SSM



Non-parametric representation

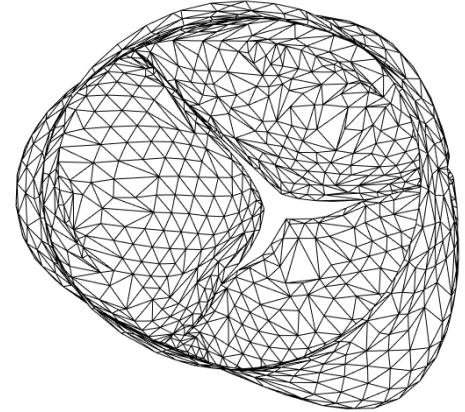
Template \bar{x}



N deformation vectors β_k

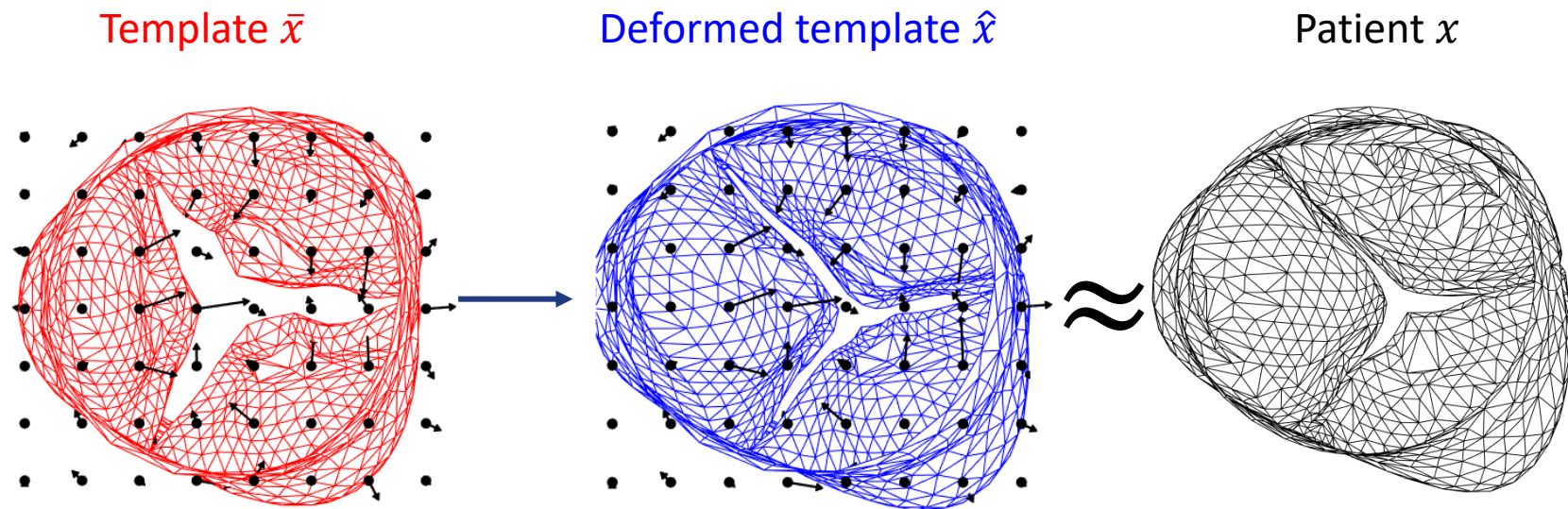


Patient x



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

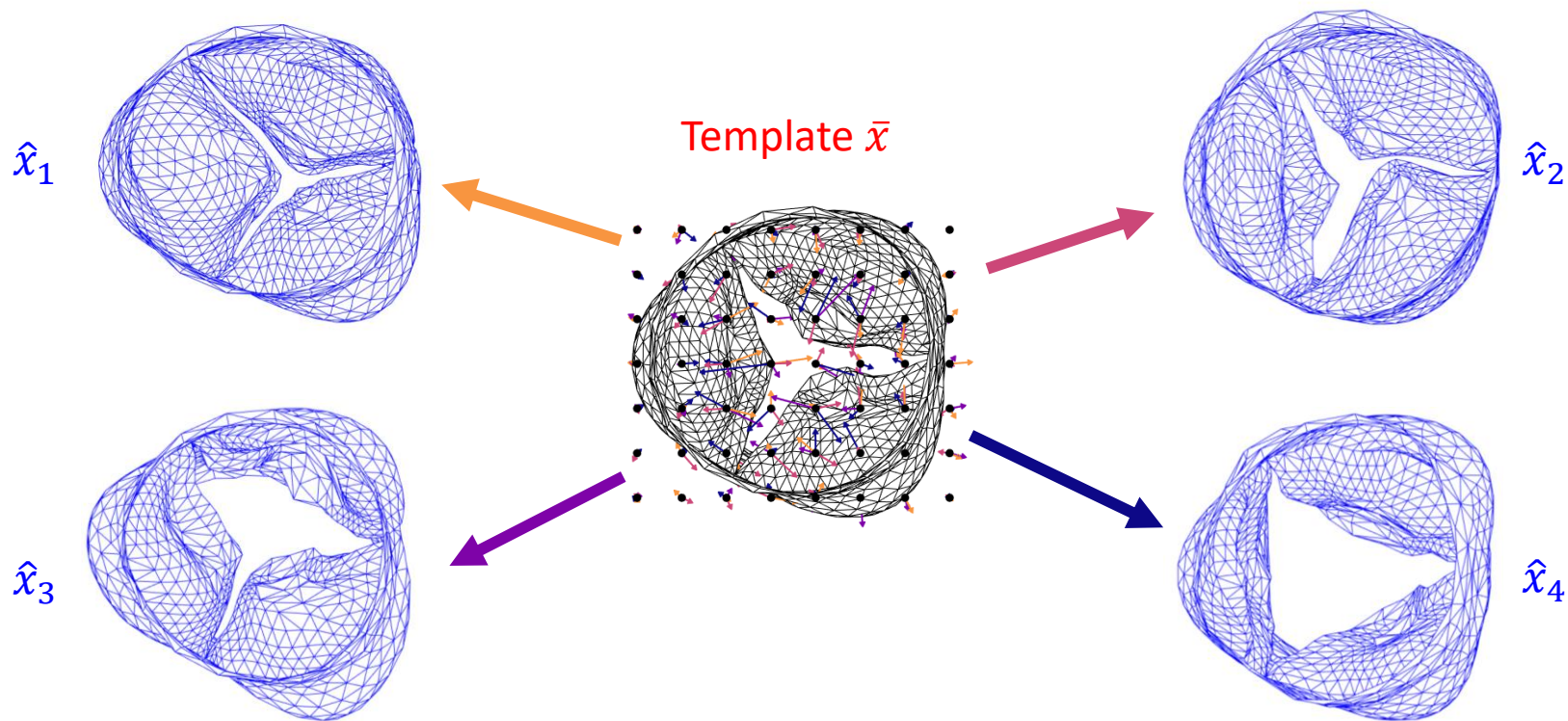
Non-parametric representation



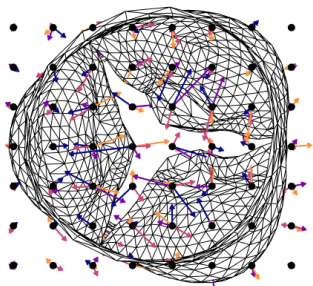
N deformation vectors β_k

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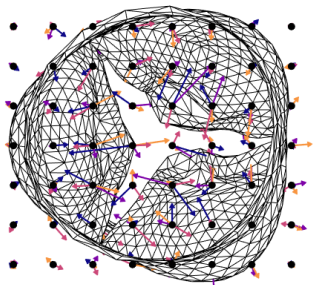
Non-parametric representation



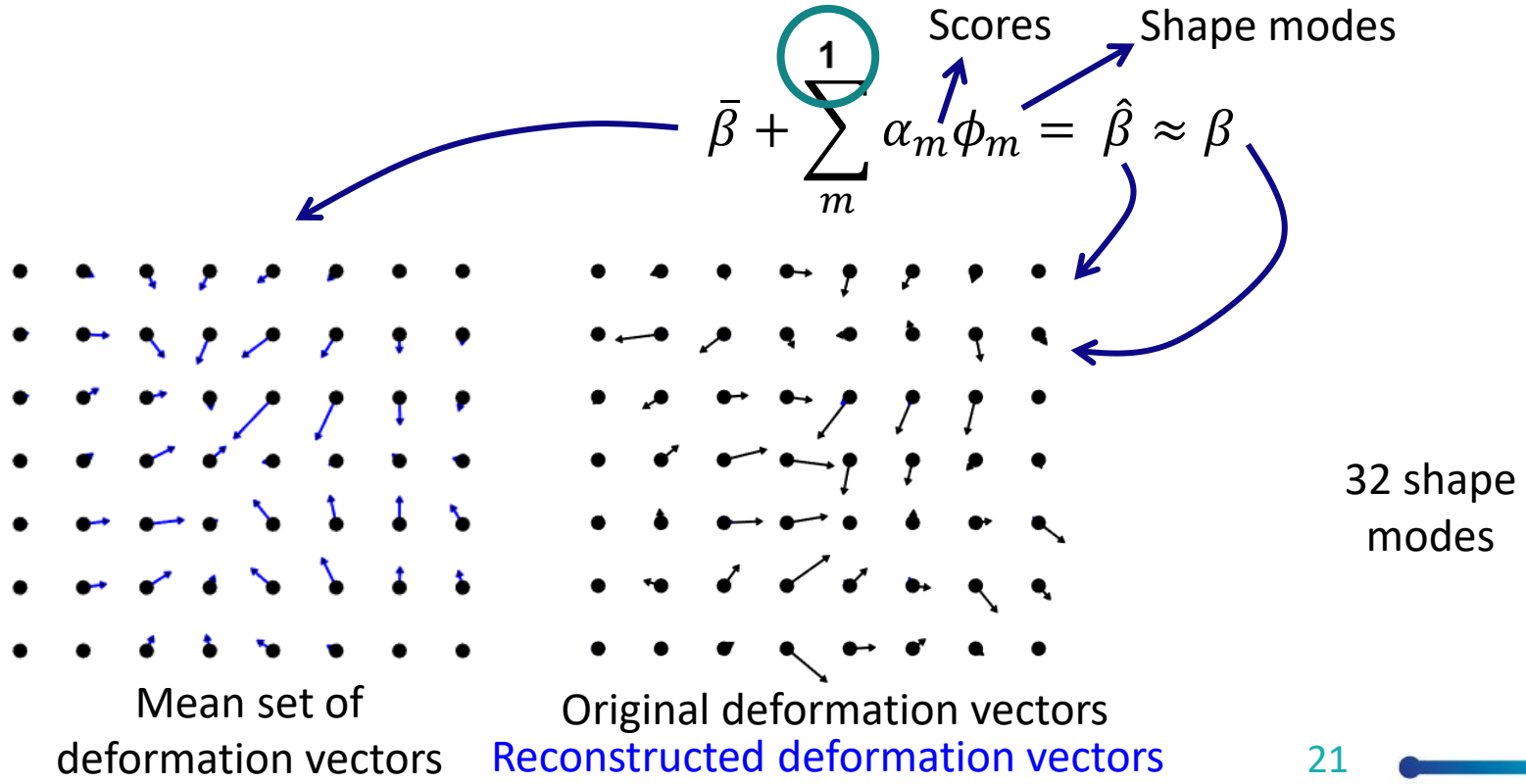
Synthetic geometries with non-parametric SSM



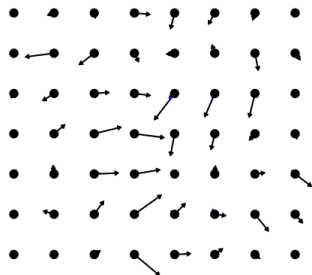
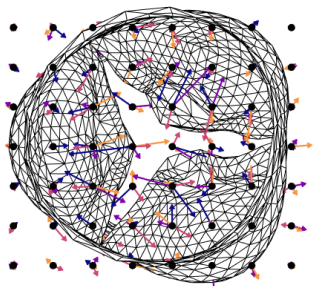
Synthetic geometries with non-parametric SSM



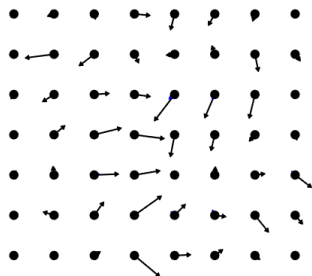
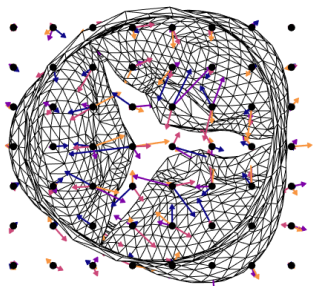
Non-parametric SSM



Synthetic geometries with non-parametric SSM

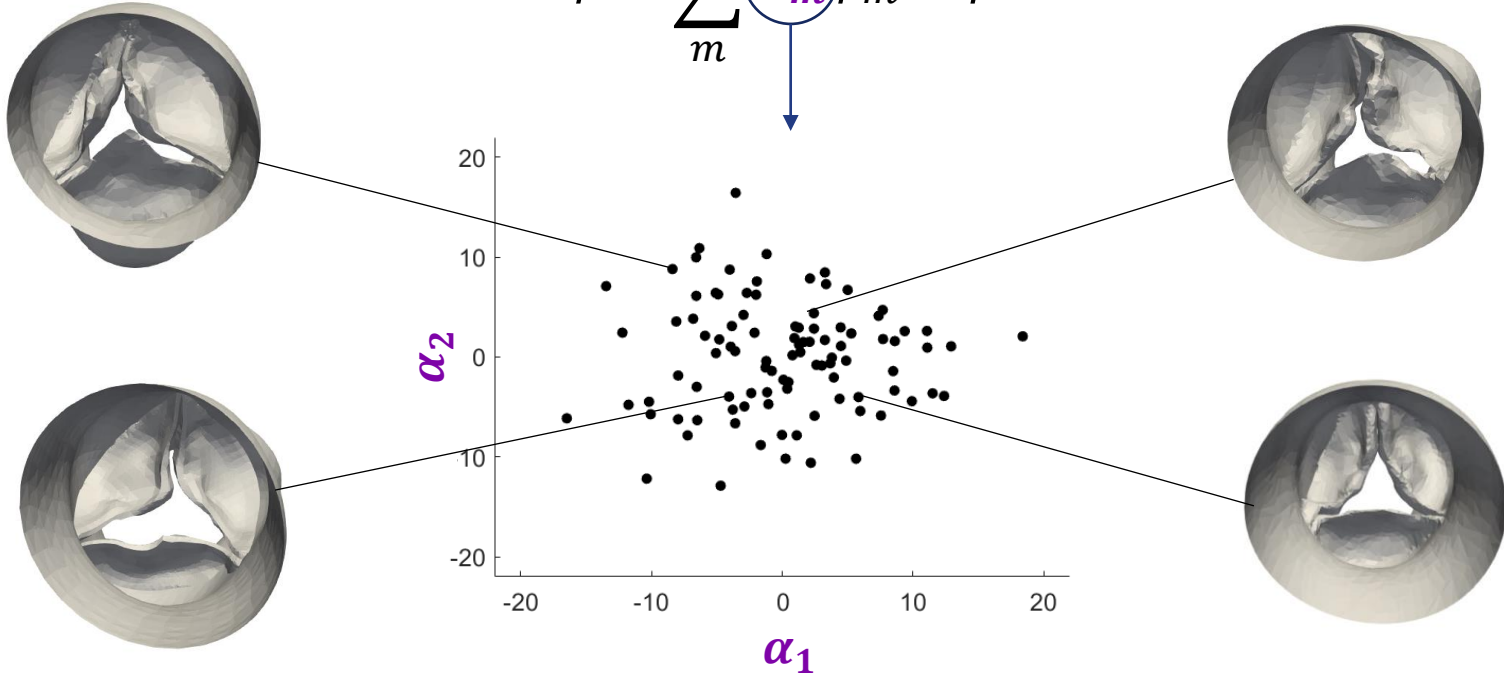


Synthetic geometries with non-parametric SSM



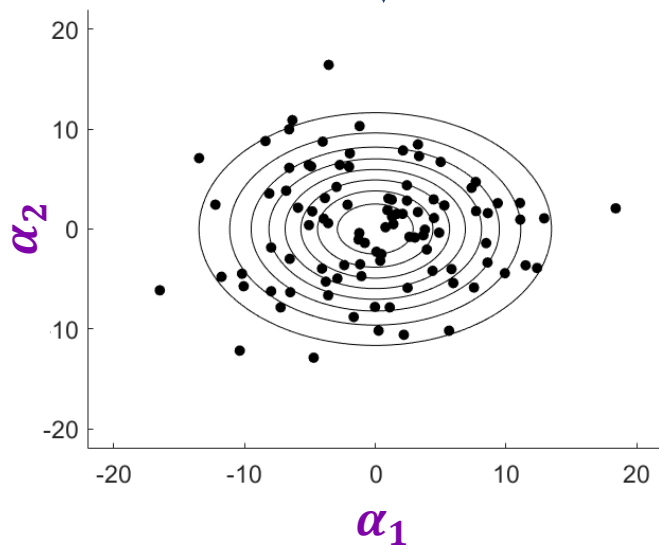
Generation of synthetic geometries

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



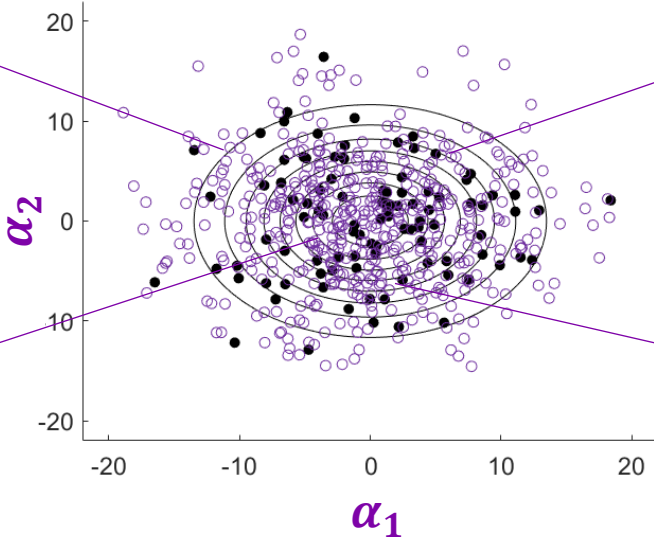
Generation of synthetic geometries

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

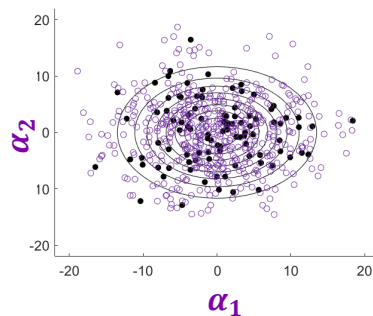
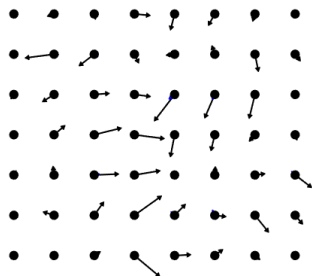
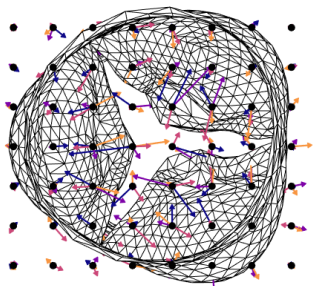


Generation of synthetic geometries

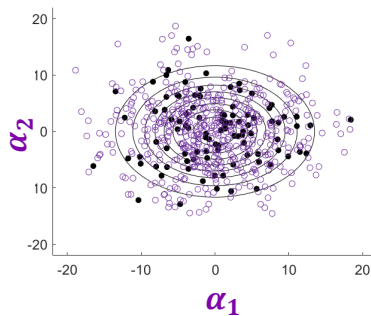
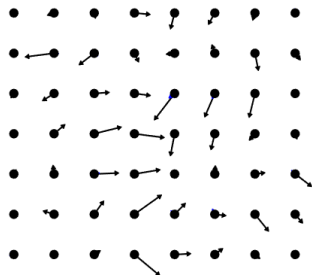
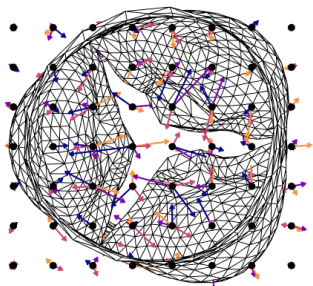
$$\bar{\beta} + \sum_m^{32} \alpha_m \phi_m = \hat{\beta}$$



Synthetic geometries with non-parametric SSM

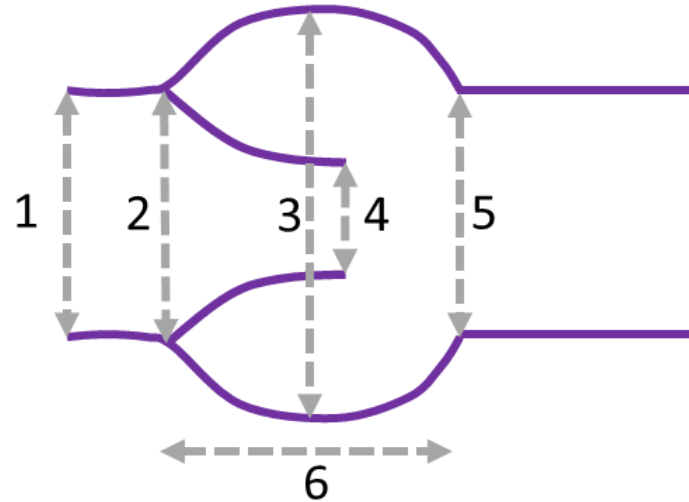


Synthetic geometries with non-parametric SSM



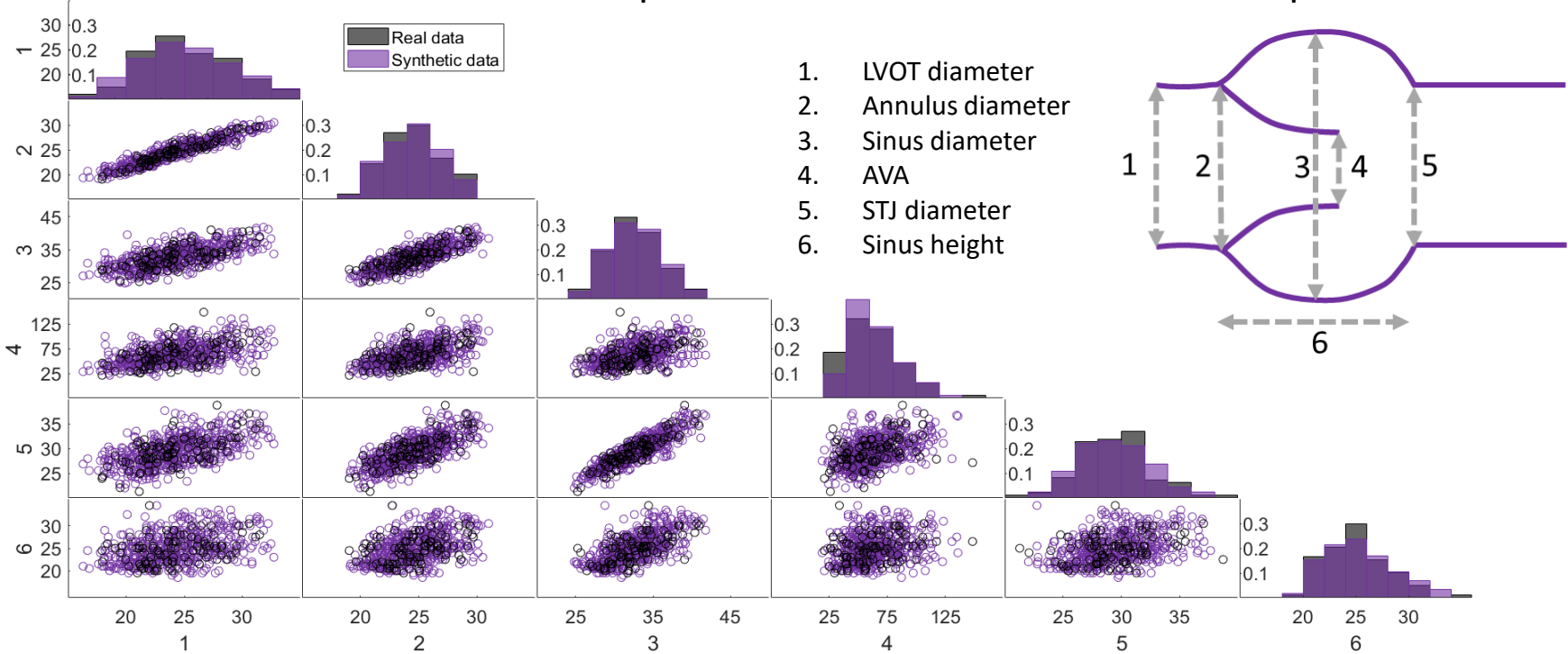
Validation

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



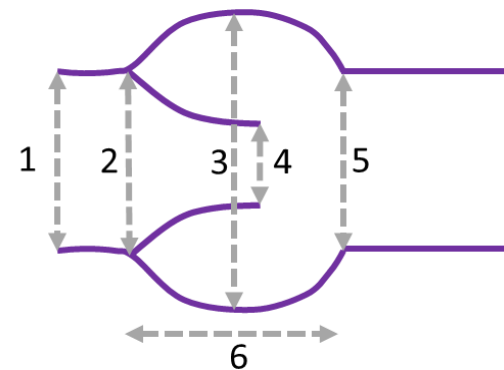
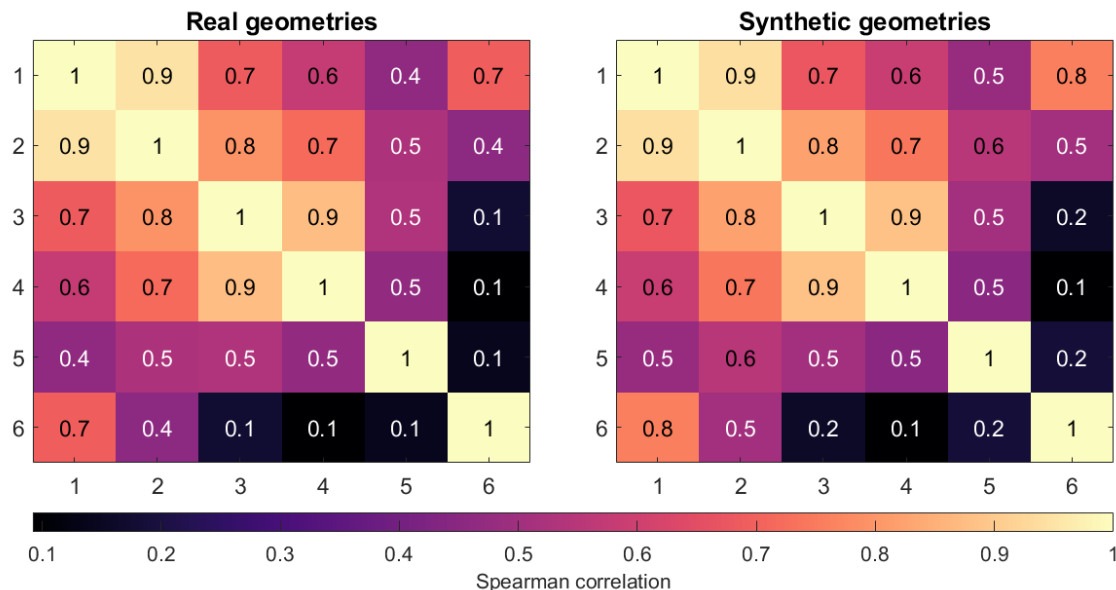
Validation

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



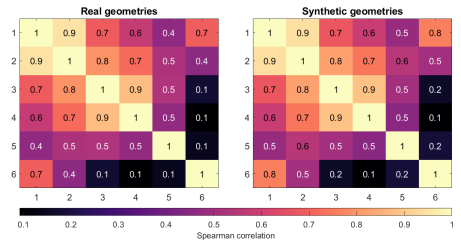
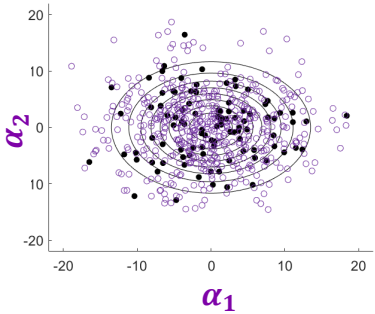
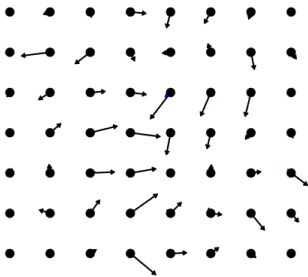
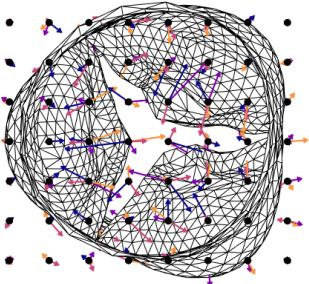
Validation

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



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

Synthetic geometries with non-parametric SSM



Virtual cohort generator



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

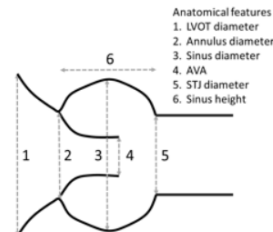
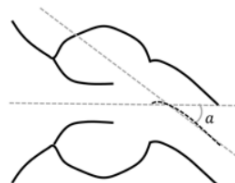
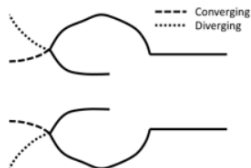
Choose range of angles (α) between LVOT and ascending aorta

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

SIMCor Virtual cohort generation for *in silico* trials of transcatheter aortic valve implantation (TAVI)
 TU/e
 15 C.F.P.M. Verstraeten¹, M.J.M.M. Hoelmakers¹, P.A.L. Tonino¹, Y. Brining¹, C. Capelli¹,
 P.S. Van de Vosse¹, W. Houben¹, on behalf of SIMCor consortium
¹Cardium Institute, ²Technology, ³HEALTH, ⁴Healthcare, ⁵Healthcare, ⁶Healthcare, ⁷Healthcare, ⁸Healthcare, ⁹Healthcare, ¹⁰Healthcare, ¹¹Healthcare, ¹²Healthcare, ¹³Healthcare, ¹⁴Healthcare, ¹⁵Healthcare, ¹⁶Healthcare, ¹⁷Healthcare, ¹⁸Healthcare, ¹⁹Healthcare, ²⁰Healthcare

Need for *in silico* trials
In silico trials can speed up the long and expensive process of developing cardiovascular implantable devices, by integrating them in the validation chain.

Computational fluid dynamics (CFD) and Fluid-structure Interaction (FSI) models can simulate valve dynamics before and after the treatment, using patient-specific geometries. However, real patient data is scarce and reconstructing geometries from imaging data is time-consuming. Using synthetic geometries is a promising solution.

Aim
 The aim of this study is to develop a virtual cohort generator that is:
 1. Able to generate physiologically plausible, synthetic aortic valve recess geometries.
 2. Allows for the selection of clinically relevant anatomical features.

Example applications of virtual cohort generator

- Industry:** All cardiac geometries, Conforming CFD, Data performance in silico, Train with our learned AI models.
- Academy:** 100 synthetic geometries, AI: training a neural network on a large dataset, needed for FS simulation of aortic valves.
- Clinic:** 100 geometries, Angle 1-60°, Also conforming 3D0 case, switching to large angle geometries using CFD.

Workflow: LVOT shape filter (Logistic regression model) → Sampling (Geometries are parameterized by 32 shape coefficients) → Angle filter (Linear regression model) → Validation (1. LVOT diameter, 2. Annulus diameter, 3. Sinus diameter, 4. AVA, 5. STJ diameter, 6. Sinus height).

Scan for poster video



Virtual cohort generator to generate synthetic stenosed aortic valve geometries

Enter desired number of virtual cases

Choose template type

Choose desired LVOT shape

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

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

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

Start

Poster session III: 12/07 13.15 – 14.15

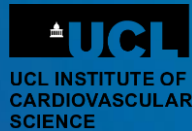
Submitted paper: generation of synthetic aortic valve stenosis geometries for *in silico* trials (Verstraeten et al. 2023)

Special thanks to

Charité
Jan Brüning



University college of London
Claudio Capelli, Jan Bruse



And all other SIMCor partners

Ansys
Martijn Hoeijmakers



SIMCor

Thanks!

Sabine Verstraeten

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Scan for poster video



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