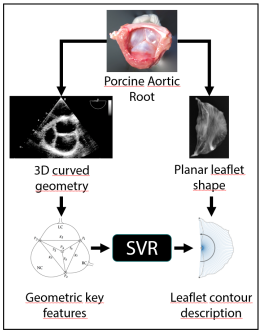
An SVR-based Data-driven Leaflet Modeling Approach for Personalized Aortic Valve Prosthesis Development

Jannis Hagenah, Tizian Evers, Michael Scharfschwerdt, Achim Schweikard, Floris Ernst

Institute for Robotics and Cognitice Systems, Universitiy of Lübeck
Lübeck, Germany

Aim: While the aortic valve geometry is highly patient-specific, state-of-the-art prostheses cannot reproduce this individual geometry. One challenge in manufacturing personalized prostheses is the mapping from the curved 3D shape extracted from imaging modalities to the planar 2D leaflet contour that is cut out of the fabrication material. We propose the use of machine learning to estimate this mapping completely data-driven.

Methods: We set up a database to derive and evaluate leaflet shape models. First, 3D ultrasound images of ex-vivo porcine valves were acquired under realistic pressure to extract geometric key parameters describing the individual geometry. In a second step, the valves' leaflets were cut out, spread on an illuminated plate and photographed in this state. From these images, the leaflet shape was extracted using segmentation and edge detection. The resulting database (10 heart valves, i.e. 30 leaflet images) allows the derivation of a data-driven leaflet shape model using Support Vector Regression. This method was evaluated using 10-fold cross validation by calculating the average symmetric contour distance (ascd). Additionally, an existing geometric leaflet shape model from Sievers et al. was evaluated on the dataset.



Sketched workflow.

Prediction error of both models for different leaflet types, given as mean ascd in mm

Leaflet	Sievers et al.	Data-driven
Left-coronary	2.77	0.69
Right-coronary	2.96	0.64
Non-coronary	2.65	0.41
Mean	2.79	0.58

Results: The data-driven approach provided an acceptable leaflet shape estimation error of 0.58 mm mean ascd and clearly outperformed the existing model (2.79 mm mean ascd). Our study indicates that planar leaflet shape estimation based on 3D image data is possible and presents an important step towards personalized aortic valve prostheses.