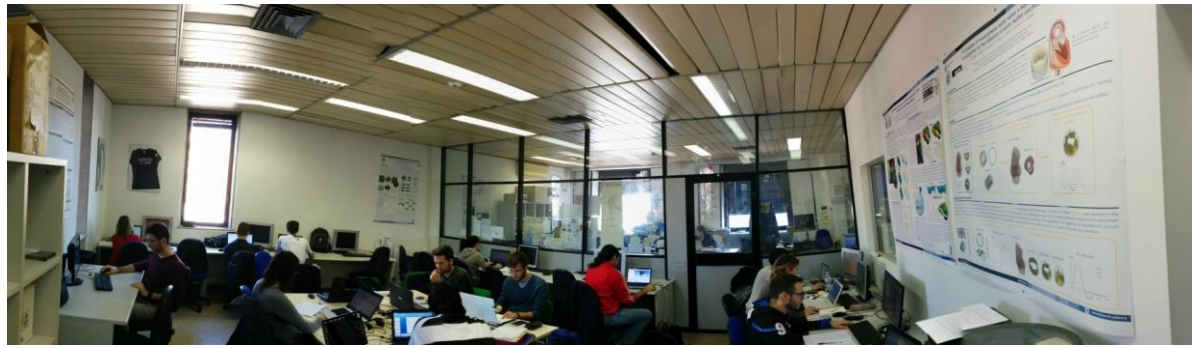
Thesis Topics & Projects 2023
Biomech@DEIB
CBLab and C3DLab

CBLab and C3DLab
Computational modeling at the continuum length-scale

The Laboratories

Computational Biomechanics Lab (CBLab AKA The Cube)
Building 21, 4th floor



3D and Computer Simulation Laboratory
IRCCS Policlinico San Donato

The Team


Alberto Redaelli


Emiliano Votta


Francesco Sturla


Simone Saitta


Alessandra Riva


Guido Nannini


Riccardo Munafò


Veronica Ruozzi


Davide Astori

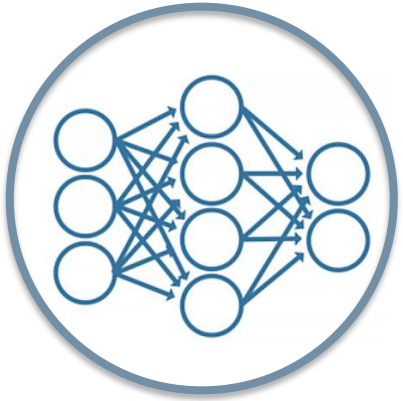

Davide Tondi

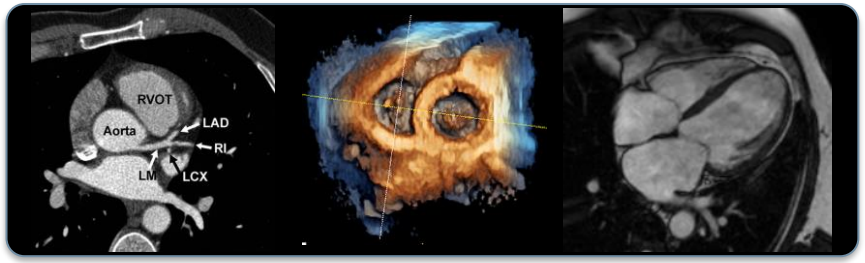

Alessandro Albanesi

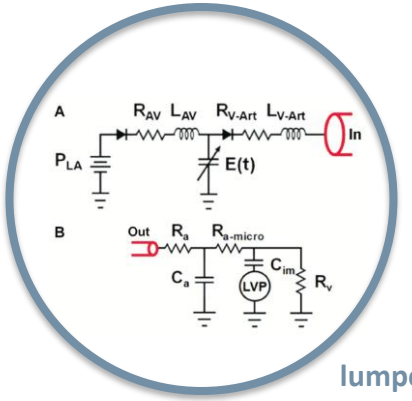

Luca Mariani

Technologies, Techniques, and Applications

AI for image analysis
nd patient classification

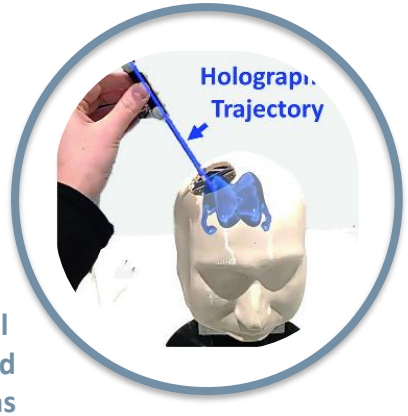


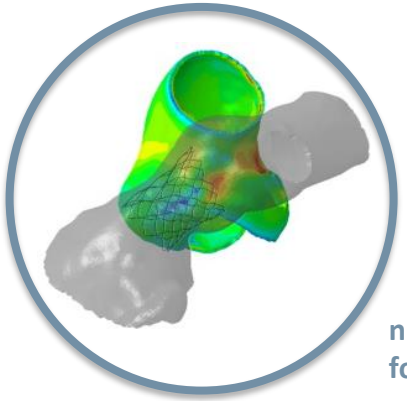




lumped parameter
modeling

XR to support surgical
training, planning, and
interventions





numerical modeling
for interventional
planning

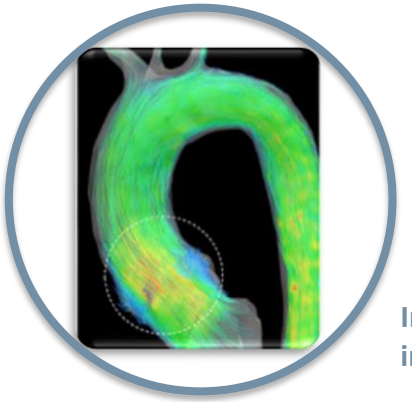


Image-based
in vivo biomechanics

Who works on what

Finite Element Modeling for Structural Mechanics


Francesco Sturla


Davide Astori


Davide Tondi

Computational in vivo fluid dynamics (4Dflow)


Francesco Sturla


Alessandra Riva


Simone Saitta

Computational Fluid Dynamics and FSI modeling


Francesco Sturla


Simone Saitta


Guido Nannini


Luca Mariani

Artificial Intelligence


Riccardo Munafò


Simone Saitta

Augmented Reality


Veronica Ruozzi


Alessandro Albanesi


Alberto Redaelli


Emiliano Votta

Different Projects with Different Levels of Novelty

To the Edge

- Previously developed approaches substantially improved or extended
- Safe exploration of new methods (a backup solution is already available)

And Beyond

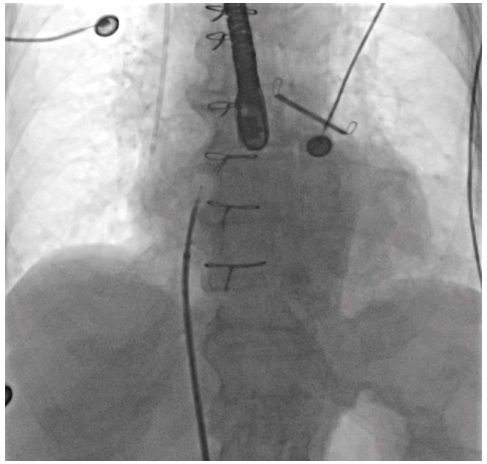
- Development of brand-new approaches
- Rather intensive coding
- Deeper involvement of tutors

Ultra – XR: An intuitive training tool

Developing a fluoroscopy simulator to train operators on fluoroscopic guidance during percutaneous cardiac procedures

SOLD

augmedics.com



Starting point

Physical phantom of blood vessels complemented by high-speed cameras and image-processin software to transform camera acquisitions into fluoroscopy-like images

Activities

- designing, building and testing an actuator to change camera positions and simulate the use of a C-arm
- improving the image-processing algorithm
- rendering fluoroscopy-like imaging via augmented reality
- running a preliminary experimental campaign to assess the impact of AR visualization on trainees ergonomy and performance

Background:

Quintieri and Catapano, Master Thesis. Sviluppo di un simulatore per il training in procedure transcatetere sotto guida fluoroscopica simulata. 2020.

Contacts:

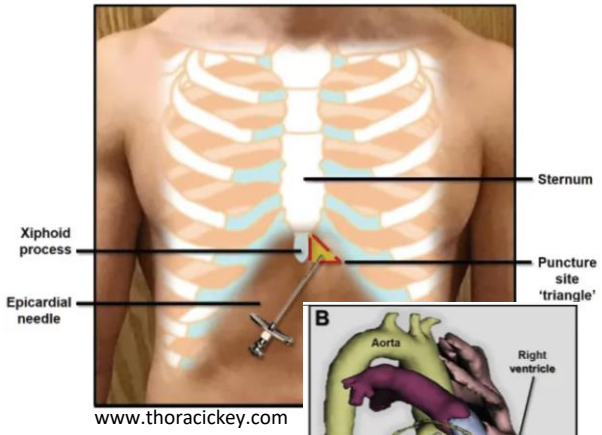
Veronica Ruozzi, Fabio Pappalardo

Epicardial puncture – pre-procedural planning tool

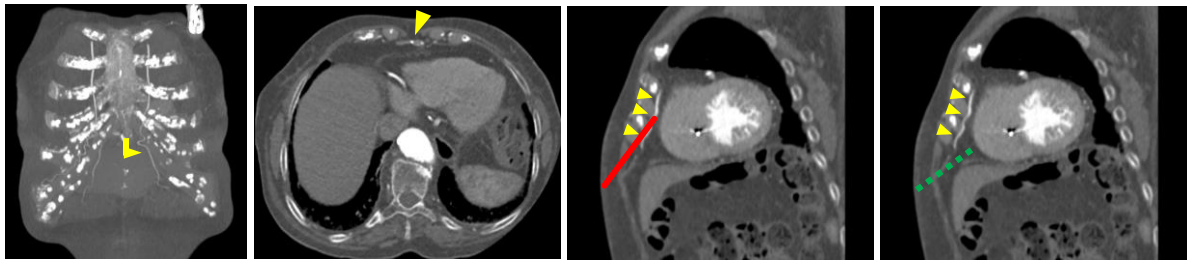
Development of a planning tool for percutaneous epicardial access through subxiphoid puncture based on 4D CT datasets

Activities

- Designing and implementing aPython-based software to identify a safe access trajectory while accounting for heart motion



www.thoracickey.com



Collaborations

I.R.C.C.S. Ospedale San Raffaele
Gruppo San Donato

Background:

Van den Bosch et al. Augmented Reality-Assisted CT-Guided Puncture: A Phantom Study. Cardiovasc Intervent Radiol 45, 1173–1177 (2022). https://doi.org/10.1007/s00270-022-03195-y

Contacts:
Veronica Ruozzi

AI-based automated workflow for TPVI planning in the native RVOT from 4D CT imaging

Developing a user-friendly tool to support the planning of transcatheter pulmonary valve implantation (TPVI) based on pre-op time-resolved 4D (3D + time) CT scans

Activities

- Defining the workflow to be implemented
- Implementing and training a deep convolutional neural network (CNN) for the automated segmentation of the relevant anatomical site
- Testing the implemented CNN against a gold standard
- Preliminarily validating the implemented software through, e.g., in vitro experiments on 3D-printed pulsatile models tested under CT.

Collaborations

I.R.C.C.S. Policlinico San Donato

Background

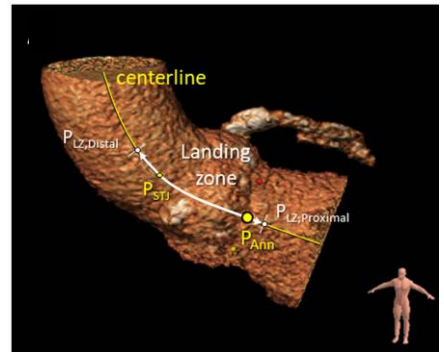
1. Han et al. (J Cardiovasc Comput Tomogr, 2023)
2. Pluchinotta et al. (Int J Cardiol, 2020)
3. Saitta et al (Comput Biol Med, 2023)

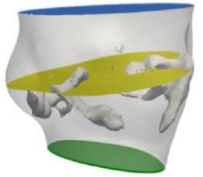
Contacts

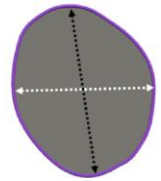
Francesco Sturla (francesco.sturla@grupposandonato.it)
Simone Saitta (simone.saitta@polimi.it)
Emiliano Votta (emiliano.votta@polimi.it)

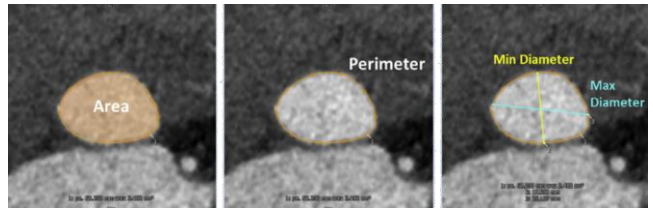
Improving and engineering an AI-based automated workflow for TAVI planning

To improve and optimize an AI-based automated workflow for planning transcatheter aortic valve implantation (TAVI) in patients with severe aortic valve stenosis from preoperative computed tomography (CT).









Activities

- Extending and automating the pool of variables provided by the platform and relevant for TAVI planning, in accordance with current clinical guidelines.
- Developing an alpha release of the pre-operative platform for testing in a real clinical setting by final users (i.e., cardiologists)

Collaborations

I.R.C.C.S. Policlinico San Donato

Background

1. *Saitta et al.* (Comput Biol Med, 2023)
2. *Elattar et al.* (Int J Cardiovasc Imaging, 2016)
3. *Blanke et al* (J Am Coll Cardiol Img, 2019)

Contacts

Francesco Sturla (francesco.sturla@grupposandonato.it)
Simone Saitta (simone.saitta@polimi.it)
Emiliano Votta (emiliano.votta@polimi.it)

Computational analysis of the effect of aortic arch morphology on cardiogenic embolic transport to the brain

Primary aims

- To simulate patient-specific sovraortic fluid dynamics extracting model geometry and hemodynamic conditions from *in vivo* imaging, i.e., from computed tomography (CT) and cardiovascular magnetic resonance (CMR) 4D Flow, respectively.
- To develop a 1-way framework for aortic blood flow particle transport and tracking, e.g., based on the modified Max[illegible] (Mukherjee *et al.*).
- To compare different types of aortic arch anatomies (Type I, II and III) in terms of the cardiogenic embolic predilection [illegible] brain.

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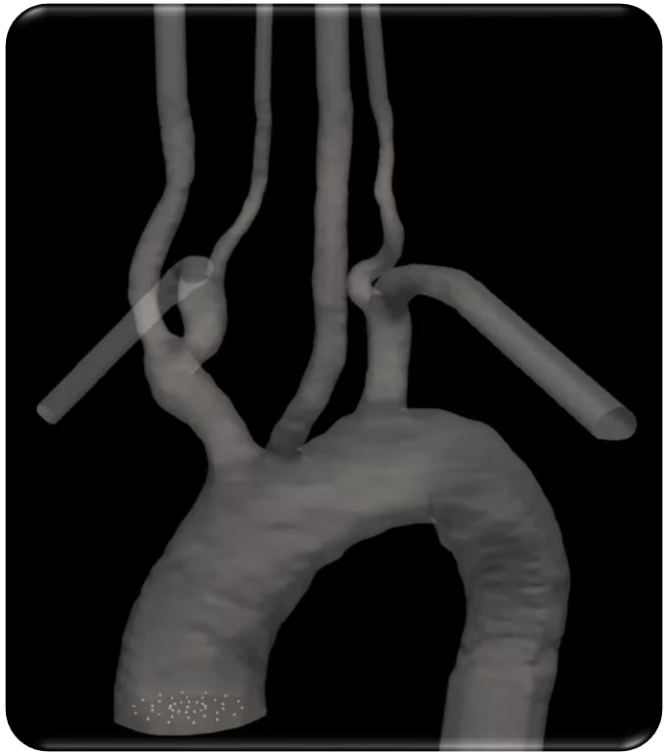


Project in collaboration with the Department of Biomechanical Engineering at TU Delft (Delft, The Netherlands).

Possible experience @TUDelft during the thesis project.

TU Delft

I.R.C.C.S. Policlinico San Donato

Background:

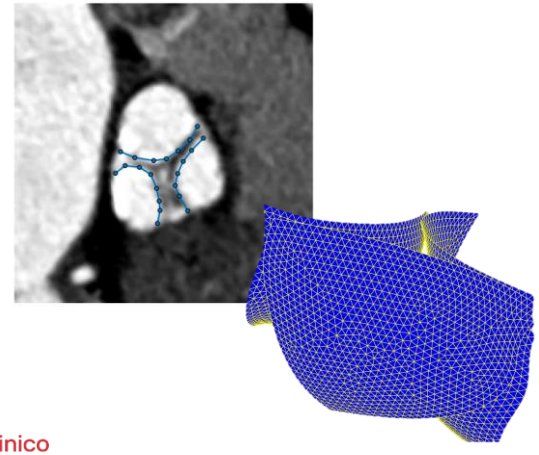
1. Marrocco-Trischitta et al. (2022)
2. Carr et al. (Am J Physiol Heart Circ Physiol, 2013)
3. Mukherjee et al (J Biomech Eng, 2016)

Contacts: Francesco Sturla (francesco.sturla@grupposandonato.it)
Simone Saitta (simone.saitta@polimi.it)
Selene Pirola (s.pirola@tudelft.nl)
Emiliano Votta (emiliano.votta@polimi.it)

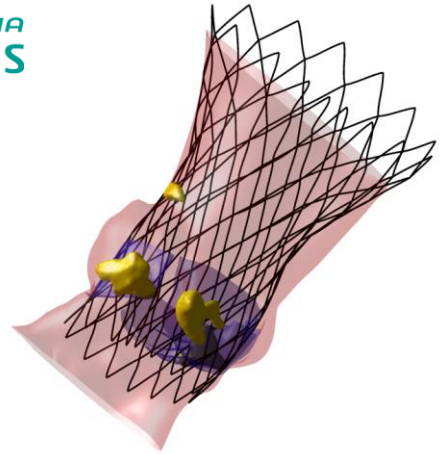
Time-efficient and user-friendly finite element modeling of TAVI for surgical planning

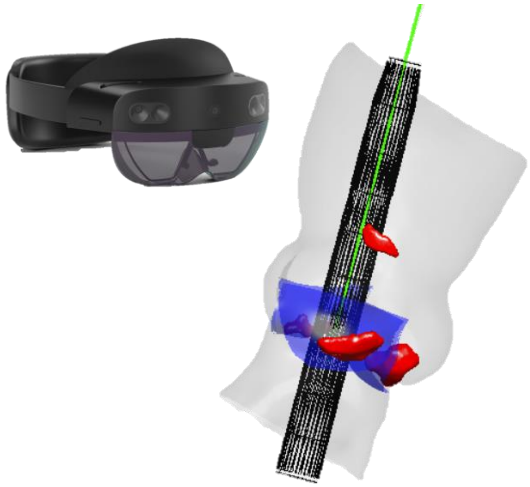
1. Designing and implementing the semi-automated segmentation of the native aortic valve from pre-op CT scans
2. Exploiting a previously developed Finite Element workflow to test the approach on a virtual population of
3. Building a user-fiendly VR/AR application for the positioning and visualization of the stent inside the
4. Building a user-friendly GUI to use segmentation and modeling tools

SOLD



SIMULIA ABAQUS





Collaborations

I.R.C.C.S. Policlinico San Donato

Background:

Belpiede, Master Thesis. A semi-automatic workflow for TAVI pre-procedural planning through finite element modelling : a time-saving approach. 2023

Contacts
Emiliano Votta
Davide Astori
Alessandro Albanesi
Davide Tondi

Patient-specific simulation of MV surgical repair based on 4D ultrasound imaging

Simulation of MV leaflet resection and non-rigid annuloplasty based on 4D ultrasound imaging

Activities

- Integrating pre-existing AI-based tools for automated MV segmentation into the workflow
- Automating the generation of the computational grid and of the image-based BCs
- Automated definition of patient-specific and heterogeneous tissue thickness patterns
- Modelling of MV leaflet tissue resection
- Modelling of non-rigid or incomplete MV annuloplasty
- Development of a GUI to manage the whole modelling process

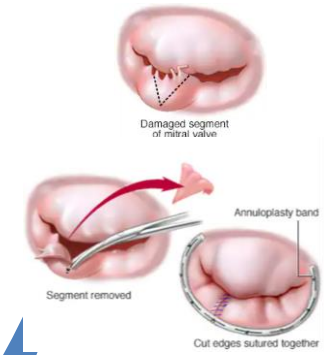
Collaborations

I.R.C.C.S. Policlinico San Donato

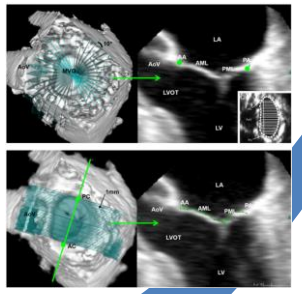
Background

1. Verma et al. *(New England Journal of Medicine, 2009)*
2. Aguilera et al. *(Journal of Biomechanics, 2022)*
3. Rego et al. *(International Journal for Numerical Methods in Bioengineering)*

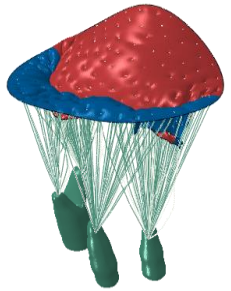
MV surgical repair

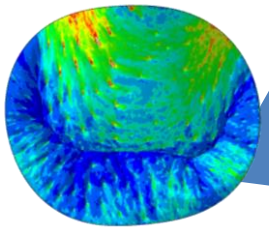


MV anatomy reconstruction



MV FE modelling of pre- and post-surgery biomechanics





Contacts

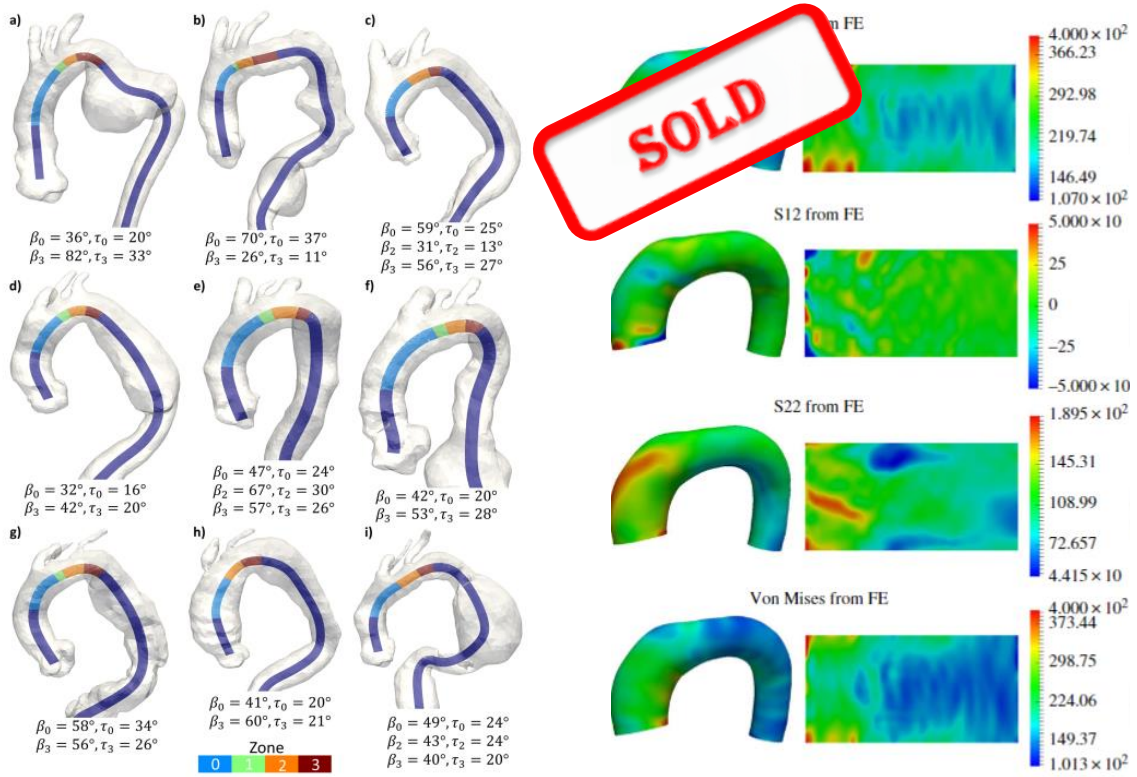
Emiliano Votta
Francesco Sturla
Davide Tondi

Large scale finite element analysis for the creation of a virtual population of thoracic aortas

1. Developing a robust and automated FEA setup for simulating a large number (N>500) of patient-specific cases, including pre-stress and hyperelastic constitutive models.

2. Adapting and applying a previously developed geometric analysis pipeline to extract relevant morphological features of the thoracic aorta.

3. Testing statistical correlations between aortic geometry and stress/strain fields.



Background:

1. *Liang et al.* (*J of the Royal Society, 2018*)
2. *Saitta et al.* (*JDIM, 2022*)

Contacts

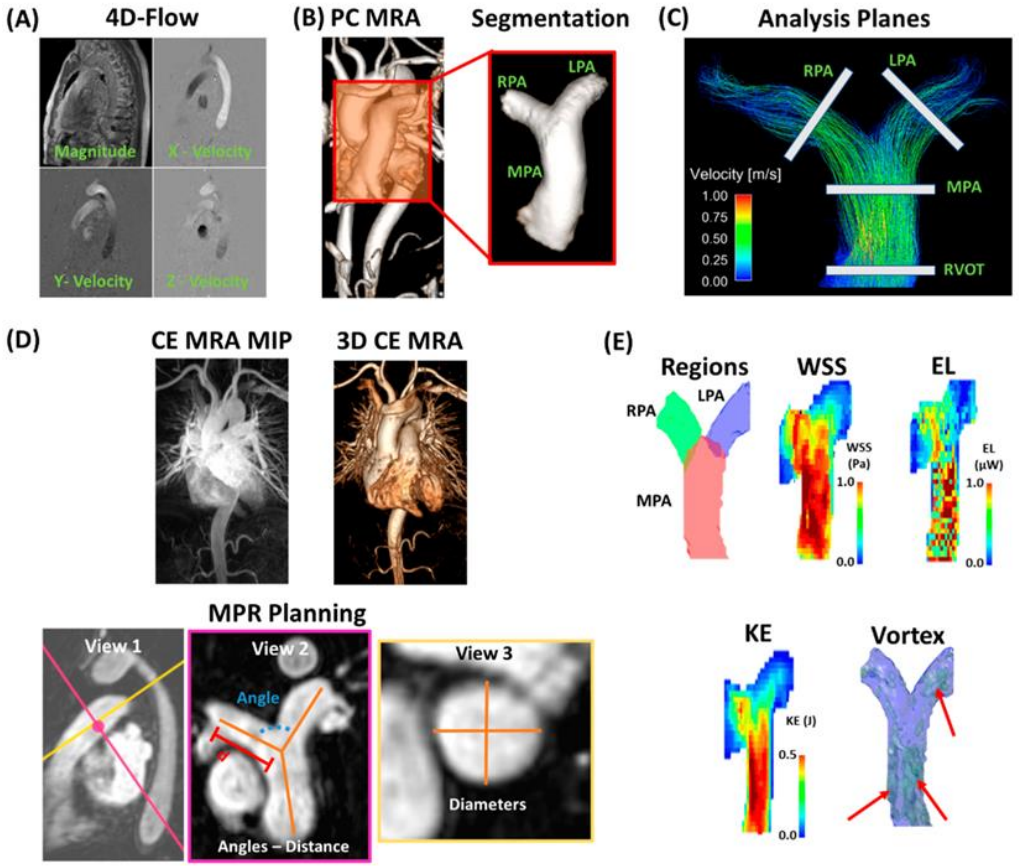
Simone Saitta
Emiliano Votta
Alberto Redaelli

Fluid dynamic analysis of the pulmonary artery in Tetralogy of Fallot patients through 4D Flow MRI

1. Designing and developing a MATLAB graphical user interface for the segmentation of the pulmonary artery

2. Implement the computation of advanced hemodynamic parameters for the study of the pulmonary artery

3. Test the developed methods for the analysis on Tetralogy of Fallot patients and healthy controls



Collaborations

I.R.C.C.S. Policlinico San Donato

Background:

1. *Hong & Garcia (Applied Sciences, 2022)*
2. *Tsuchiya et al. (Sci Rep, 2021)*

Contacts

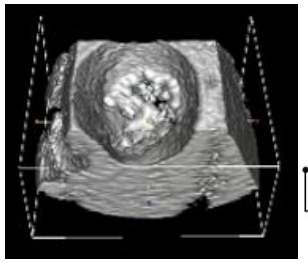
Alessandra Riva

Catheter Localisation Framework in Echocardiography Based on Deep Learning

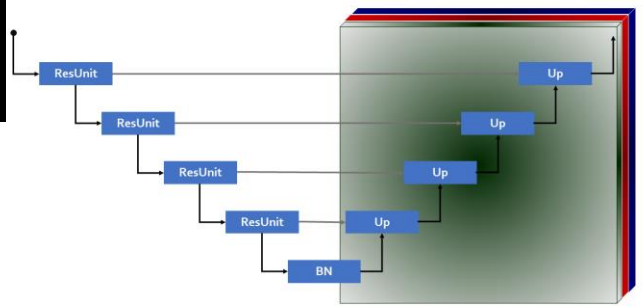
Primary aims

- Training and testing AI neural network for automatic localisation of catheter and percutaneous devices from 3D transesophageal echocardiography (3DTEE) image
- Clinical use-cases: percutaneous mitral valve repair with MitraClip, and percutaneous left atrial appendage (LAA) closure

TEE volumes



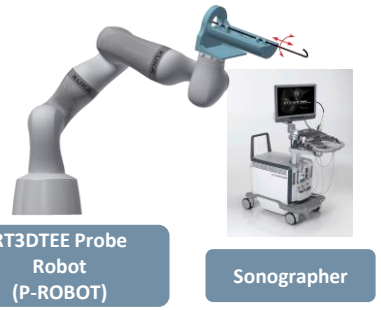
3D NN



MitraClip

LAA occluder

- DL-based tracking method can be combined with external method, e.g Electromagnetic tracking, to **offer a novel solution to identify the moving medical device** and be used in **robotic platforms**



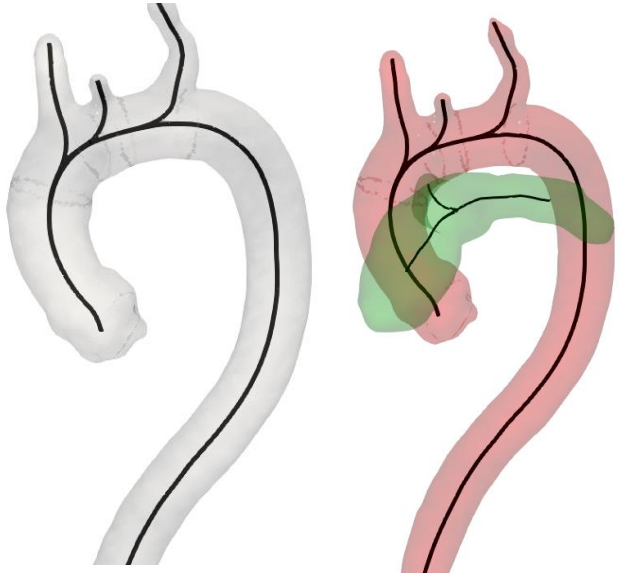
Background:
Jia et al., (medRxiv, 2022)

Contacts:
Riccardo Munafò (riccardo.munafo@polimi.it)

Large vessel 3D segmentation from non contrast enhanced MRI

Primary aims

- To train a neural network for 3D semantic segmentation of vascular structures from novel MRI sequences.
- To investigate transfer learning and image inpainting techniques leveraging models pre-trained on different imaging modalities.
- To implement a standalone image post-processing module that can be integrated within an existing software development framework.



Collaborations

SIEMENS Healthcare

Background:

Saitta S, et al. A deep learning-based and fully automated pipeline for thoracic aorta geometric analysis and planning for endovascular repair from computed tomography. Journal of Digital Imaging. 2022 Apr;35(2):226-39.

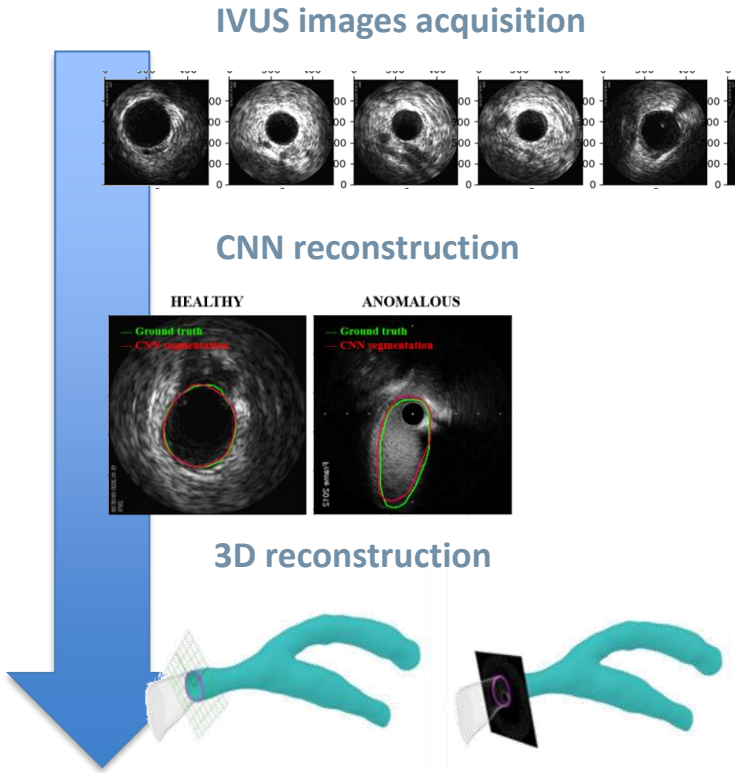
Contacts:
Simone Saitta (simone.saitta@polimi.it)

AI-based characterization and reconstruction of coronary arteries from Intravascular Ultrasound (IVUS) images

Implementing a deep learning model for the segmentation of coronary arteries from IVUS images and co-register it to coronary centerlines for 3D reconstruction

Activities

- Implementing and training a deep convolutional neural network (CNN) for the automated segmentation of coronary cross section
- Implement an automated algorithm for the co-registration of the segmented slices on coronary centerlines (extracted from computed tomography (CT))
- Test the implemented method's 3D reconstruction versus CT/angiography reconstruction
- Characterizing the reconstructed geometries based on coronary morphology (e.g. stenosis, anomalous congenital shaping…)



Collaborations

Centro Cardiologico Monzino

Background

1. *Wu et al.* (Scientific Reports, 2023)

Contacts

Guido Nannini (guido.nannini@polimi.it)
Simone Saitta (simone.saitta@polimi.it)
Alberto Redaelli (alberto.redaelli@polimi.it)

3D segmentation and morphological analysis of glioblastoma and cerebral vessels from MRI

Primary aims

- To train a neural network for 3D semantic segmentation of glioblastomas and cerebral vasculature from MR images.
- To extract complex radiomics features for classification and risk stratification.

Collaborations

Fondazione I.R.C.C.S.
Istituto Neurologico Carlo Besta

Background:

Palumbo MC, et al. Mixed Reality and Deep Learning for External Ventricular Drainage Placement: A Fast and Automatic Workflow for Emergency Treatments. International Conference on Medical Image Computing and Computer-Assisted Intervention 2022

Contacts:

Simone Saitta (simone.saitta@polimi.it)

Last but not least: policy

Starting your thesis

- **No specific enrollment criterion (as, e.g., mean mark>27, mandatory background)**
- **1 month test period –** once you pick a thesis project, we'll test you over a month. You'll be asked to complete tasks that will tell us about your capability to acquire and apply skills that are relevant to the project. In this period, somehow, you'll test us as well.
- Advice for Prof. Votta projects: although not mandatory, it could be a good idea to select a project **when you have the time to start working** on it or at least to work on the test period

During your thesis

- **Build knowledge and competences** (with our help)
- **Become independent and become the expert** of your project topic

Ending your thesis

- **You decide when and how to tackle the final defense** (we can advise you, but you have the last word)
- **Start thesis review at least 1 month before the deadline for the thesis upload –** otherwise, your menthor cannot guarantee to provide you with a proper review in due time