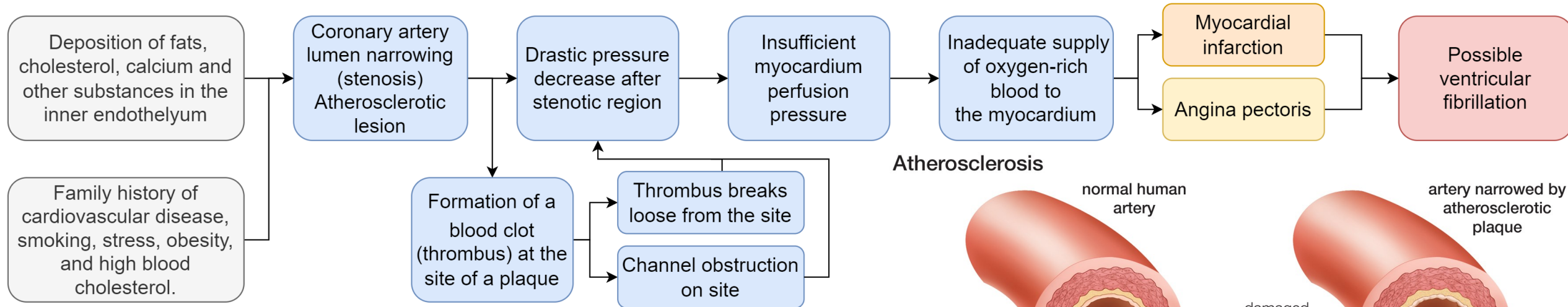**Neuroengineering A.Y. 2023/24**
PW 3
MAPPING VESSELS AND HEART CORONARY ARTERIES FROM CCTA IMAGES FOR CORONARY HEART DISEASE DIAGNOSIS

Tutor: Matteo Leccardi (matteo.leccardi@polimi.it)
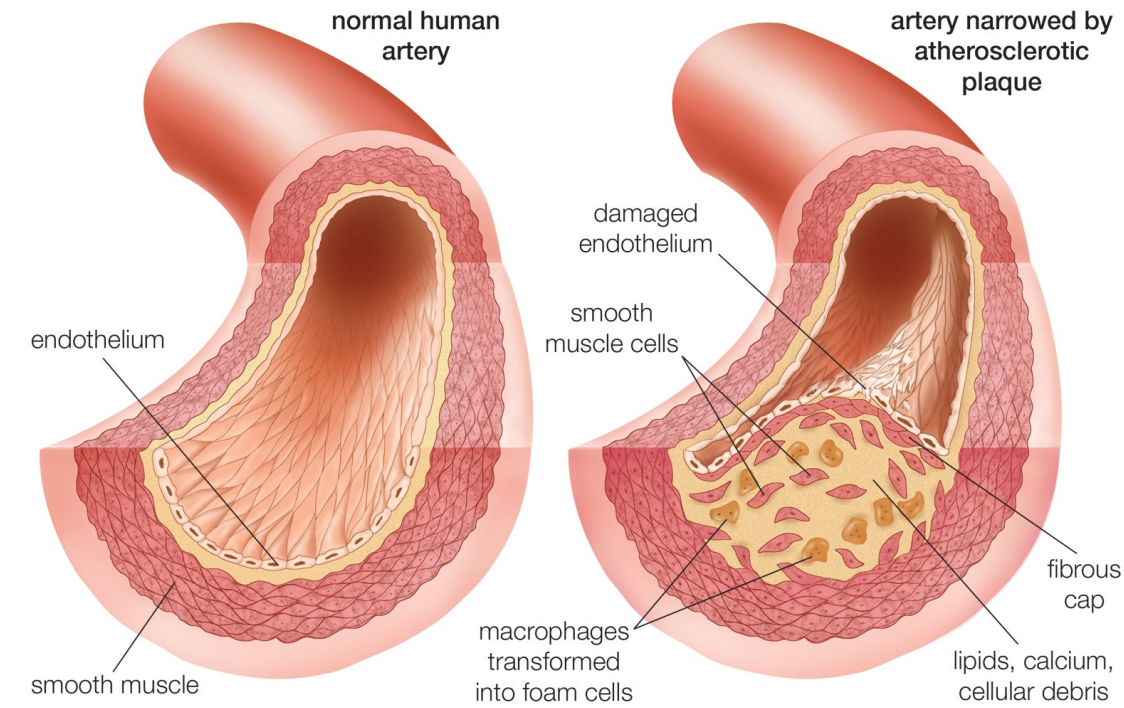
Supervisor: Prof. Pietro Cerveri

Background

Coronary Artery Disease (CAD) leading single-cause of death worldwide.

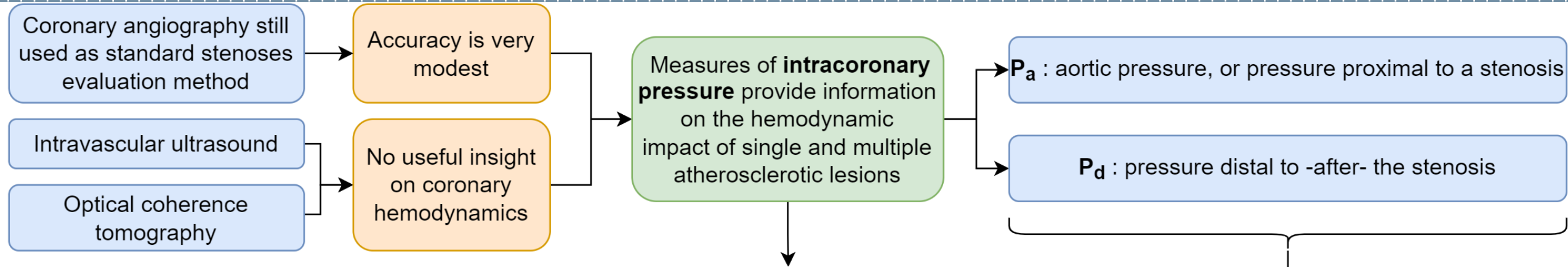Cardiovascular disease accounted for approximately 19.05 million global deaths in 2020.
Cardiovascular disease accounted for 874'613 deaths in the United States in 2019, 41.3% of which from Coronary Artery Disease.

Deposition of fats, cholesterol, calcium and other substances in the inner endothelyum

Family history of cardiovascular disease, smoking, stress, obesity, and high blood cholesterol.

Coronary artery lumen narrowing (stenosis) Atherosclerotic lesion

Formation of a blood clot (thrombus) at the site of a plaque

Thrombus breaks loose from the site

Channel obstruction on site

Drastic pressure decrease after stenotic region

Insufficient myocardium perfusion pressure

Inadequate supply of oxygen-rich blood to the myocardium

Myocardial infarction

Angina pectoris

Possible ventricular fibrillation

Atherosclerosis

normal human artery

artery narrowed by atherosclerotic plaque

endothelium

smooth muscle

damaged endothelium

smooth muscle cells

macrophages transformed into foam cells

fibrous cap

lipids, calcium, cellular debris

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Coronary angiography still used as standard stenoses evaluation method

Intravascular ultrasound

Optical coherence tomography

Accuracy is very modest

No useful insight on coronary hemodynamics

Measures of **intracoronary pressure** provide information on the hemodynamic impact of single and multiple atherosclerotic lesions

P_a : aortic pressure, or pressure proximal to a stenosis

P_d : pressure distal to -after- the stenosis

Fractional Flow Reserve (FFR)

$$FFR = P_d/P_a$$

(under hyperemia condition)

FRACTIONAL FLOW RESERVE

INDEX (FFR)

Used for invasive, hemodynamically informative assessment of severity of coronary stenosis

P_a = Aortic Pressure with a Guide Catheter

Blood flow

P_d = Distal Coronary Pressure with the Pressure Guidewire

FFR

0   0.8   1

Stenosis is **hemodynamically significant**

Stenosis is irrelevant

PROBLEM

The FFR measurement is invasive, risky, requires a considerable degree of training resources

SOLUTION

Use contrast-liquid enhanced CT images instead (CCTA)

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Coronary Computed Tomography Angiography
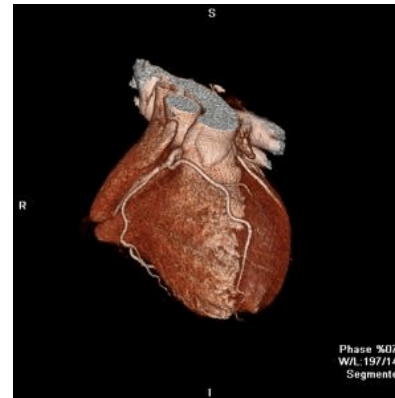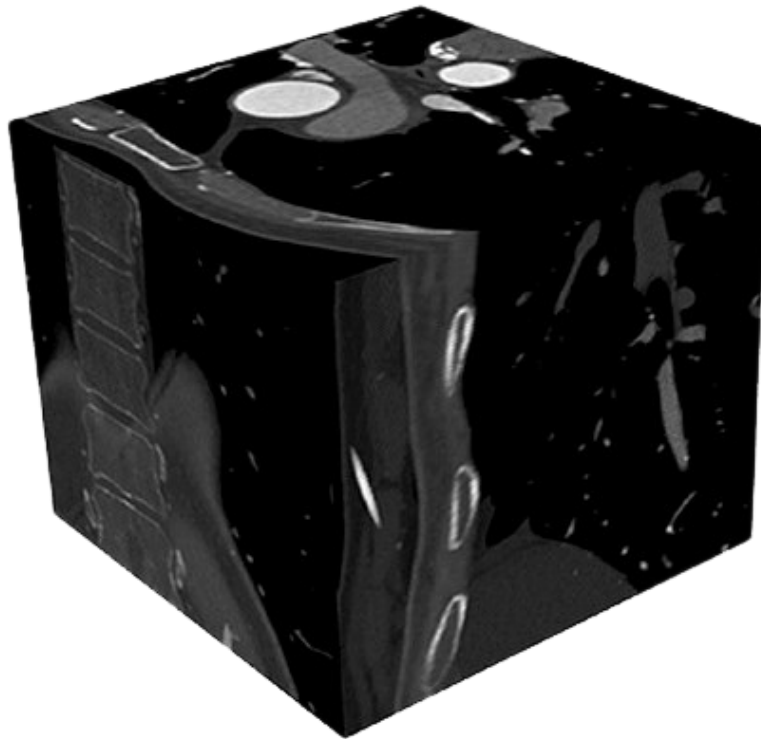
Coronary Computed Tomography Angiography images are obtained from an X-ray CT scan.

Coronary blood vessels are made visible by a **contrast liquid** injected in the arterial blood flow.

Adenosine is typically used to induce maximum **hyperemia condition** (maximum dilation of the blood vessels).

CCTA images are widely used to **assess the severity** and characteristics atherosclerotic plaque and lesions.

Computation Fluid Dynamic methods

Deep Learning methods
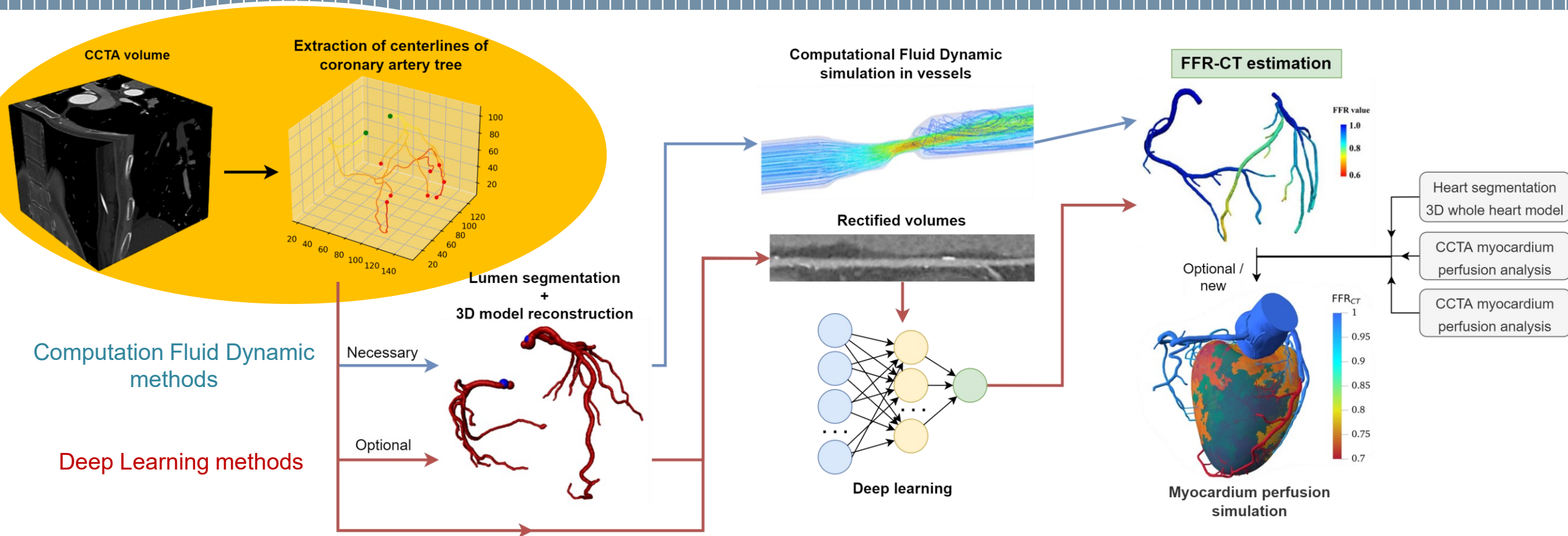
FFR-CT allows non-invasive assessment of the severity of stenoses and Coronary Artery Disease

Multiplanar Reformatted Volume (MRV) visualization

CCTA volume

Extraction of centerlines of coronary artery tree

Final connected centerline graph
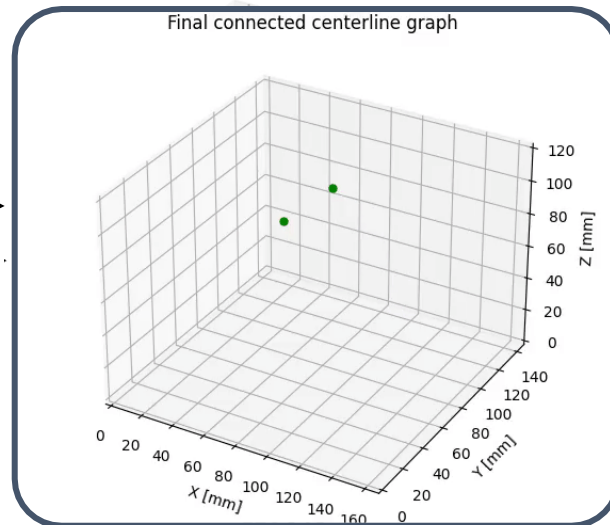
Classic application

New application

Slices ❌

Slices ❌

MRV ✅
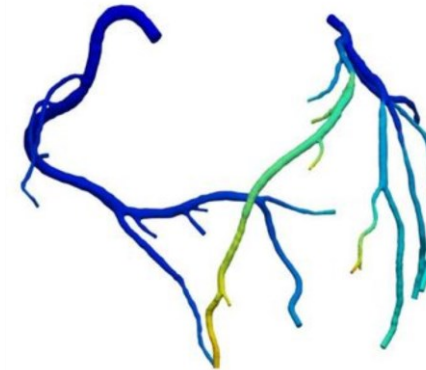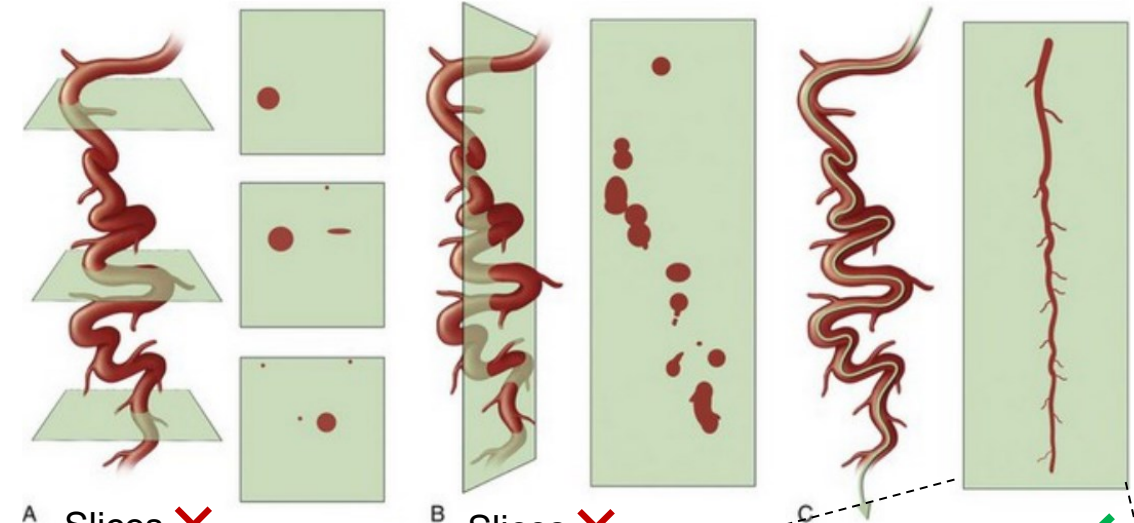
FFR value

FFR-CT estimation in subsequent algorithms

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CORONARY ARTERY TRACKING PIPELINE
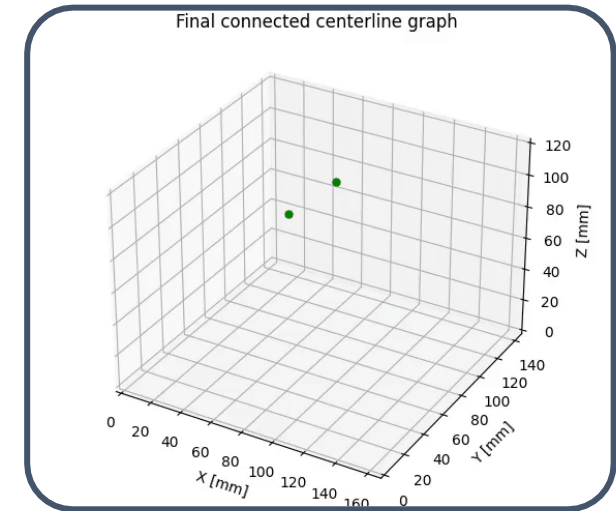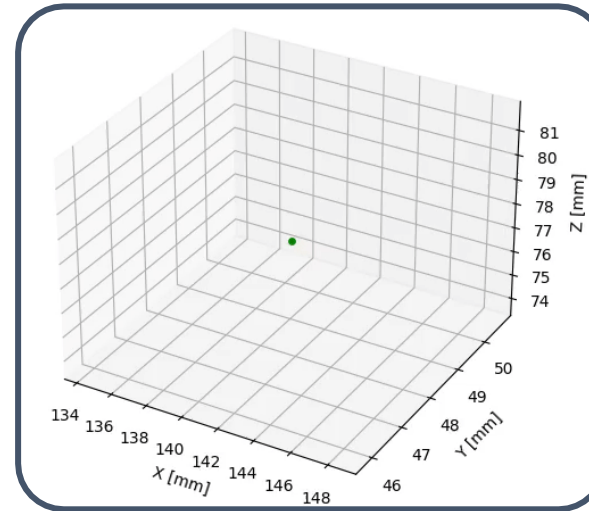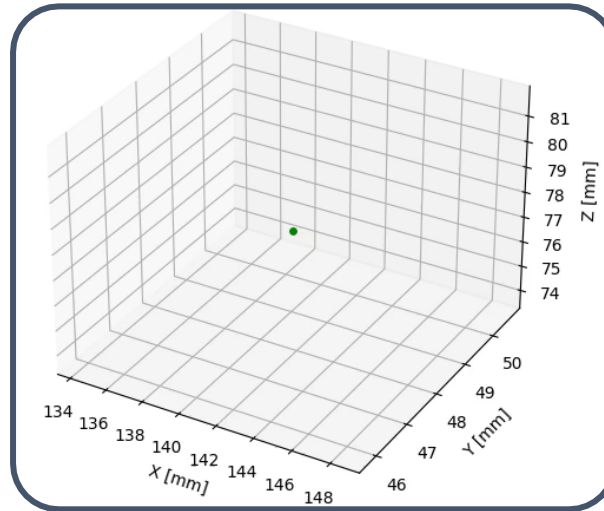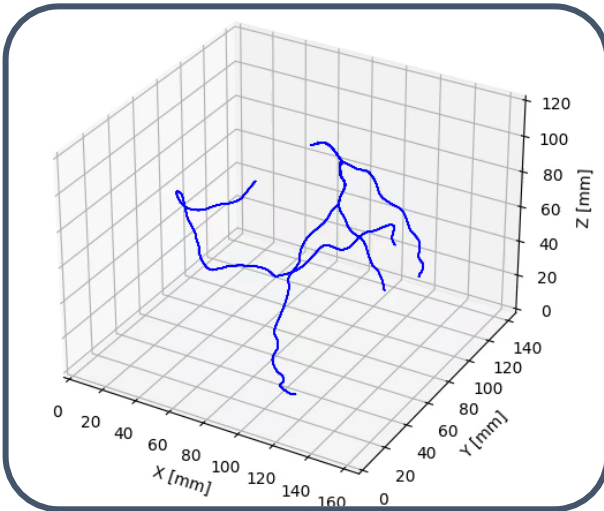
MANUALLY SET THE STARTING POINTS

FOLLOW ONE DIRECTION, THEN THE OTHER
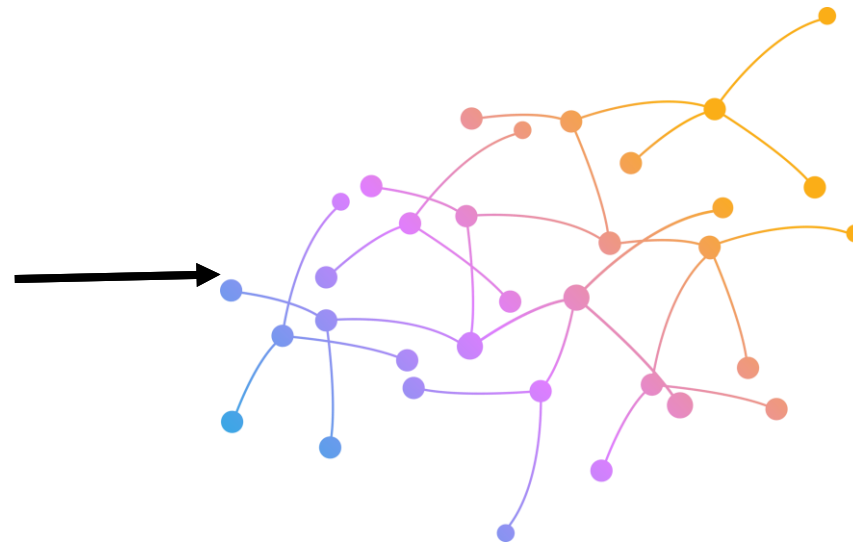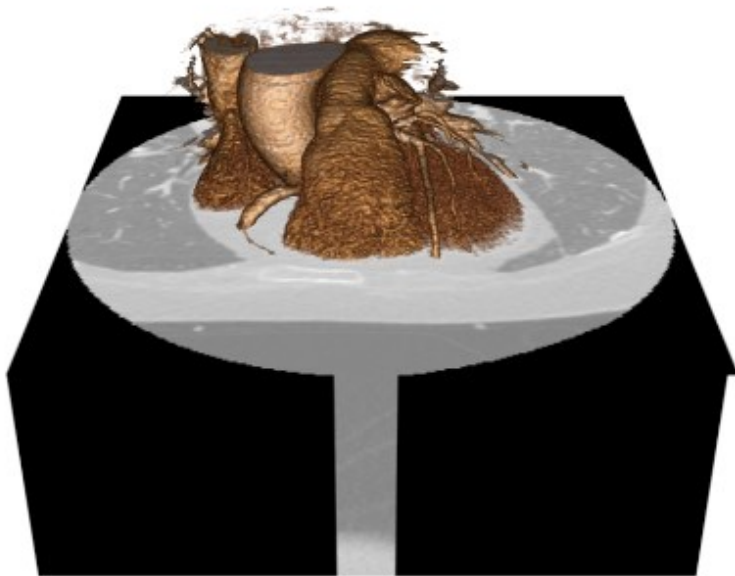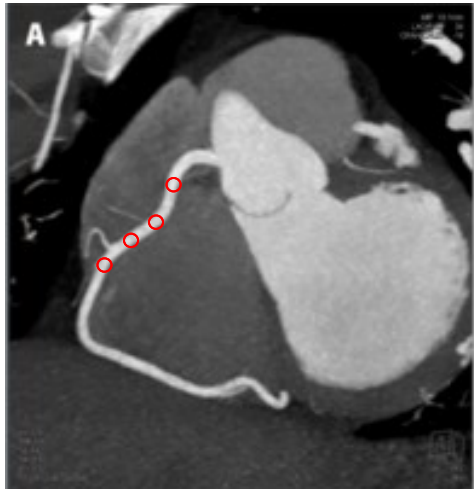
START TRACKING IN 2 DIRECTIONS

END RESULT

USE DEEP LEARNING TO DEVELOP THE BUILDING BLOCKS OF THIS COMPLEX PIPELINE
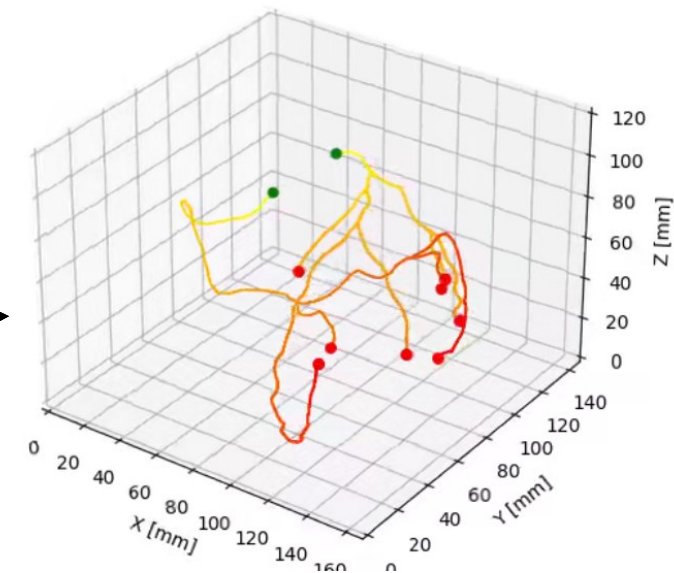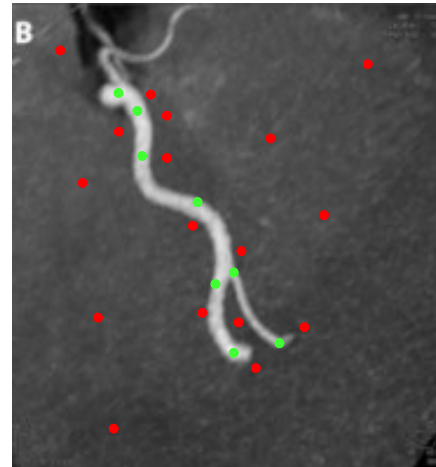
EACH GROUP SHOULD DEVELOP, TRAIN AND TEST A NEURAL
NETWORK (**CONVOLUTIONAL** OR **IMAGE TRANSFORMER-LIKE**)
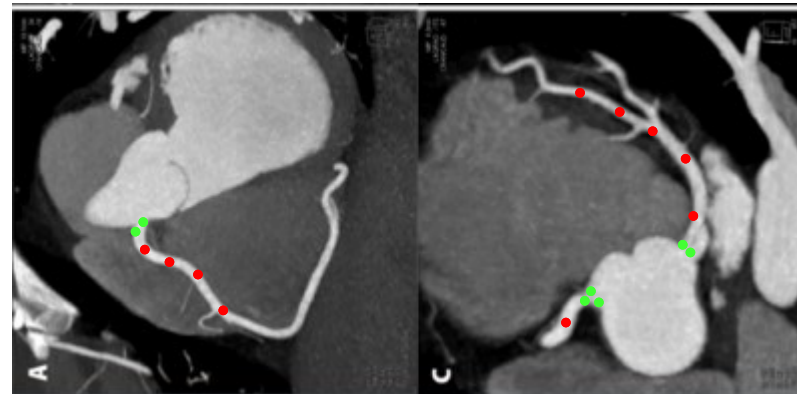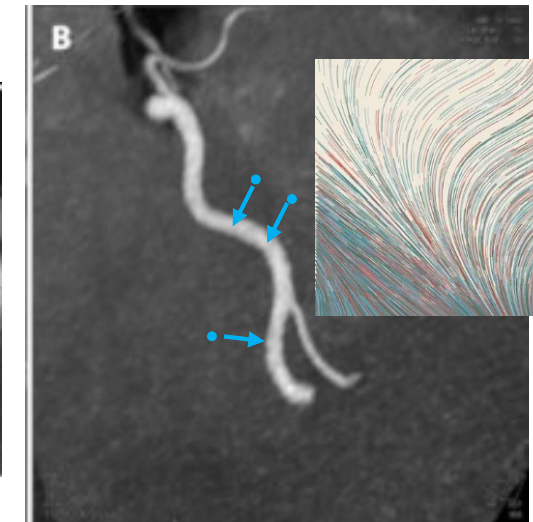TO EITHER:

REGRESSION OF THE ARTERY LUMEN RADIUS

BINARY CLASSIFICATION ON POINT BELONGING TO ARTERY OR NOT

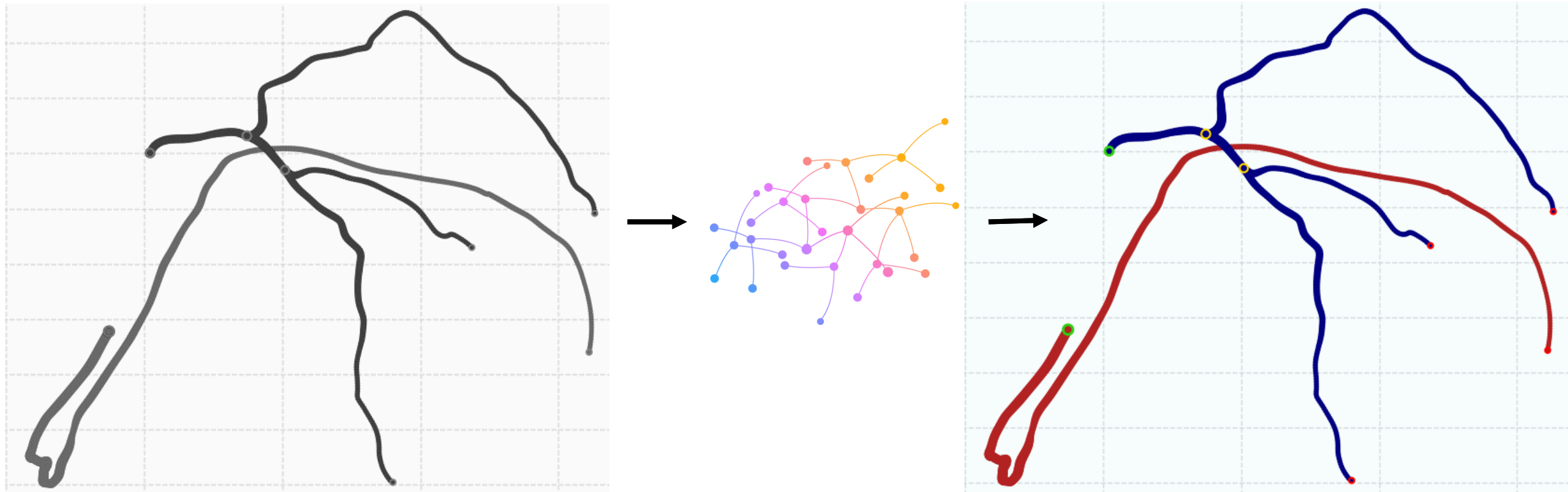POINT IN ARTERY BELONGING TO THE CORONARY OSTIUM

DISPLACEMENT VECTOR PREDICTION TOWARDS NEAREST CENTERLINE

Extra project for an extra challenge

ARTERIAL TREE CLASSIFICATION VIA SPECTRAL CONVOLUTION GRAPH NEURAL NETWORK

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DATA

THE DATASETS, AN EXAMPLE CODE ON HOW TO USE THE READY-MADE INSTRUMENTS AND FURTHER REFERENCES FOR THE EXTRA PROJECT WILL BE DELIVERED ON WEBEEP

DATA WILL BE SHARED ON ONEDRIVE, YOU WILL FIND THE LINK ON WEBEEP IN THE "DATA" FOLDER OF OUR SUB-PROJECT

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GROUPS FORMATION

GROUPS WILL BE FORMED BY THE TUTOR

A FORM WILL BE HANDED TO YOU TO BE FILLED

GROUPS WILL BE COMMUNICATED TO YOU BY EMAIL AND AFTERWARDS ON THE CORONARY ARTERY WEBEEP FORUM.

https://forms.office.com/Pages/ResponsePage.aspx?id=K3EXCvNtXUKAjjCd8ope60oQFO5WWyVAh9DpGOL8bzVUMVRIUEVWVEtFSjRINjQ4NTRCR0tXMEM5WC4u

(SUBSCRIBE TO THE PROJECT WORKSHOP FORUM, THIS IS WHERE I'LL HAND DOWN INFORMATION AND THE DETAILED TIMETABLE