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Segmentation of Coronary Arteries from X-ray Angiography Sequences During Contrast Fluid Propagation by Image Registration

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Motivation

- **Angina** is chest pain caused by lack of oxygen to the heart
- Angina can be a symptom of possible stenosis (blockage of an artery)
- Angina can occure due to dysfunction in the microvascular system - **Syndrom X**
- Different diagnoses require completely different treatment.

***SYNDEX,* The *Syndrome X-ercise* study**

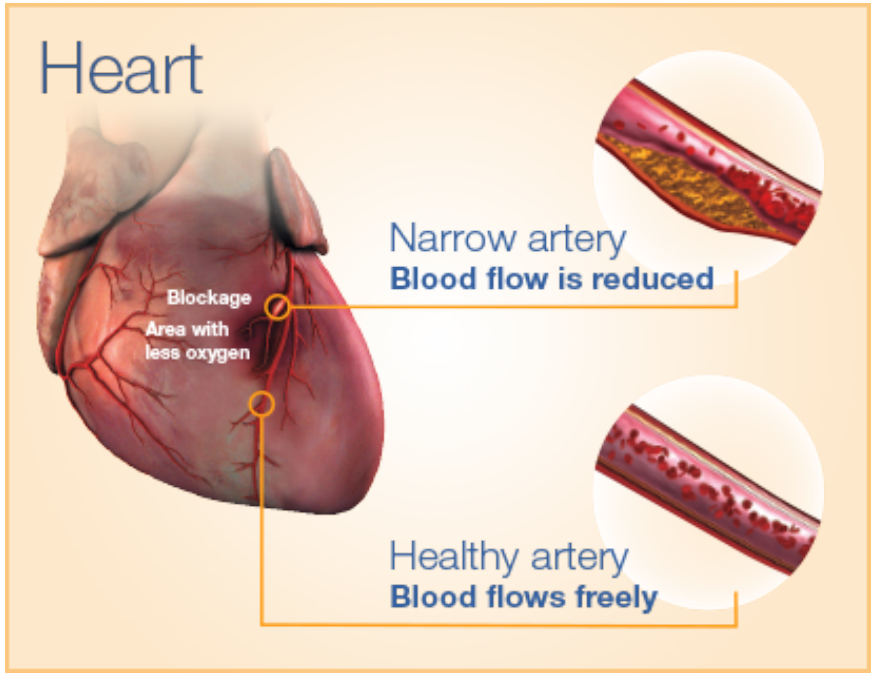

Photo from:
https://medlineplus.gov/ency/article/000201.htm

Assessment of angina by X-ray angiography

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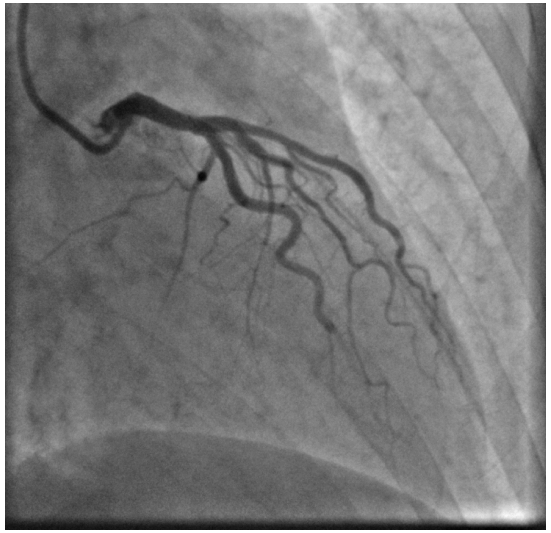
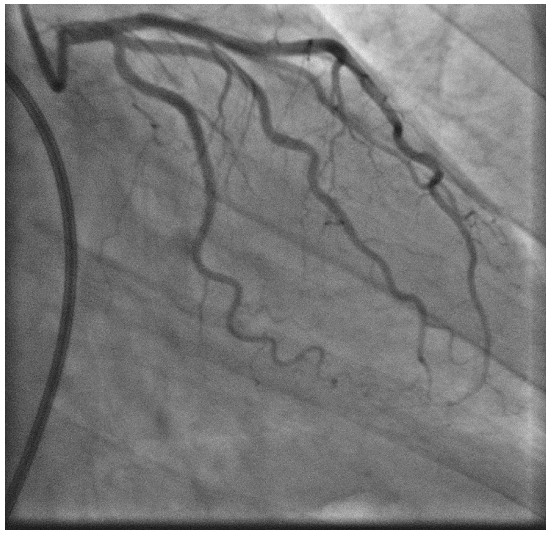
- X-ray angiography is commonly used (invasive)
- In syndrom X patients – no visible stenosis. But a slow blood velocity due to the malfunction in the microvascular system

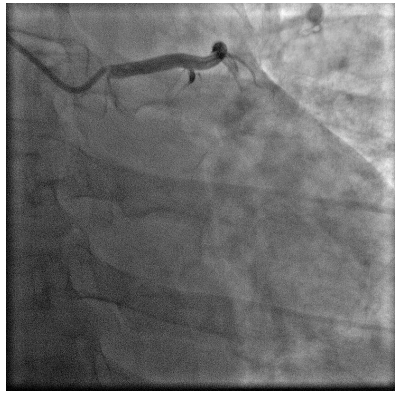
- Would like to estimat the **coronary flow reserve (CFR)**: ratio between resting and maximal possible blood flow in the coronary arteries – indication of Syndrom X.
- Need to estimate the blood velocity in the coronary vessels
- First need to segment the coronary vessels

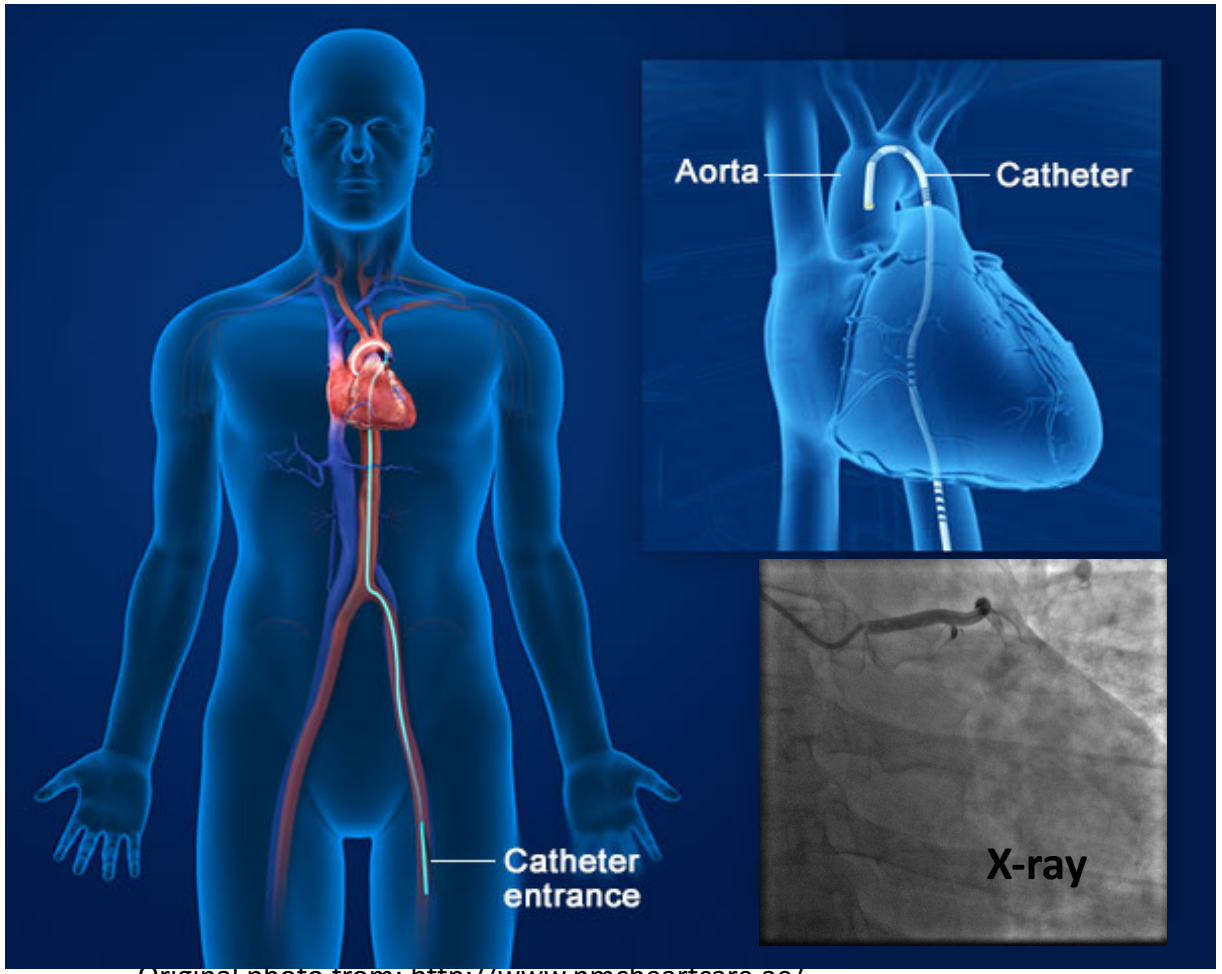




SYNDEX data: 2D + time X-ray angiography

- Angiograms from patients (N=11) were obtained at the invasive cardiology department of Stavanger university hospital
- All procedures were performed using a GE coronary angio laboratory using Iomerone 350 contrast dye.
- Videos are not synced with the heart beats.





Original photo from: http://www.nmcheartcare.ae/

Other approaches

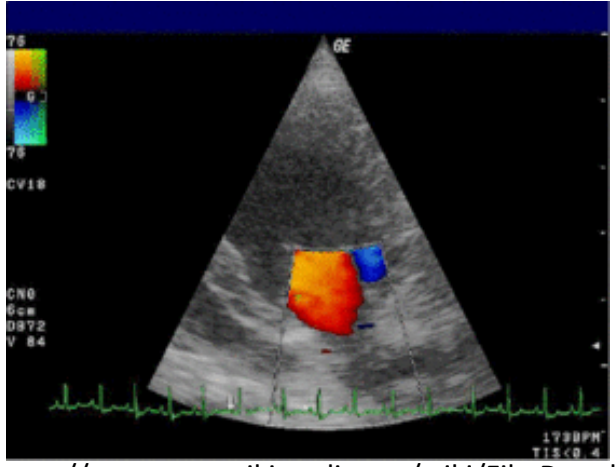
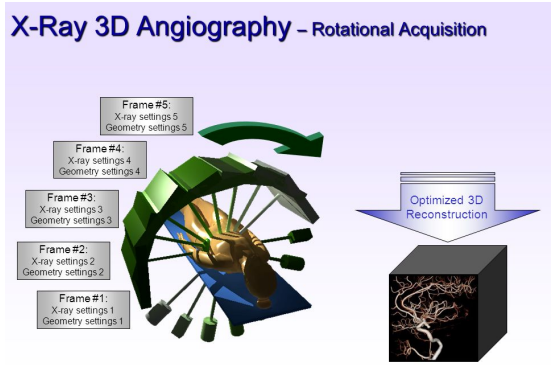


Photo from: https://commons.wikimedia.org/wiki/File:Doppler_mitral_valve.gif

- Doppler echocardiography
- 3D rotational x-ray Angiography
- Ct- Angiography



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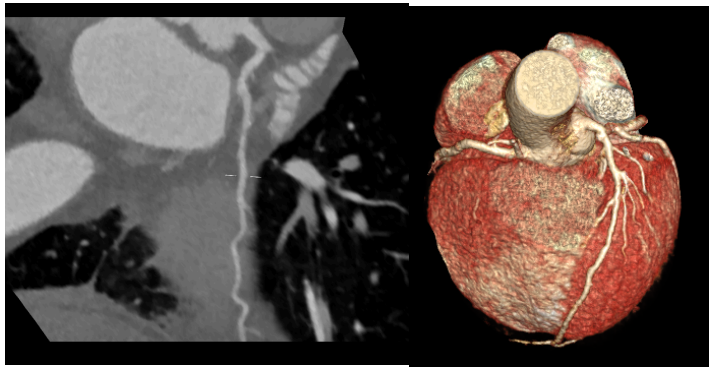
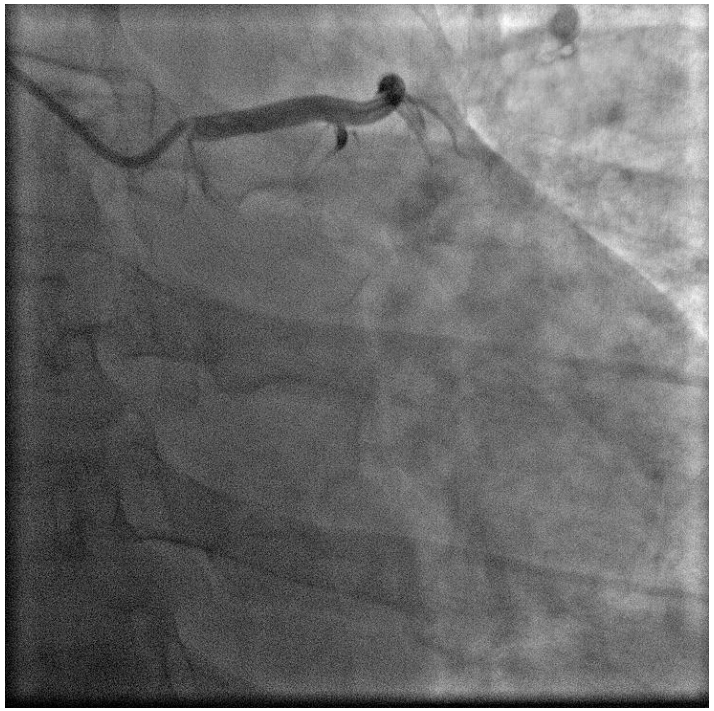


Segmentation of X-ray angiography

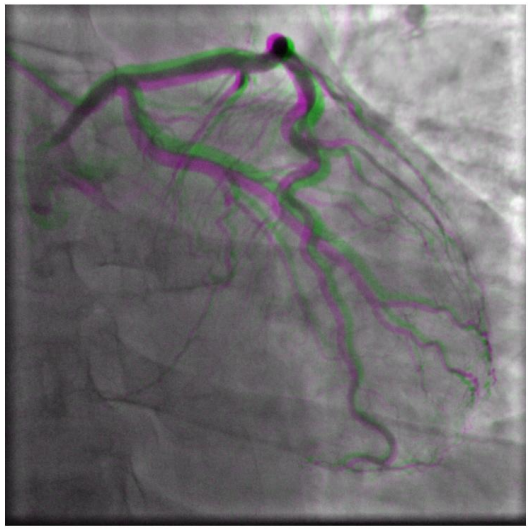
- Most published work on segmentation of the coronary tree from X-ray angiography are 2D image segmentation after the dye is fully propagated. This gives no information on the blood velocity

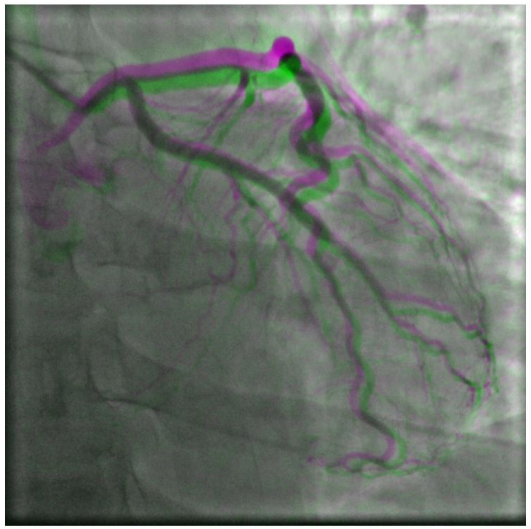
- Segmenting in 2D+time is challenging since there are movement of the heart (uninteresting) in addition to the movement of the contrast dye (ineteresting)



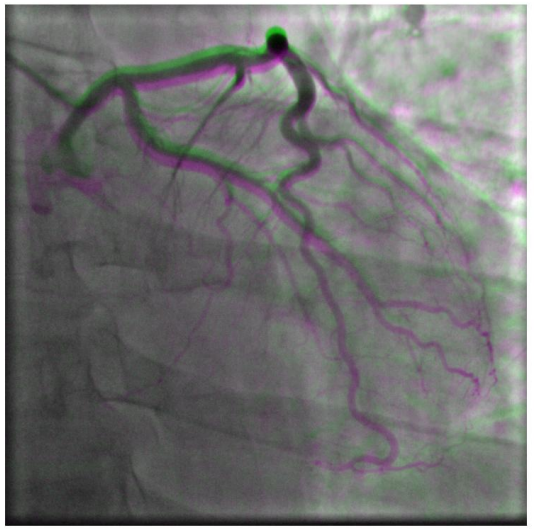
Challenges

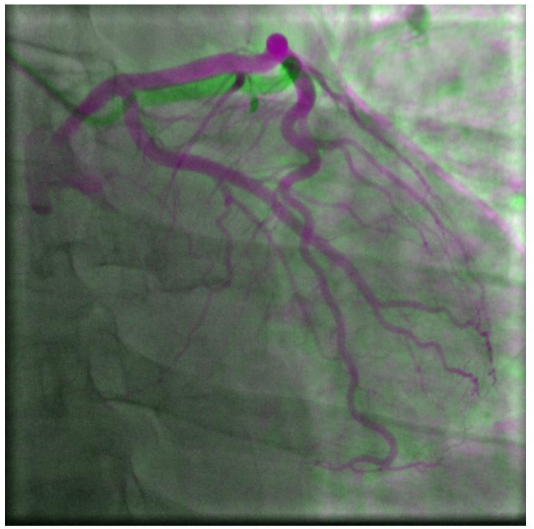
Heart motion (expansion and contraction during a hear beat)



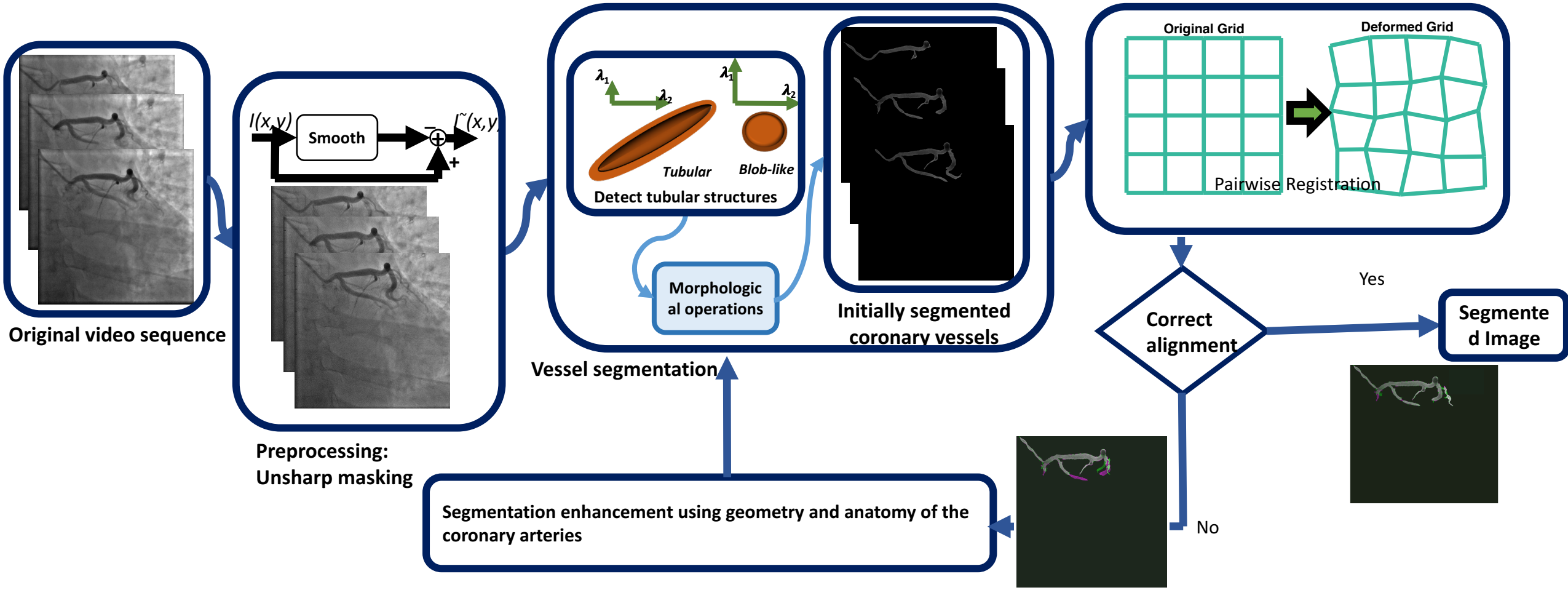


Dye propagates through the vessels; Dye movement





Proposed Segmentation algorithm

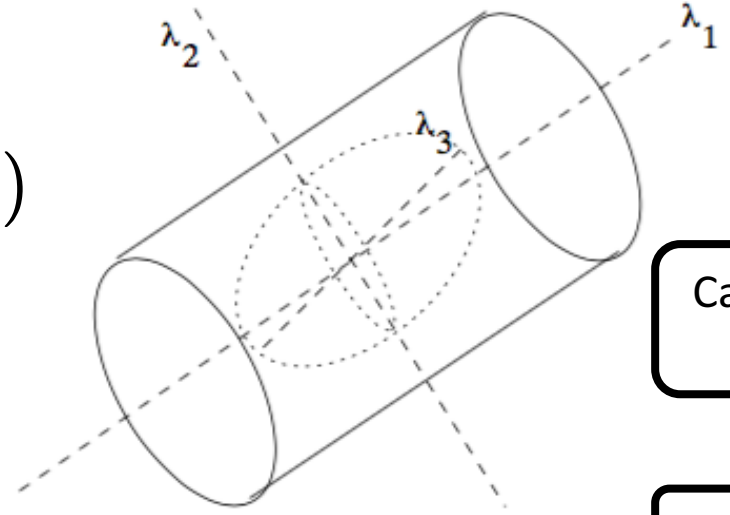


Frangi Hessian Filter

$$I = (e^{-\frac{R_B}{2\beta^2}})(1 - e^{-\frac{s^2}{2c^2}})$$

$$S = \sqrt{\sum_{j \leq D} \lambda_j^2}$$

$$R_B = \frac{\lambda_1}{\lambda_2}$$



β = 0.5
The value of the threshold c depends on the grey-scale range of the image and half the value of the maximum Hessian norm has proven to work in most cases.

X-ray Image

Calculate the Hessian (second order gradients) of the image in different scales (Sigmas)

Measure the eigenvalue and eigenvectors

Compute similarity measures:
1) Deviation from a blob-like structure (R_B)
2) Distinguishing between background and foreground (S)

Filter the image according to the similarity measures based on the eigenvalues.

Image Registration:

Find a spatial transformation that matches two images.

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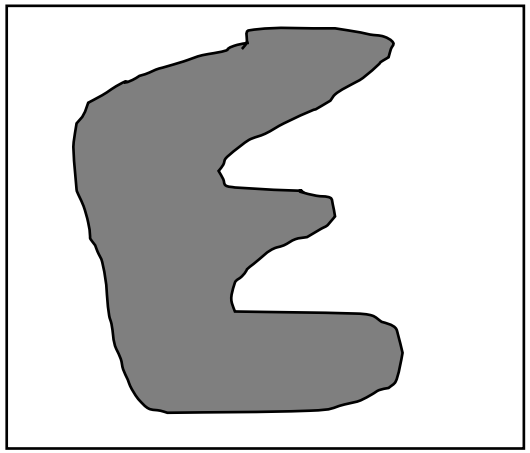
Image1



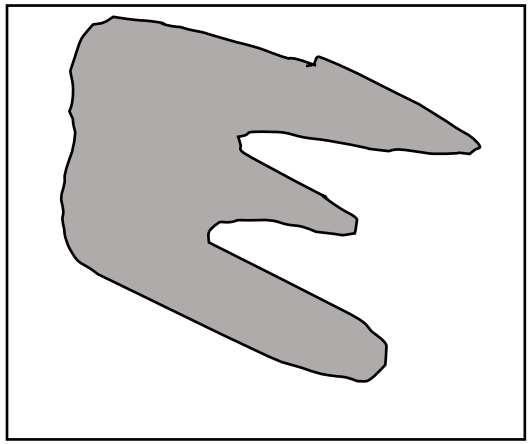
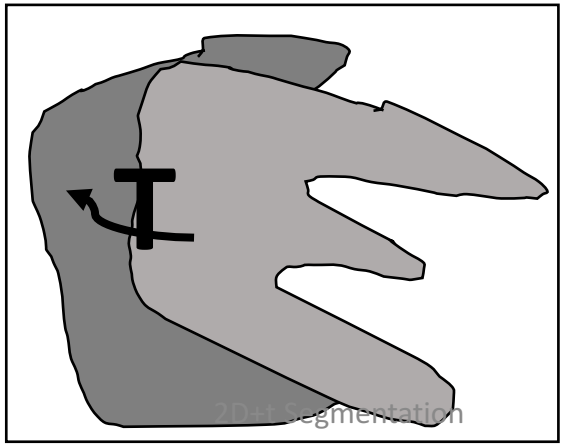


Image2



Free-form registration in angiogram videos

- **Global:** Affine Registration (transformation with 12 degrees of freedom, describing the rotations, translations, scaling, and shearing of the heart is used.)

- **Local:** The local deformation of the arteries can vary significantly across patients and also from larger to smaller vessels. Thus, free-form deformation based on B-spline is chosen.

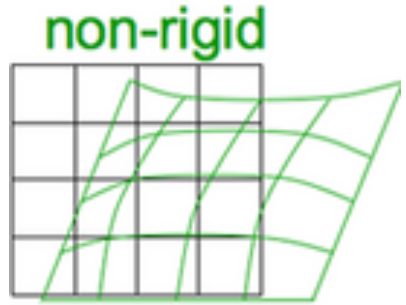
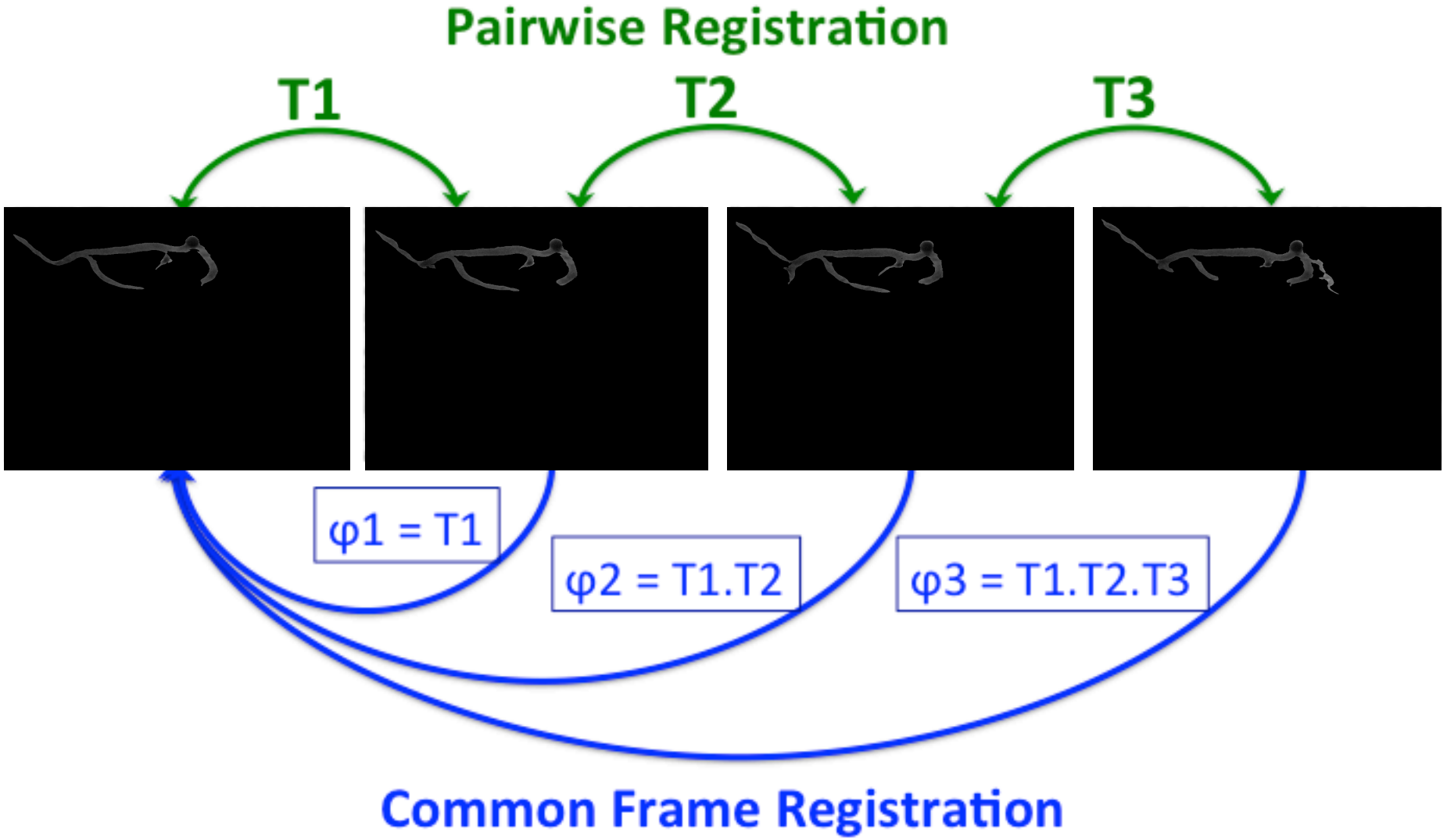


Image registration



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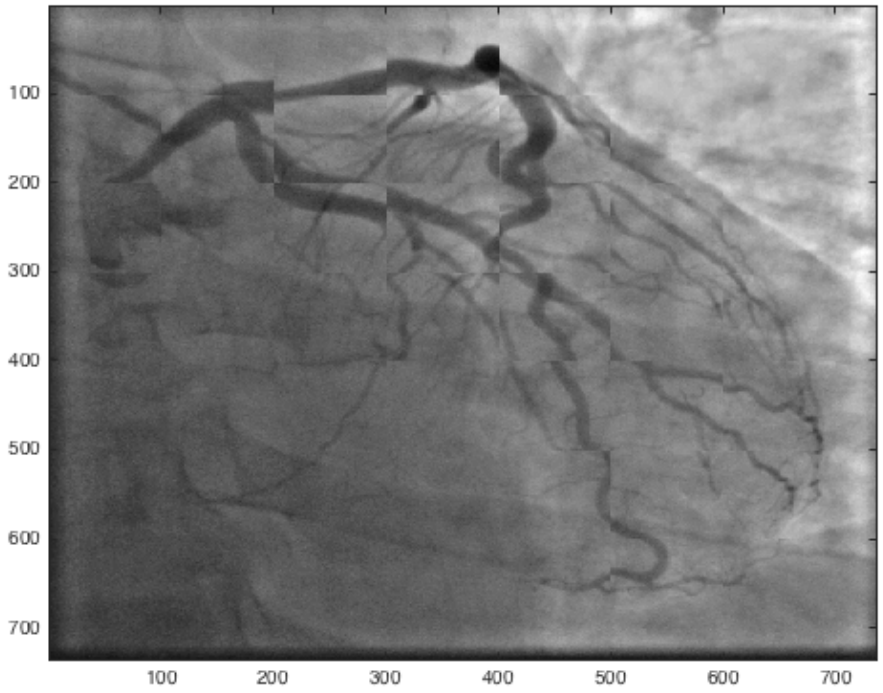
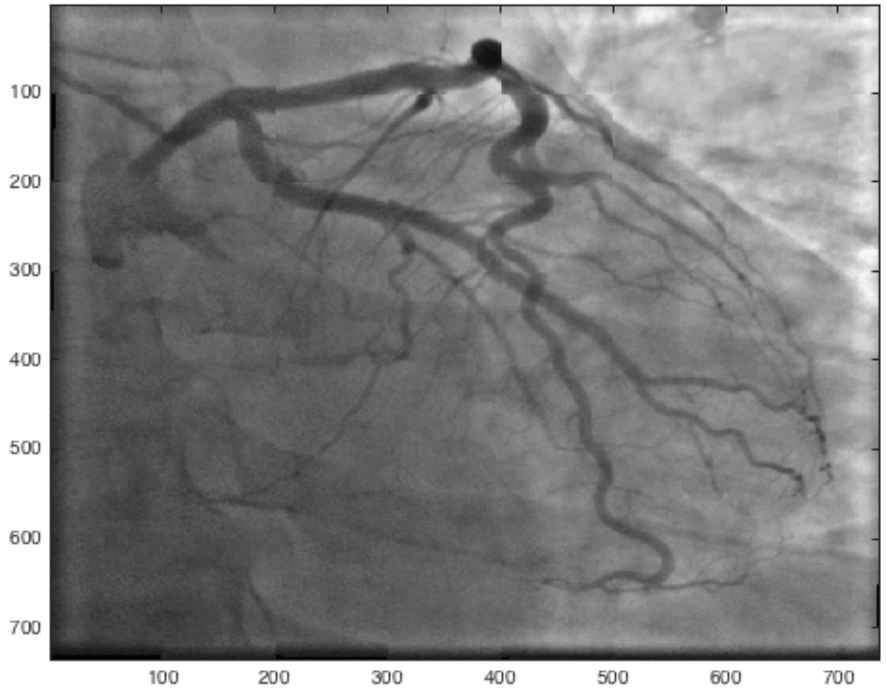
Registration results in our images

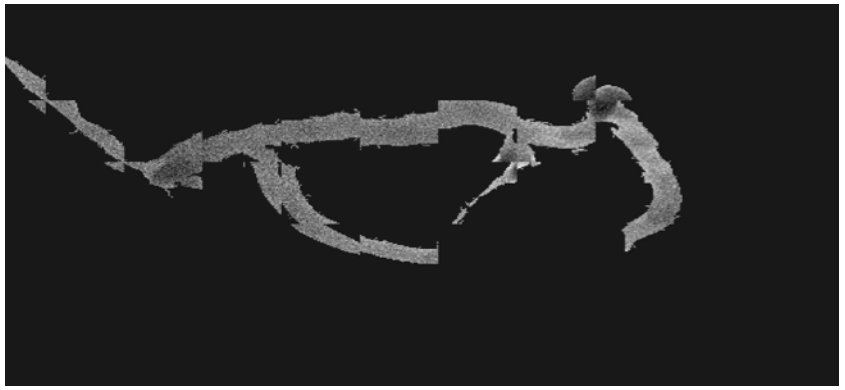


Before

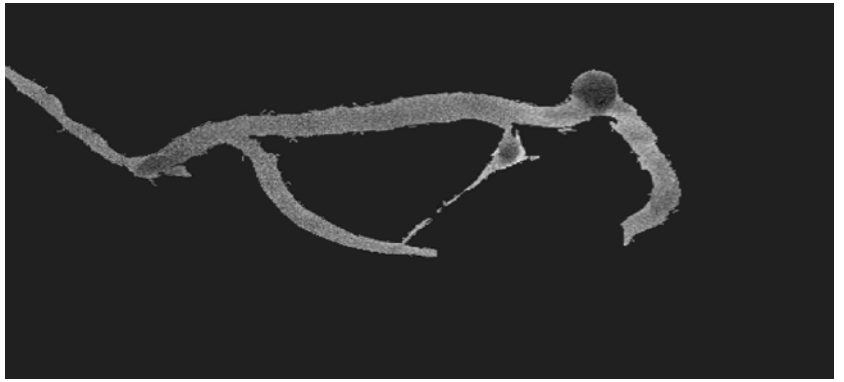


After

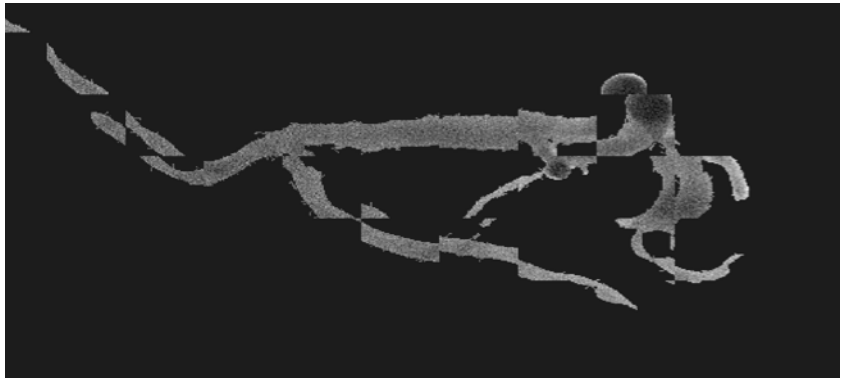
Registration results in our images



F_{t5} & F_{t6}

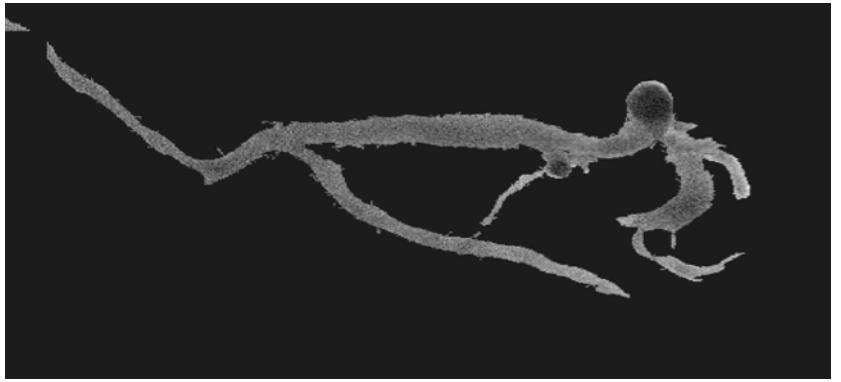


F_{t5} & F_{t6}



F_{t9} & F_{t10}

Before



F_{t9} & F_{t10}

After

Results for 2D + time sequence

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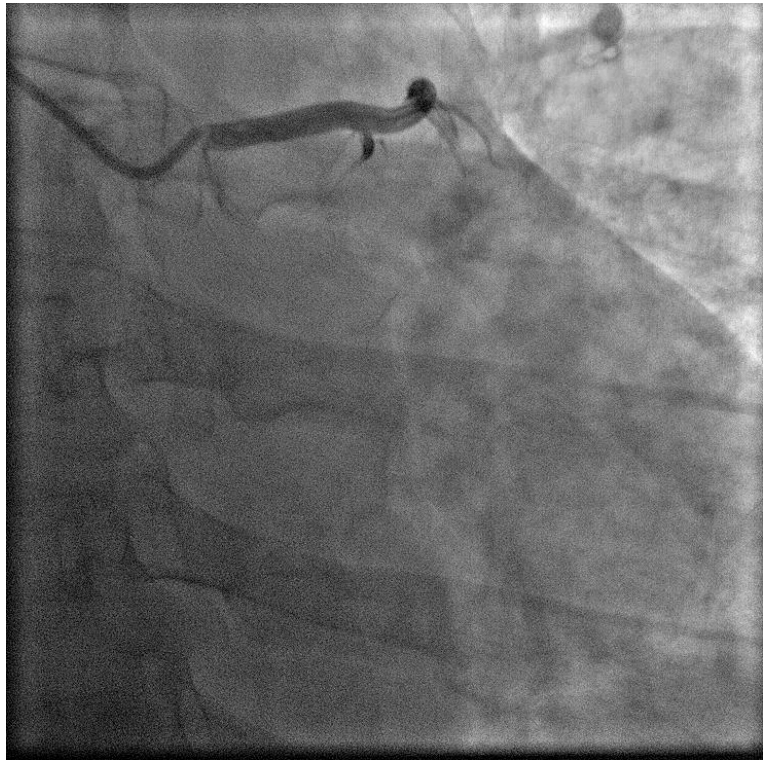
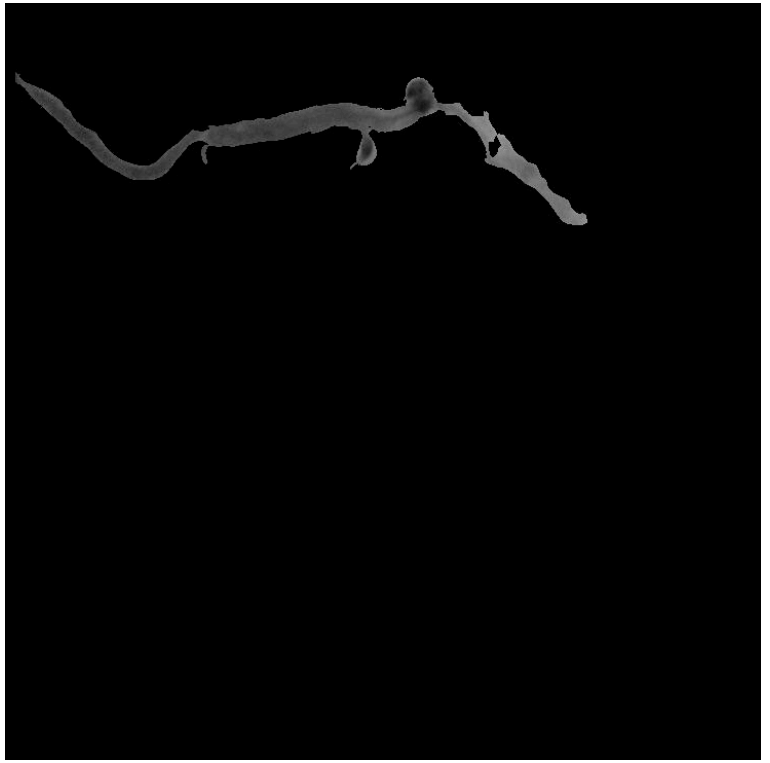
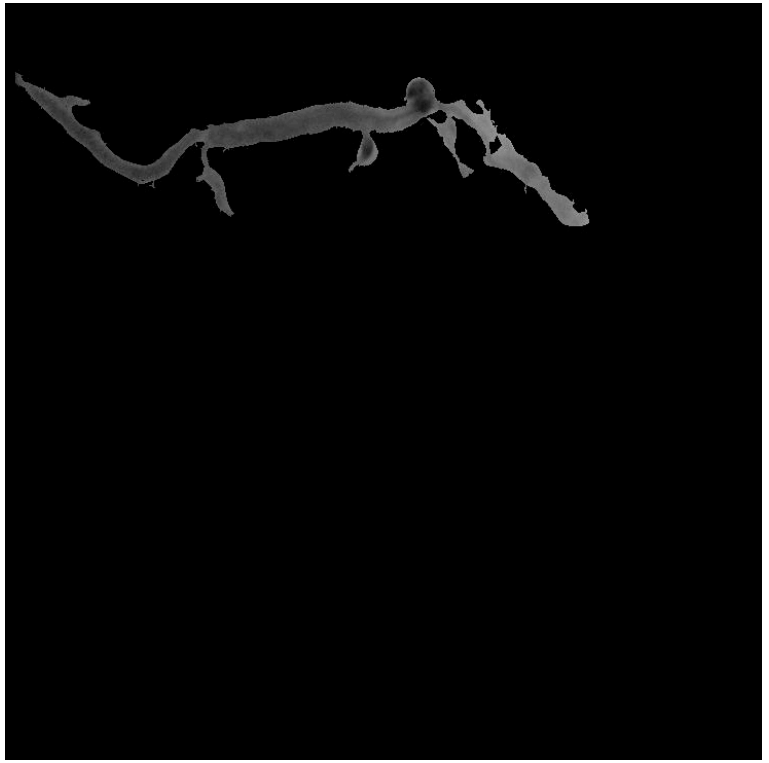


Original data



Segmentation with out registration



Better Segmentation with use of registration

Some results in random frames of angiogram from different patients

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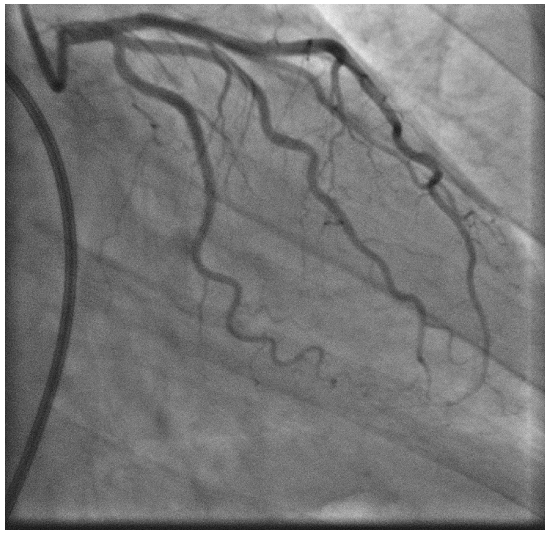
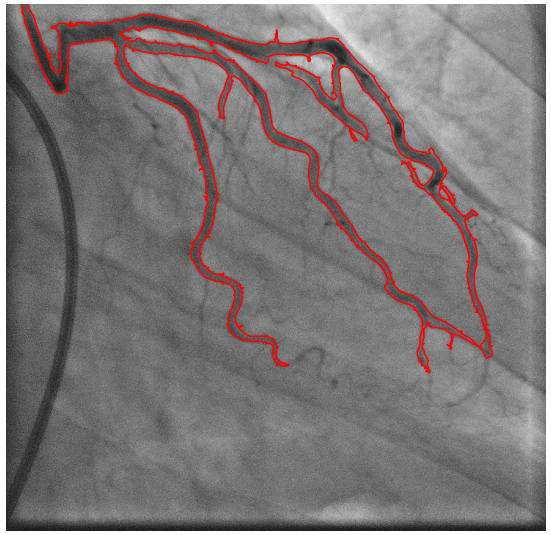
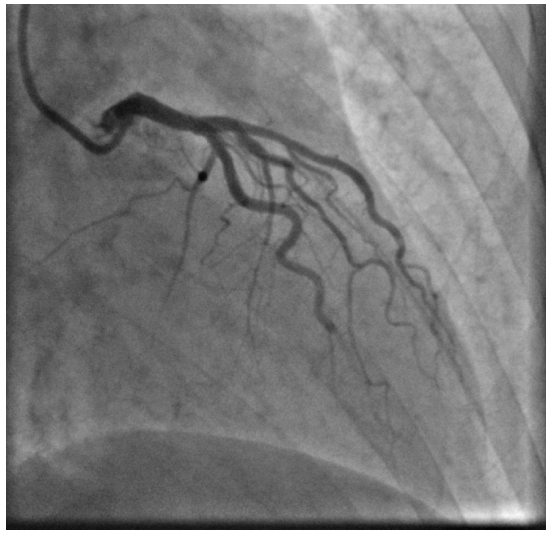
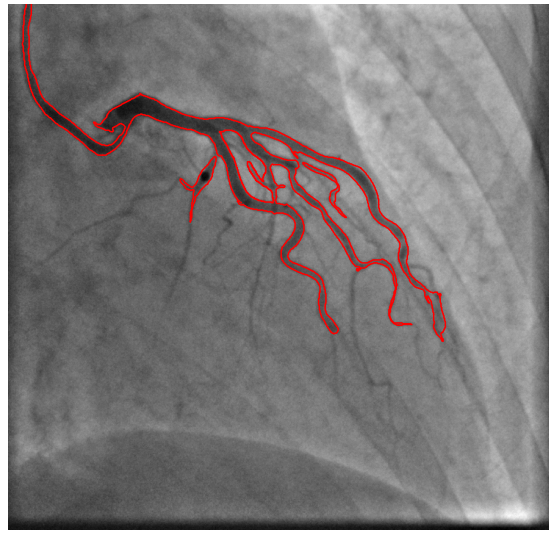

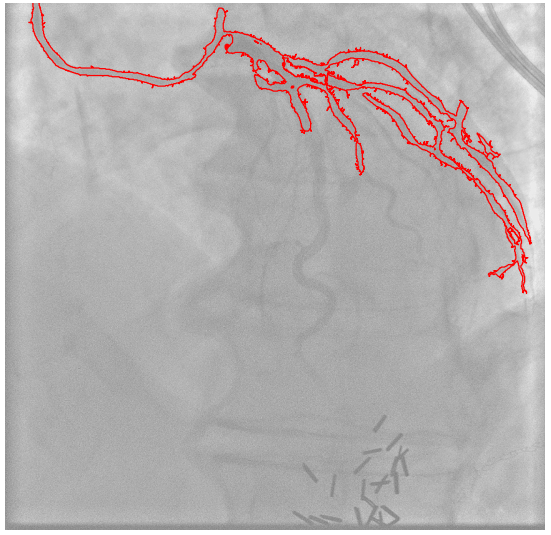

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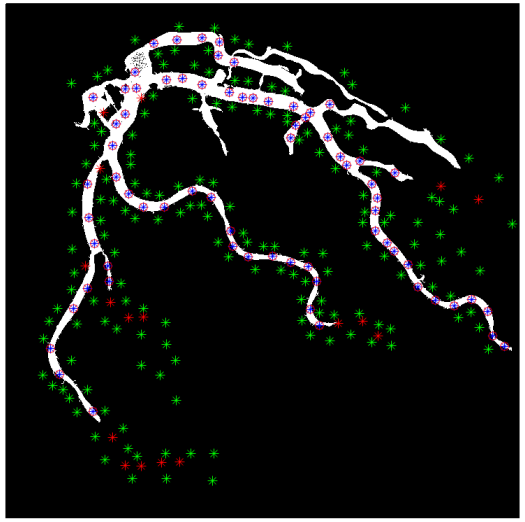
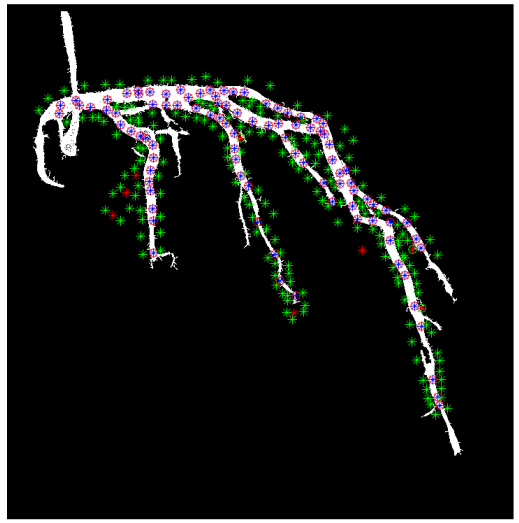
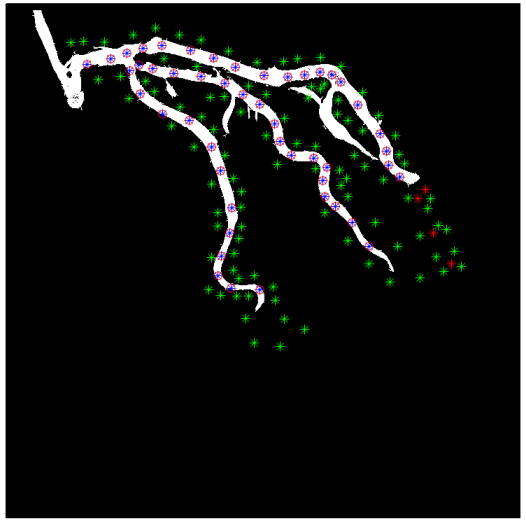
Evaluation of the obtained results


Patient	Pt1	Pt2	Pt3	Pt4	Pt5	Pt6	Pt7	Pt8	Pt9	Pt10	Pt11
Accuracy (%)	98	96	95	93	99	82	97	98	98	95	97
Specificity (%)	98	99	99	99	99	100	99	100	99	99	99
Sensitivity (%)	97	91	88	79	100	54	95	95	97	89	93
All Patients	Accuracy = 97%				Specificity = 99%				Sensitivity = 93%		

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Conclusions and Future work

- Segmenting in 2D+time is challenging since there are movement of the heart (uninteresting) in addition to the movement of the contrast dye (interesting)
- The iterative registration-segmentation approach gives improved segmentation results that are useful over time, i.e. to assess the development of the contrast dye.
- Still improvement potential

- We are currently estimating blood velocity based on the development over time of the segmented coronary tree
- By correlating with truth measurements from Transthoracic Doppler Echocardiography we have currently encouranging results.

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Thank you

Suggestions and Questions?