Computed Tomography and Stationary Digital Tomosynthesis Pulmonary Vessel Alignment

3D to 2D to 3D registration

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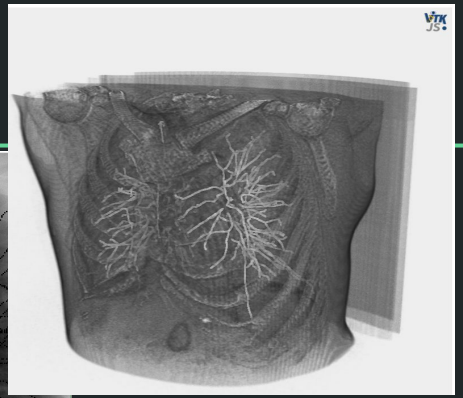
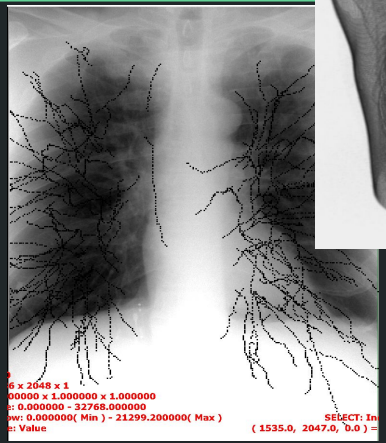
Summer Internship 2022





Background

Benefits of Tomosynthesis over CT include greater practical accessibility and less radiation exposure for the patient

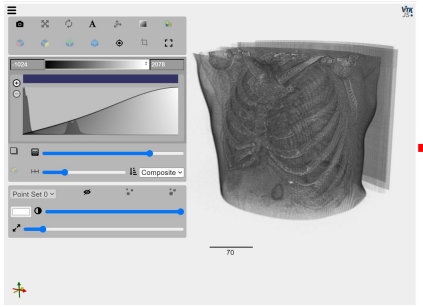
CT to tomosynthesis vessel registration can enhance guided medical procedures by increasing availability and decreasing the patient's exposure to radiation

Driving clinical problem: image-guided lung biopsy

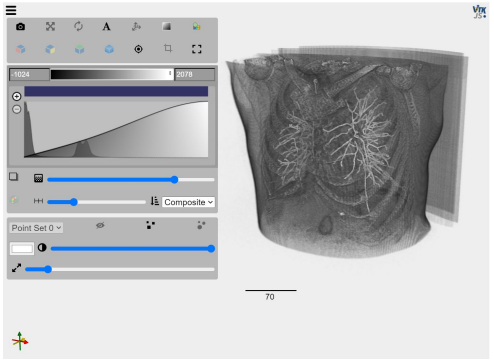
- Registering pre-operative 3D CT with intra-operative 3D Tomosynthesis reconstruction

Data

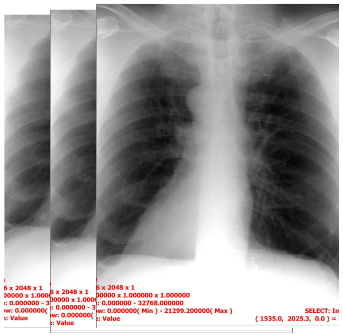
- CT volume
- Tomosynthesis projection images
- Tomosynthesis reconstruction volume
- Geometries of 29 emitter positions



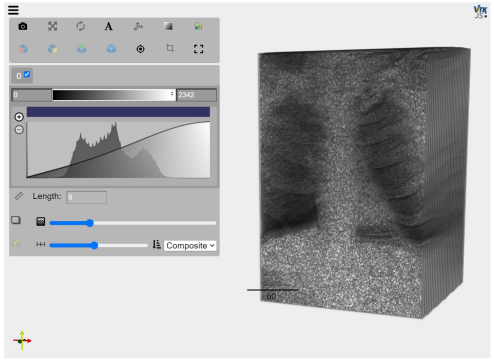
CT Volume [3D]



Segmented Vessels [3D]



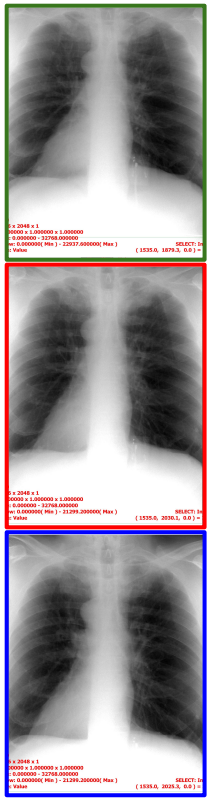
Tomosynthesis Projection* [2D]



Tomosynthesis Reconstruction [3D]

*29 images produced by 29 emitter geometries

Tomosynthesis Projections



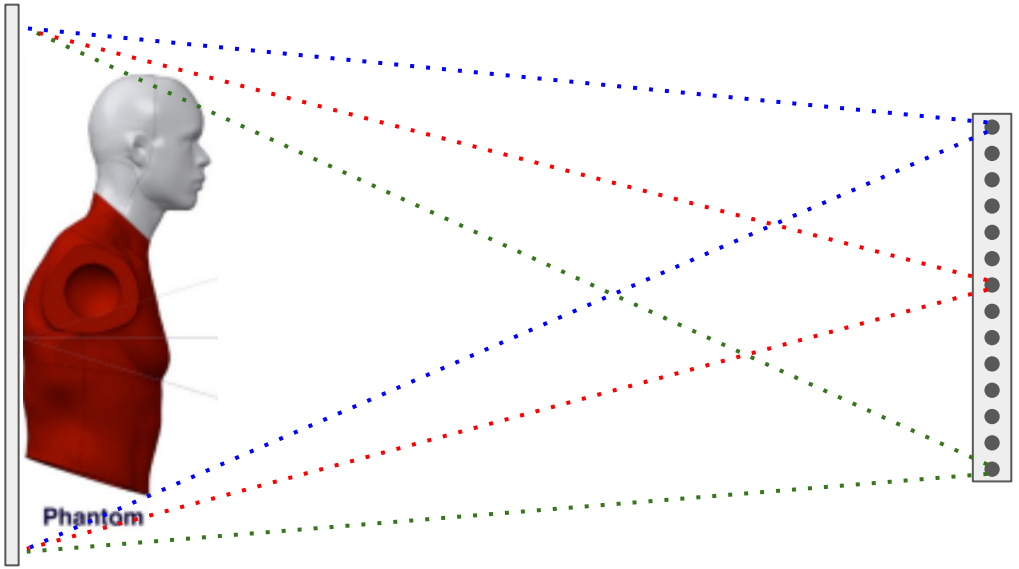
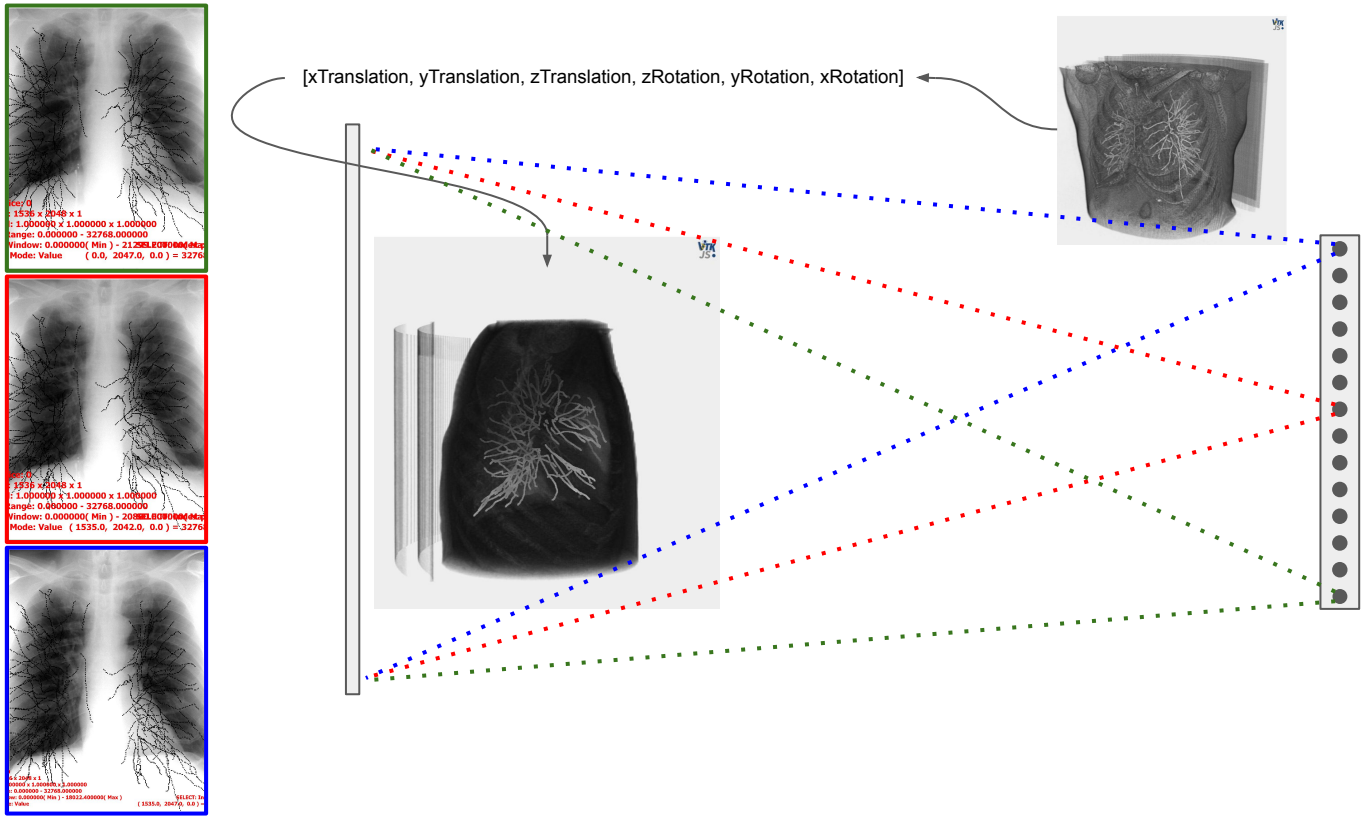


Image: Shan et.al 2015

Goal: register CT 3D vessels with 2D tomosynthesis projection image

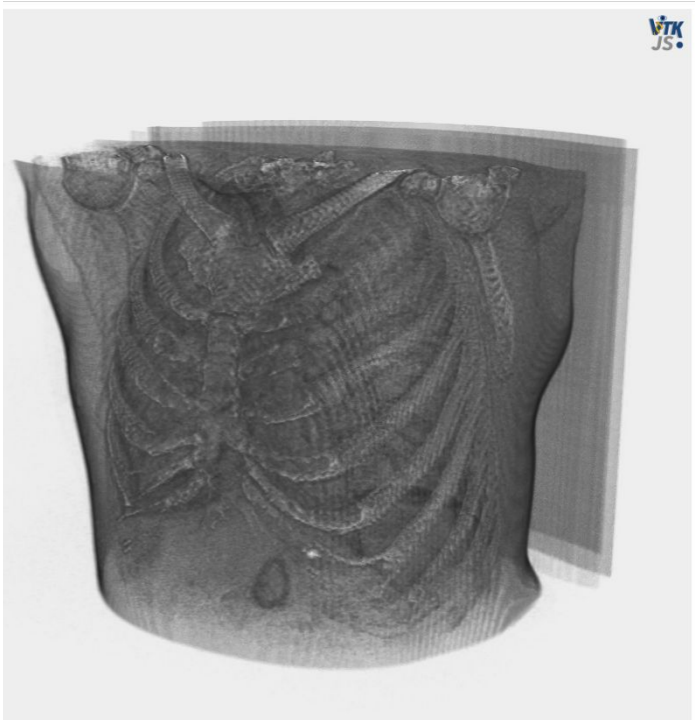


Method

1. Get CT source points from vessel extraction
2. Get tomosynthesis reconstruction vessel points from hand-drawn annotation
3. Make mask with drawn tomosynthesis reconstruction points
4. Apply the mask to each of the tomosynthesis projection images
5. Get masked tomosynthesis images (from 29 emitter positions)
6. Project and register CT source points with the mask applied to the tomosynthesis projection

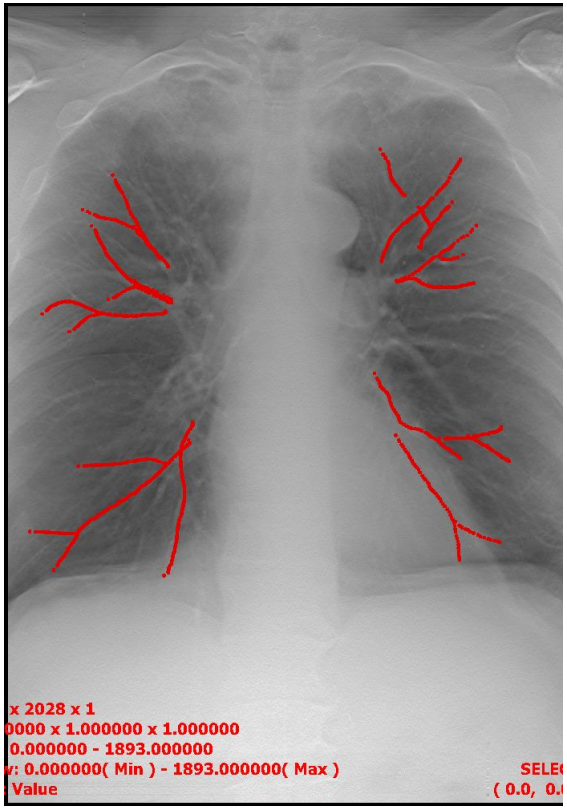
1. CT vessel centerline points from extraction

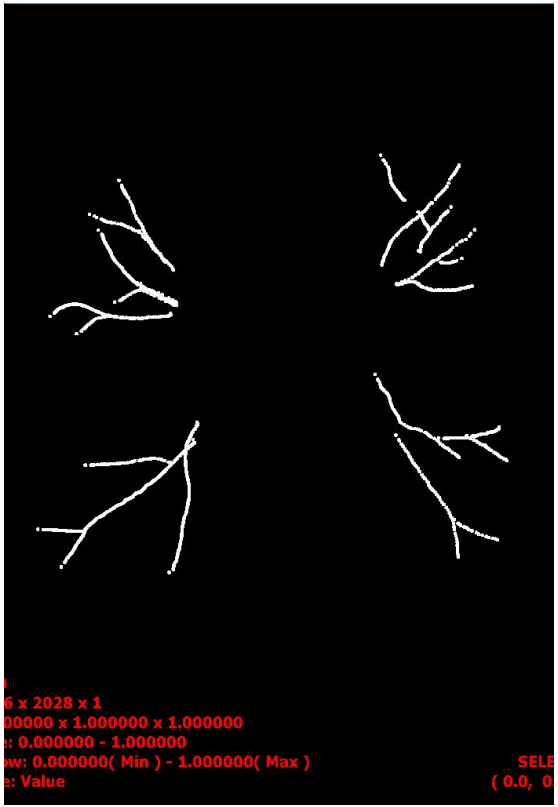
- itk-TubeTK
  - Vessel segmentation
  - Tube spatial objects
- Spatial object position in object space becomes source points for vessel registration



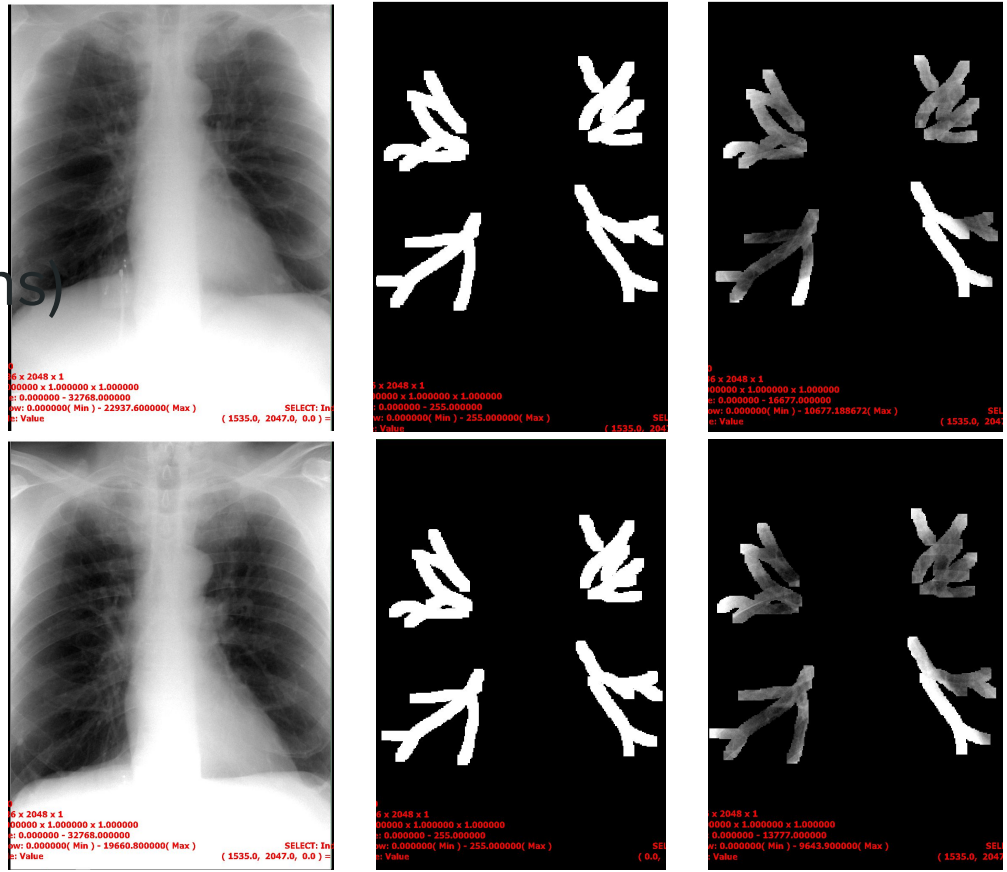
2. TomoRecon points from hand drawn annotation

- ImageViewer
  - Annotate prominent vessels in the tomosynthesis reconstruction 2D slices
- Points extracted from the overlay are used as a mask





3. Make mask with drawn tomoRecon points
4. Apply the mask to each of the tomosynthesis projection images
5. Get masked tomosynthesis images (from 29 emitter positions)



- Using the known emitter positions (geometries), use the points from the overlay to create 29 masks for the 29 tomosynthesis projections

*tomo projection images: 02 and 28

6. Project and register CT source points with the mask applied to the tomosynthesis projection (algorithm)

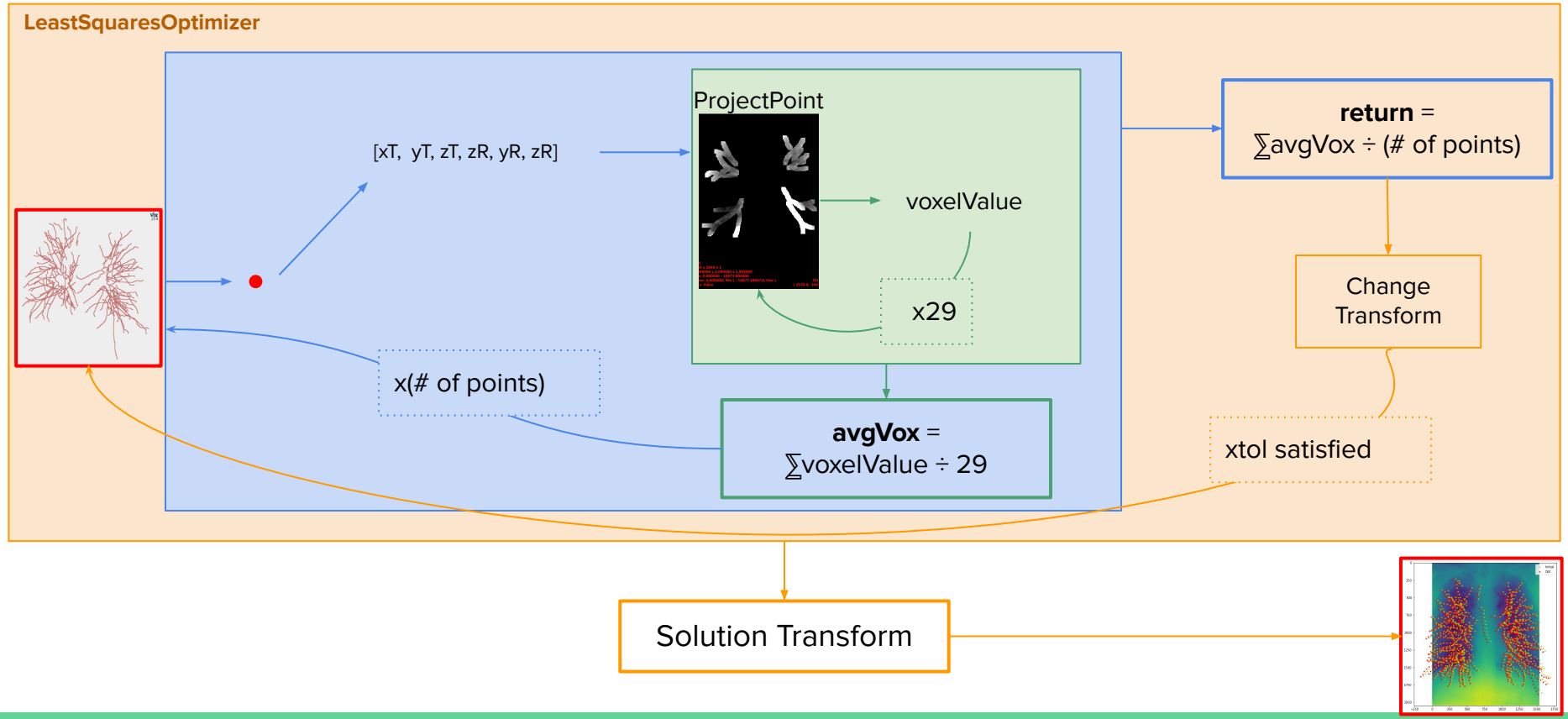
Inputs:
x=[0, 0, 0, 0, 0, 0]
u=sourcePoints
y=emitterGeometry
mask_list
x_scale
size

leastSquaresOptimizer:
for each point:
for each emitterPosition:
transform point given x
project point onto tomoProjMask
using corresponding emitter position
store voxel value at
coordinates of
projected point
avg voxel value of point across emitter positions
avg voxel value of points
maximize voxel values (optimize to brightest parts)

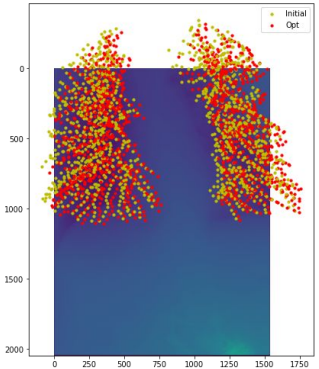
Small perturbation of values in x,
repeat until x tolerance is satisfied

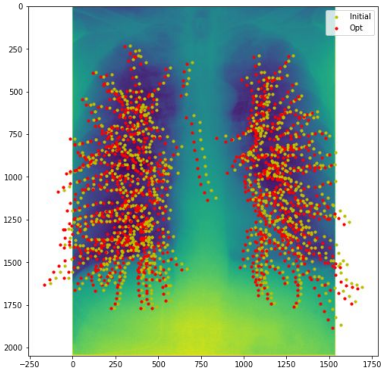
return x=[xTranslation, yTranslation, zTranslation, zRotation, yRotation, xRotation]

6. Project and register CT source points with the mask applied to the tomosynthesis projection (algorithm)



Results


Initial
Opt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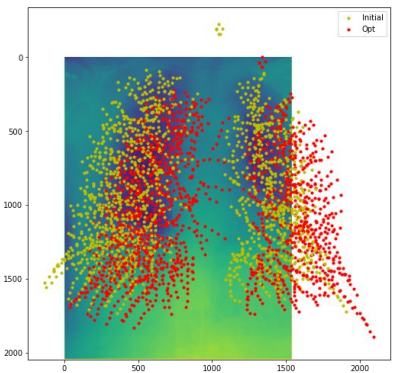
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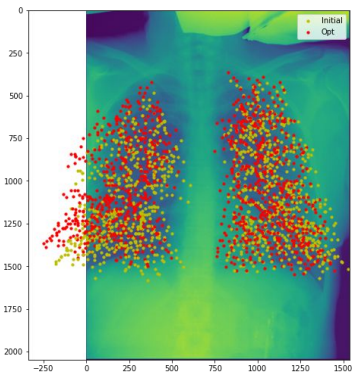
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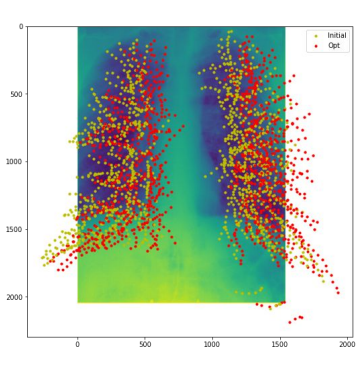
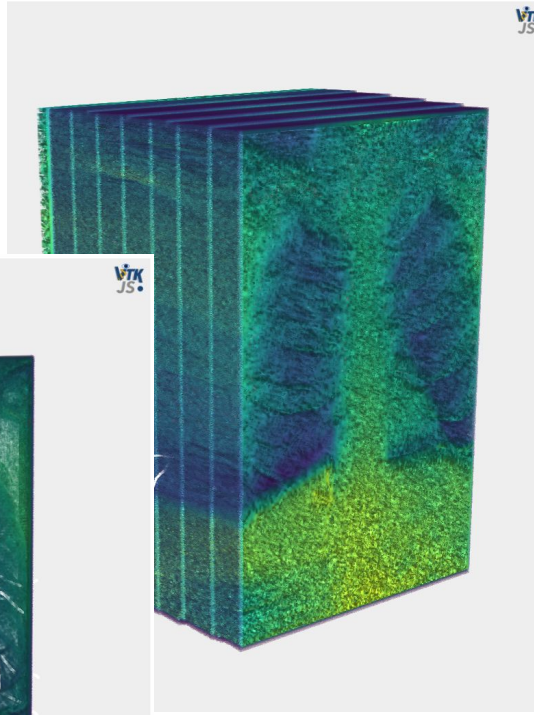

Initial
Opt

Verification: Combined Image

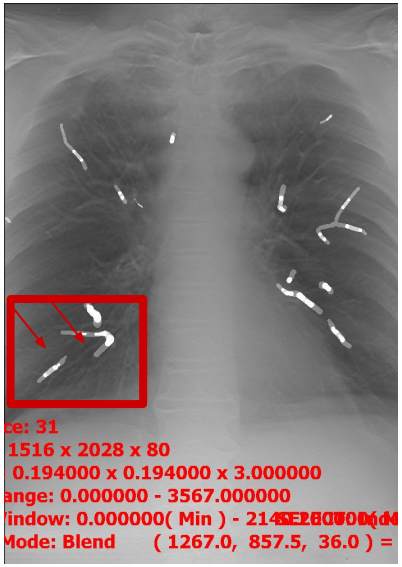
Segmented vessels from CT

Transform with solution from optimization

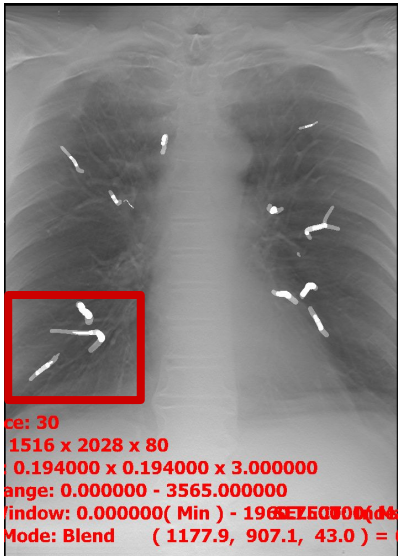


Transformed vessels from CT and tomosynthesis reconstruction

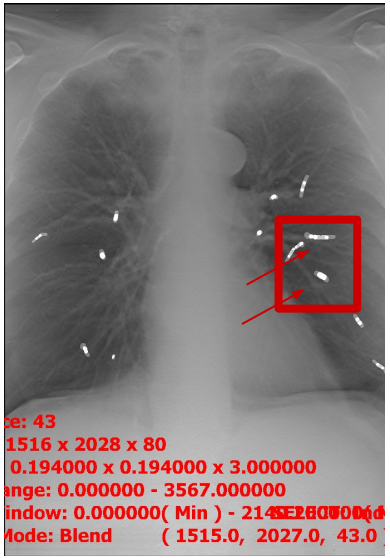
Verification: Combined Image Slices



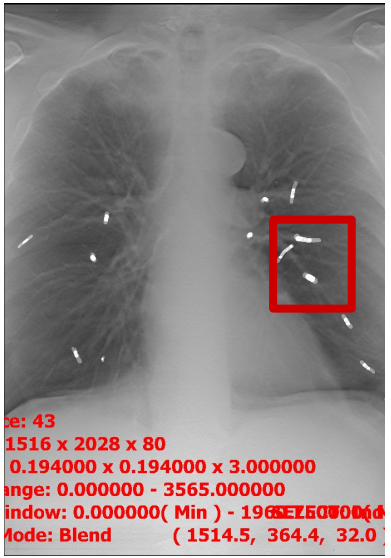
Pre-Registration



Post-Registration



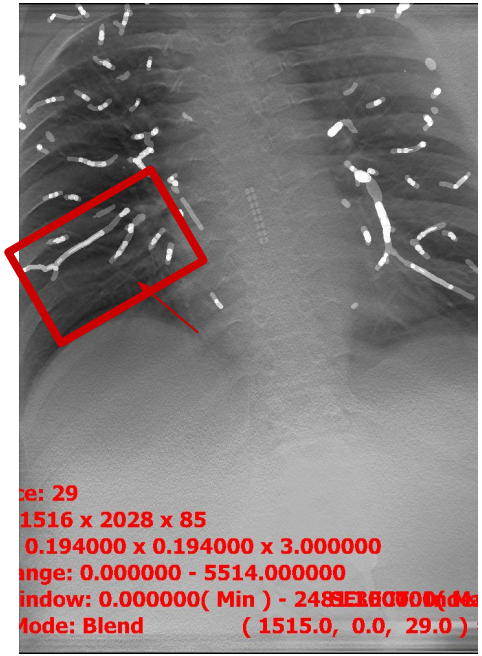
Pre-Registration



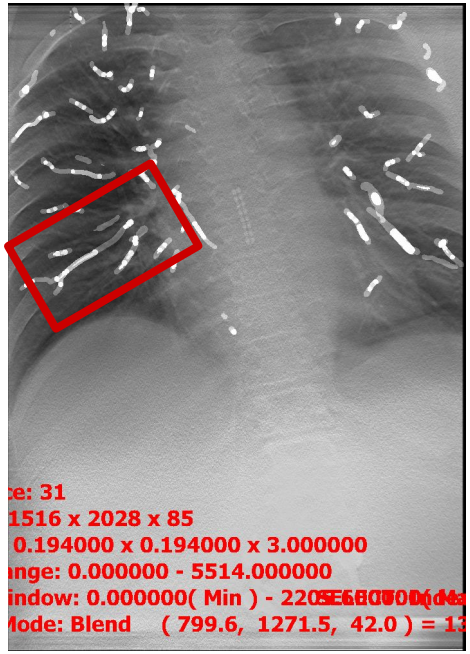
Post-Registration

Patient #2

Verification: Combined Image Slices



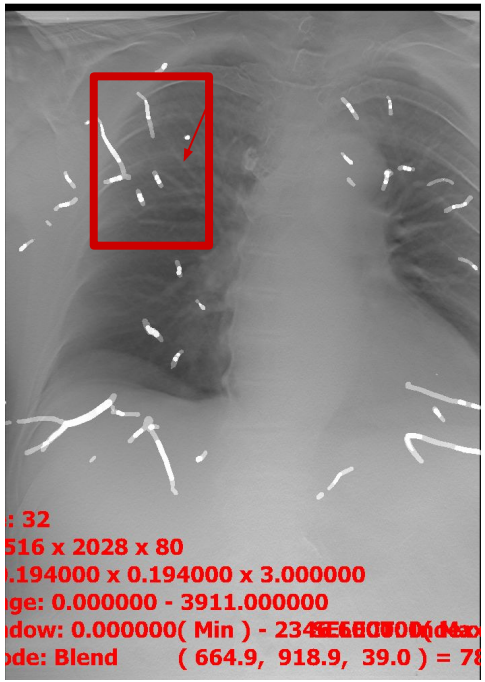
Pre-Registration



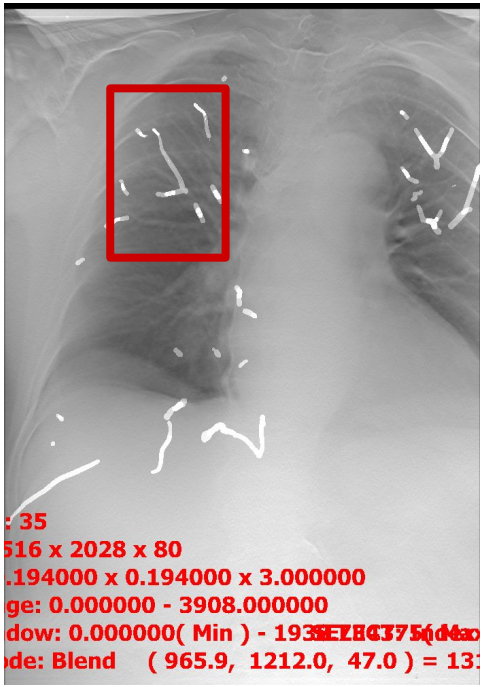
Post-Registration

Patient #1

Verification: Combined Image Slices



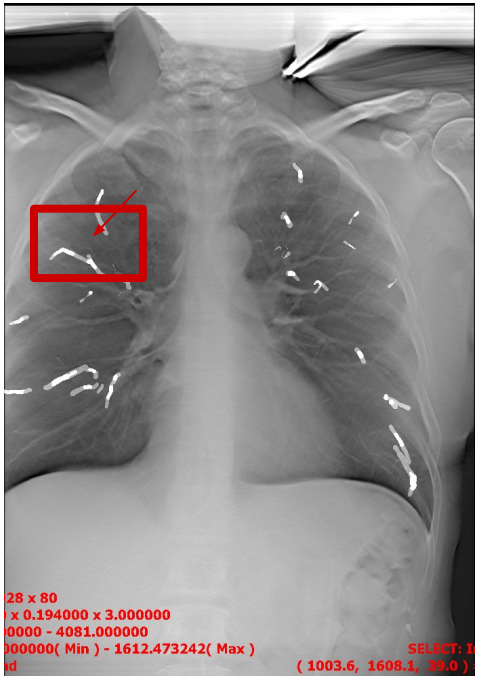
Pre-Registration



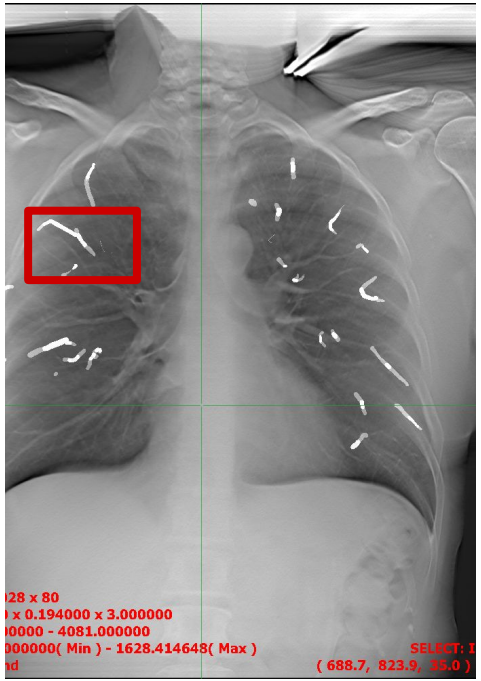
Post-Registration

Patient #3

Verification: Combined Image Slices



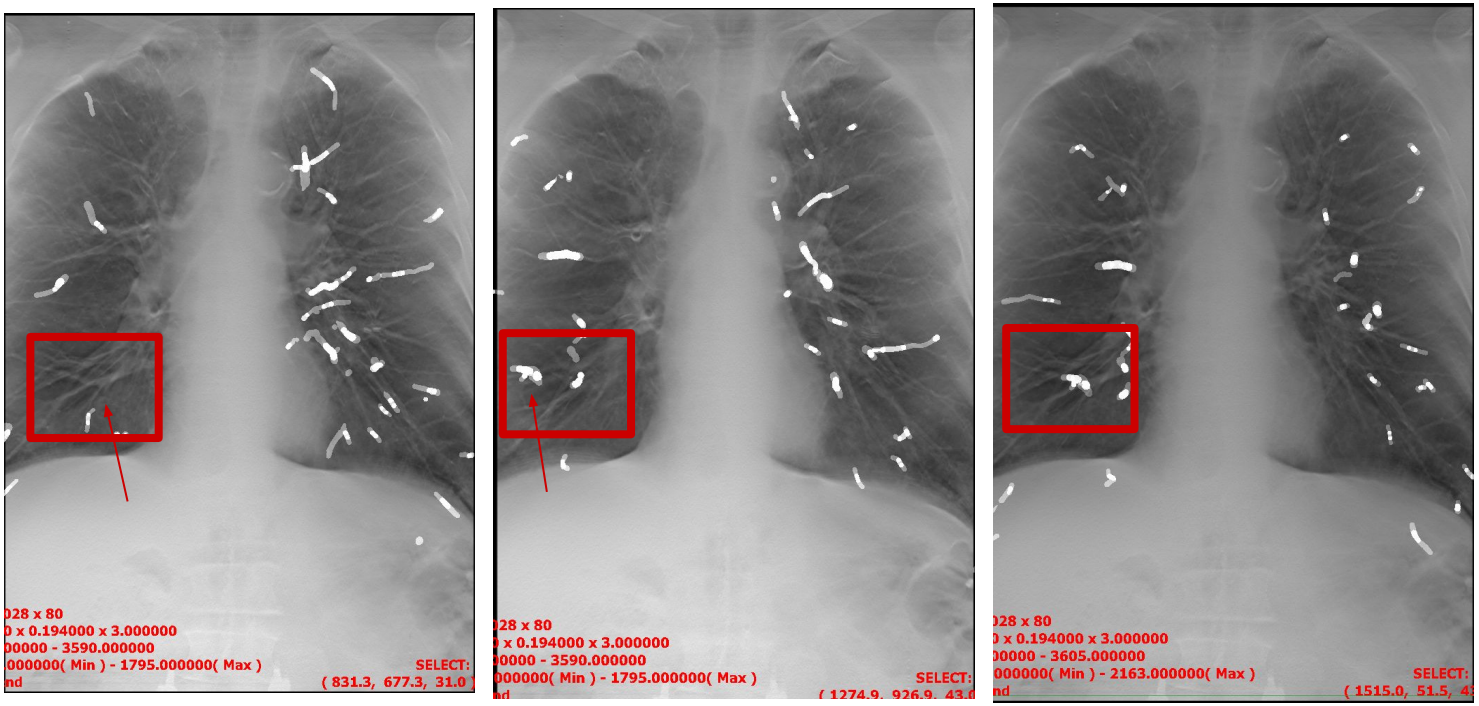
Pre-Registration



Post-Registration

Patient #4

Verification: Combined Image Slices



Pre-Registration

Post-Registration

Patient #5

Acknowledgements

Dr. Stephen Aylward

Dr. Yueh Lee