17th Summer School on Image Processing,
July 2th-11th 2008, Debrecen, Hungary

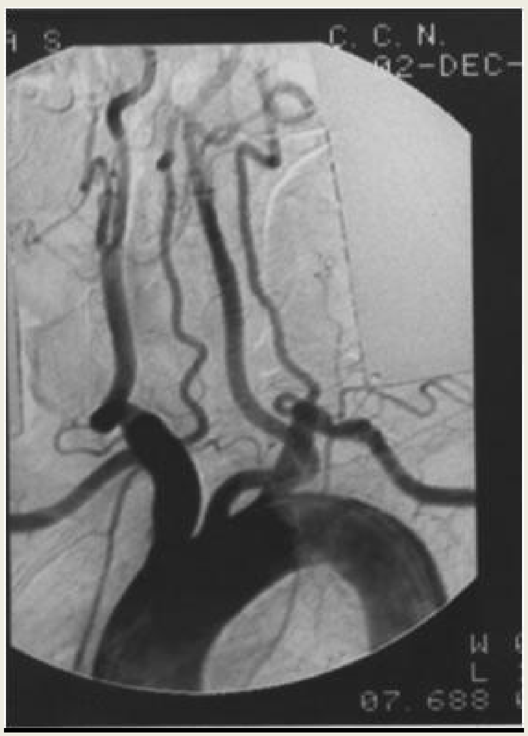
SSIP 2009

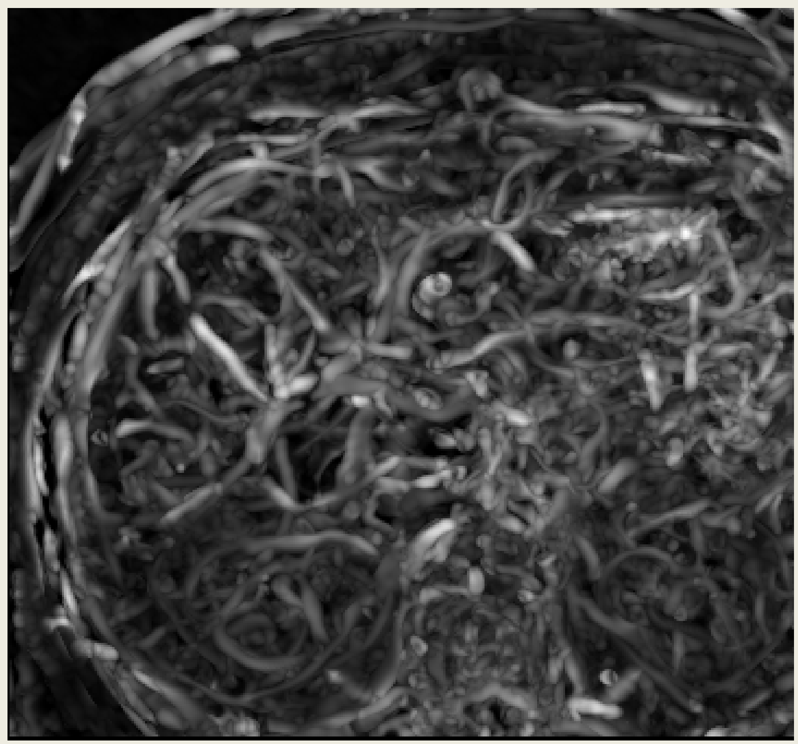
# TRACKING PIPES

**SSIP 2009**

# Problem Description

- Download images of pipes, for example a blood vessel or airway tree
- Track the tubes including bifurcations
- Define the medial axis
- Label each level of the tree
- Identify features such as obstructions of stenoses



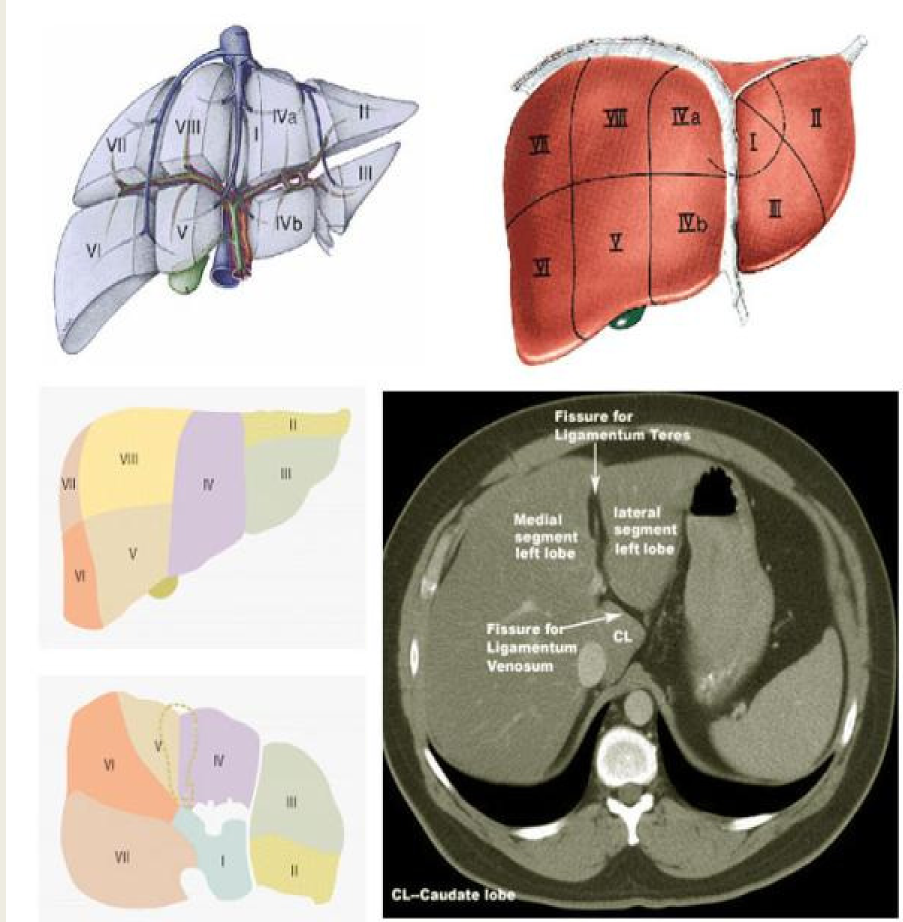



Projected Vesselness map

# Concept - Goal

Develop a
clinical application
to separate
liver segments

Improve accuracy
of treatment
of liver pathology



# Clinical workflow

Radiologist takes CT image
for the diagnosis

Radiologist contours
the liver on the image

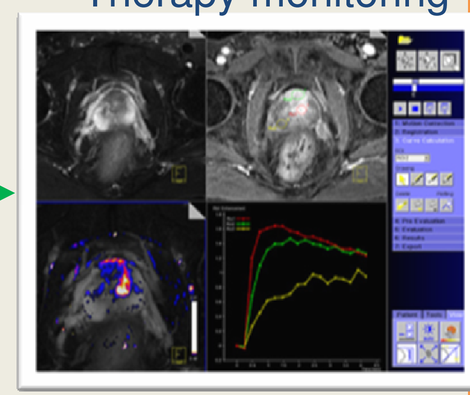
Radiologist marks
the vena cava on the image

**Application**

The matlab application gives
image to help the diagnosis

Surgery planning

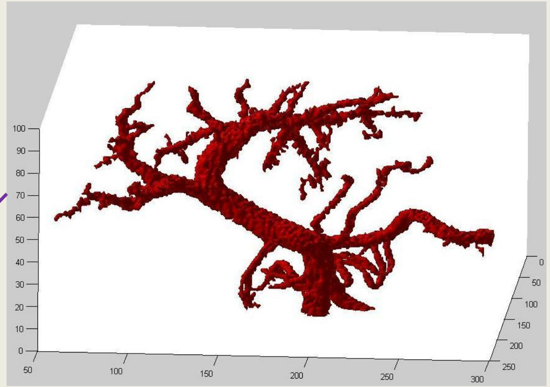
Therapy monitoring



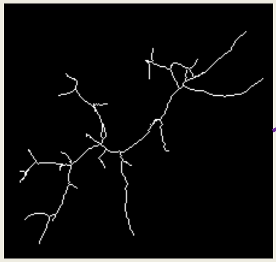
# Application workflow

*INPUT:*
*- CT image (abdomen),*
*- Liver contour*

***Vessel segmentation***

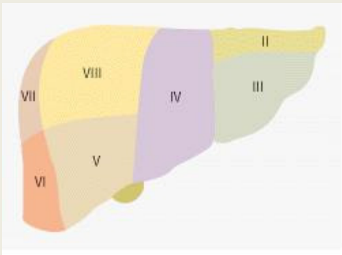



***Skeletonization***



***Labeling***

***Liver segment separation***




*OUTPUT:*
*Liver Segments*

# Vessel segmentation (attempted)

- Basic region growing
  - Problems include noise, weak vessel boundaries, similar intensity between vessel and liver.
- Generalisation of vesselness to images
  - Calculating the probability that a pixel belongs to a tubular object.
  - Difficulty extracting a binary image from the probability matrix.

# Vessel segmentation method (selected)

**Determining minimal and maximal values from a disk shaped area of the liver vessel selected by user**

↓

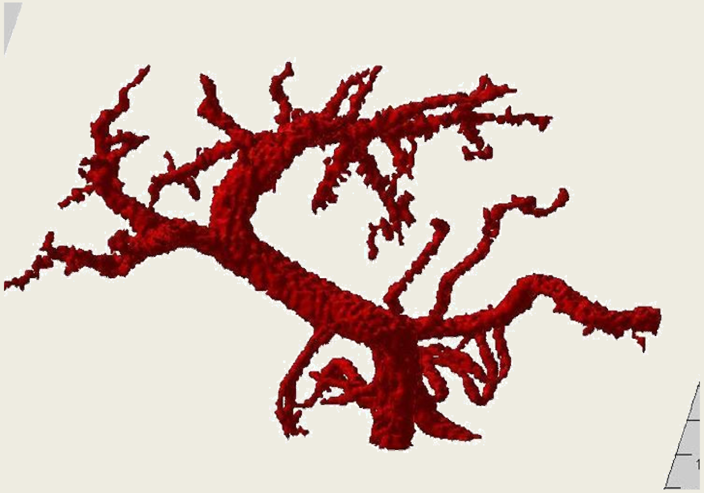
**Thresholding of volume**

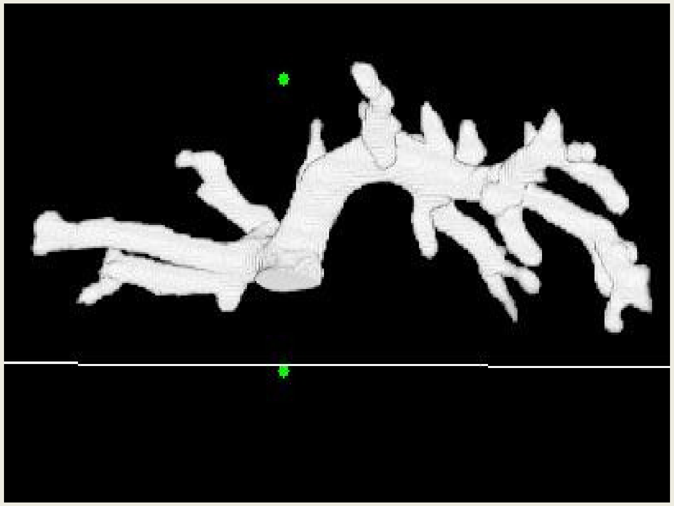
↓

**Deleting segments not connected to user defined seed point.**

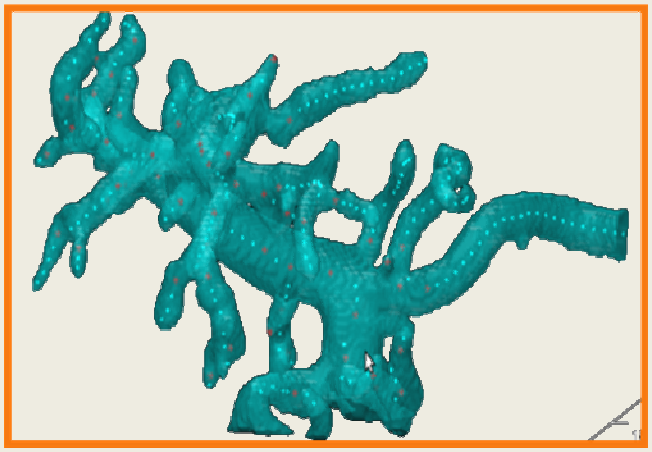
↓

**Morphological closing**

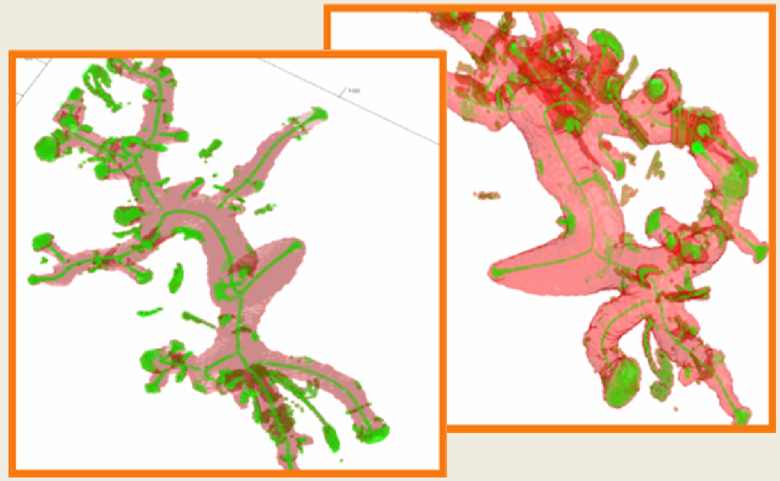




# Skeletonization (attempted)



- Bounded space dilation[1]
- Accurate for non branching points
- Relatively fast
- Disconnected skeleton



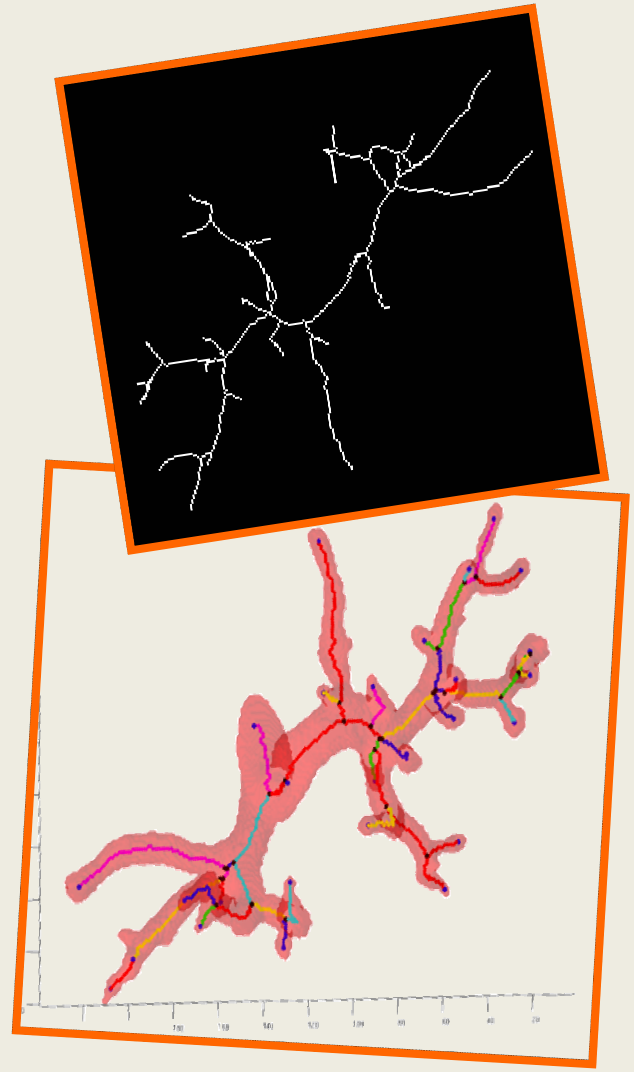
- Vanishing point detection[2]
  - Hessian matrix for each voxel
  - Eigenvectors and eigenvalues evaluated
- Subvoxel accuracy
- No need of segmentation
- Extremely slow
- No topology preserving
- Branching points not always detected

[1]**Masutani** et al "Vascular shape segmentation and structure extraction…."

[2]**Steger** et al "3D center line extraction algorithm for curvilinear structures"

# Skeletonization[1] (selected)

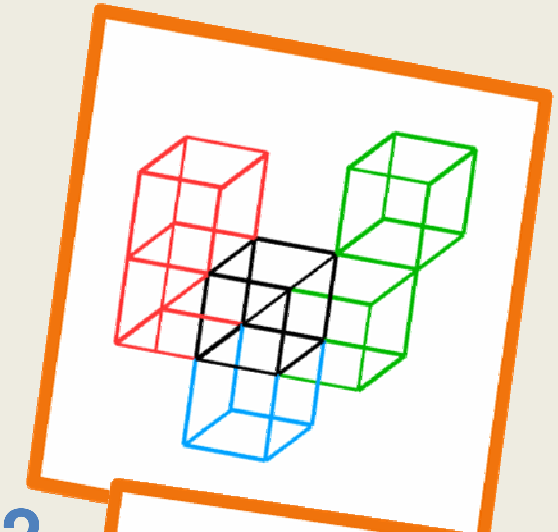
- **Iterative voxel removal**
- **Simple point identification**
- **Sequential thinning**
- **Topology preserving**
- **Pruning step included**
- **Extremely fast**
  - **Skeleton extracted in 7 iterations (~0.5 s)**
- **No subvoxel accuracy**

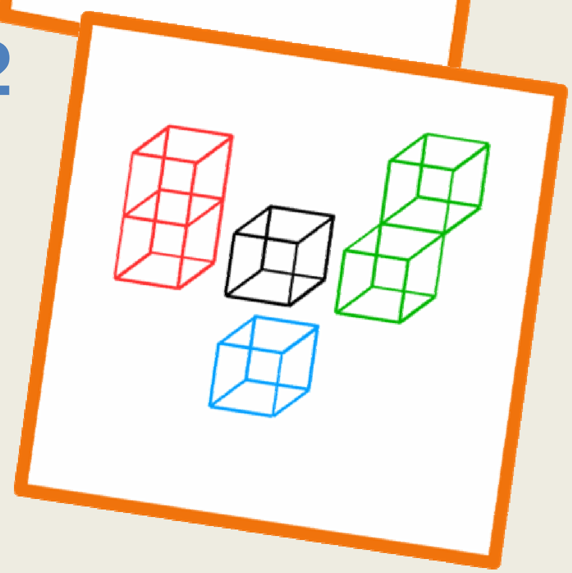


[1]Thanks to prof. **Kalman Palagyi** for providing us with code

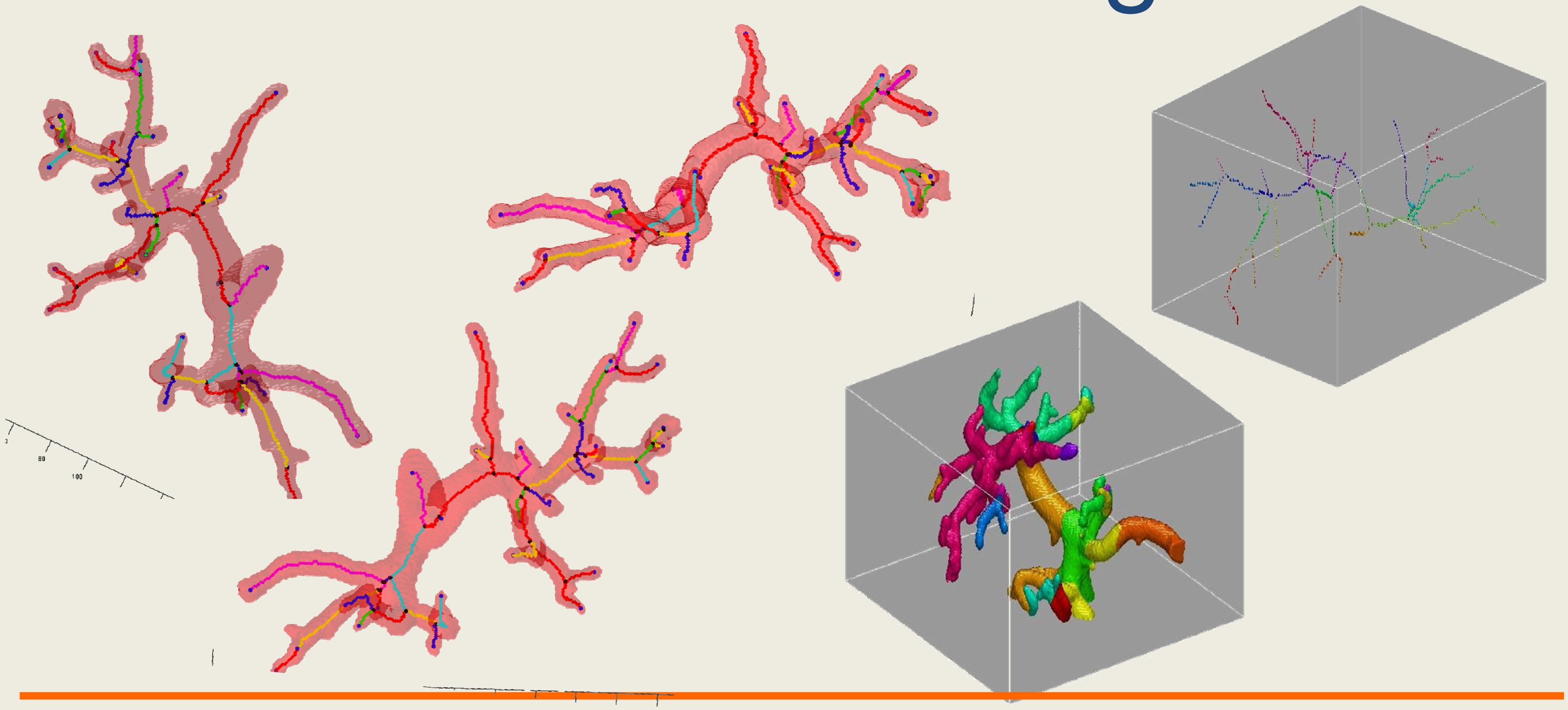
# Labeling

- **26 neighborhood (3×3×3)**
- **6, 18, 26 connectivity**
- **The central voxel (2,2,2) is removed**
- **Connectivity examined**
- **IF *#connected_components*>2**
  - ***Junction***
- **IF *sum(neigboors)*==1**
  - ***Endpoint***



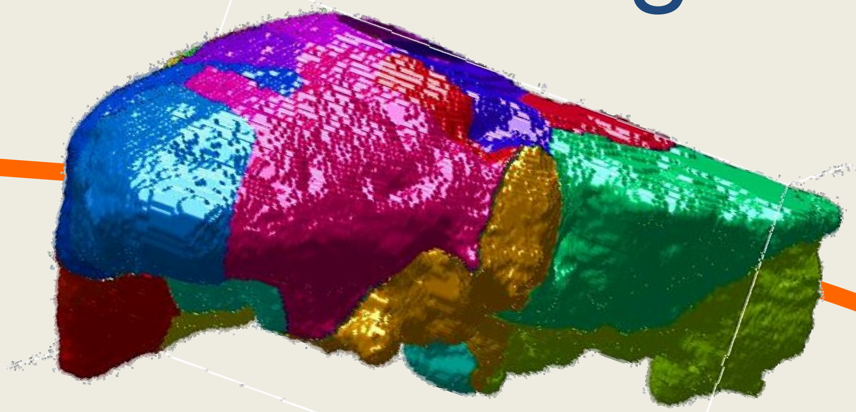


# Vessel labeling

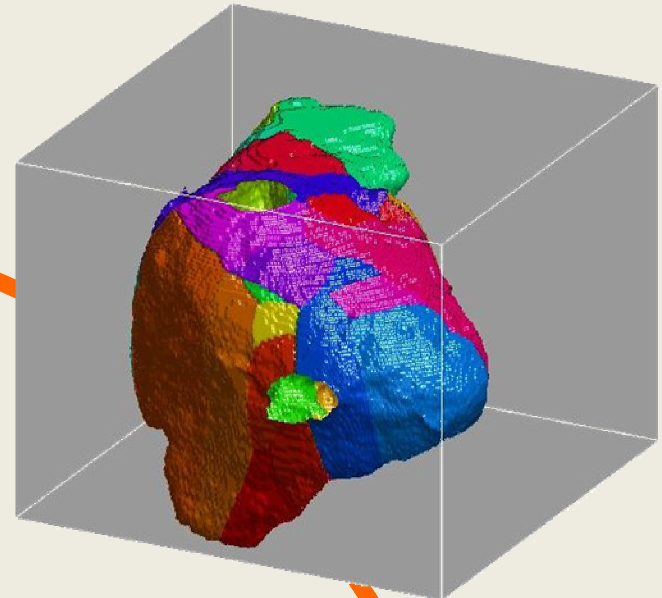


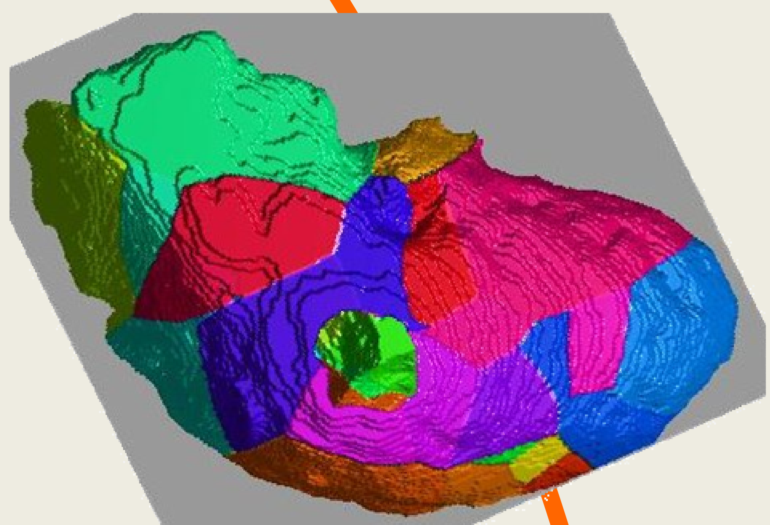
- ***Input:*** Labeled skeleton & segmented vessel
- 3D distance transform
- Nearest skeleton label was identified
- Due limited amount of available colours some branches were give the same colour

# Liver segment separation

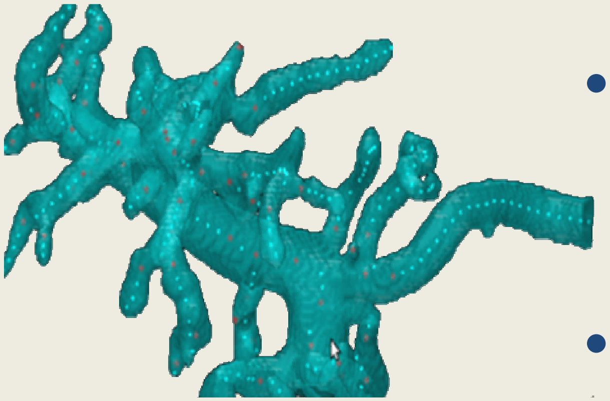


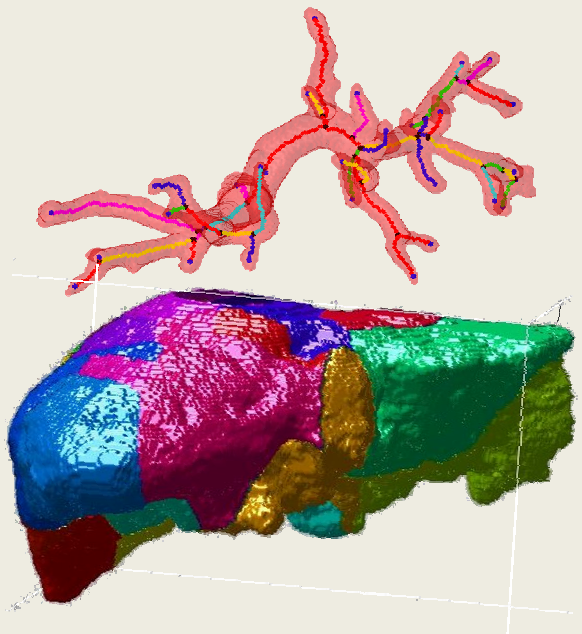
- Labeled skeleton was used as locus of closest liver surface points
- One vessel branch corresponds one liver segment





# Conclusions





- We developed a liver segment separation and vessel analysis prototype
- An accurate definition of the vessels supplying each segment will lead to proper liver separation
- To improve the accuracy more anatomical knowledge has to be incorporated

# Future work

- A larger database of images to develop the algorithm.
- Segmentation
  - Include Frangi's vesselness measurement
  - Segmentation of contrast enhanced images for more accurate and smoother vessel segmentations
  - Development of an automatic segmentation method
- Vessel labeling
  - Make a use of anatomical knowledge
- Liver separation
  - Decrease number of liver segments down to 8
  - Enhanced separation of the vessels supplying each segment
- Integrate the workflow
- Extend our study to stenosis and aneurysms analysis

# Used technologies

The MathWorks™ Accelerating the pace of engineering and science

- ***Segmentation***

- ***Skeletonization***

The MathWorks™ Accelerating the pace of engineering and science

- ***Labeling***

The MathWorks™ Accelerating the pace of engineering and science

- ***Segment separation***

ImageJ Image Processing and Analysis in Java

- ***Visualization***

# THANK YOU!

BYE BYE