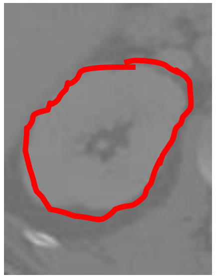
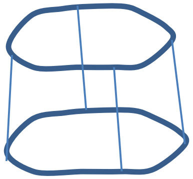
Finding and Reconstructing Organs

original image kidney.jpg

Idea of Finding Kidneys

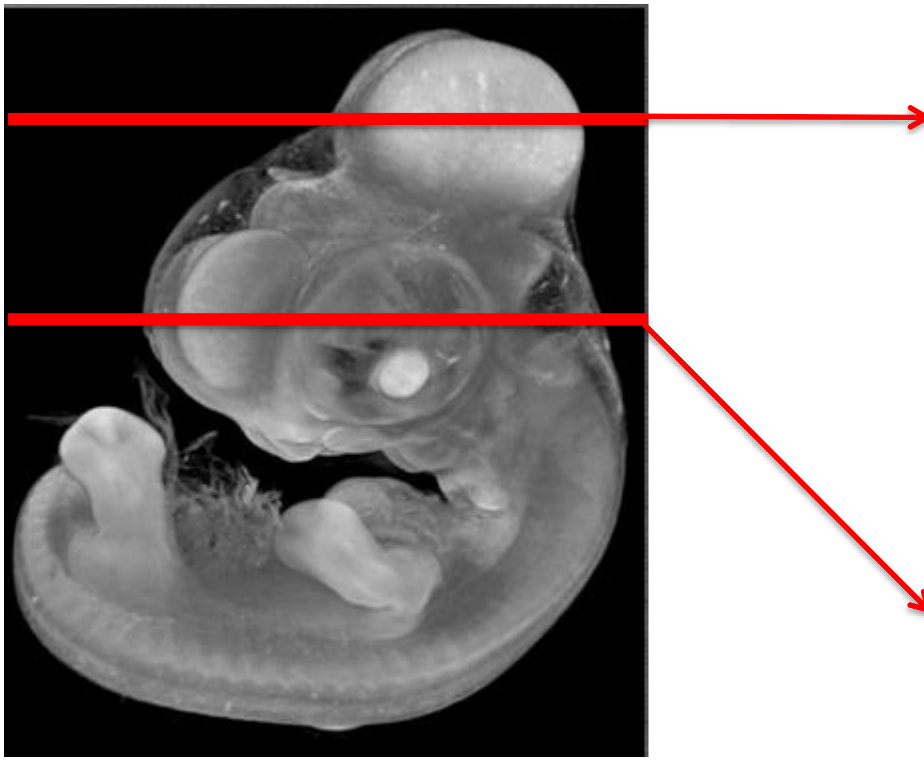
- Find a (say right) kidney in every slice that contains them.
- Find the contours of each one.





- Connect up all the contours.
- Create a 3D mesh representing the right kidney.

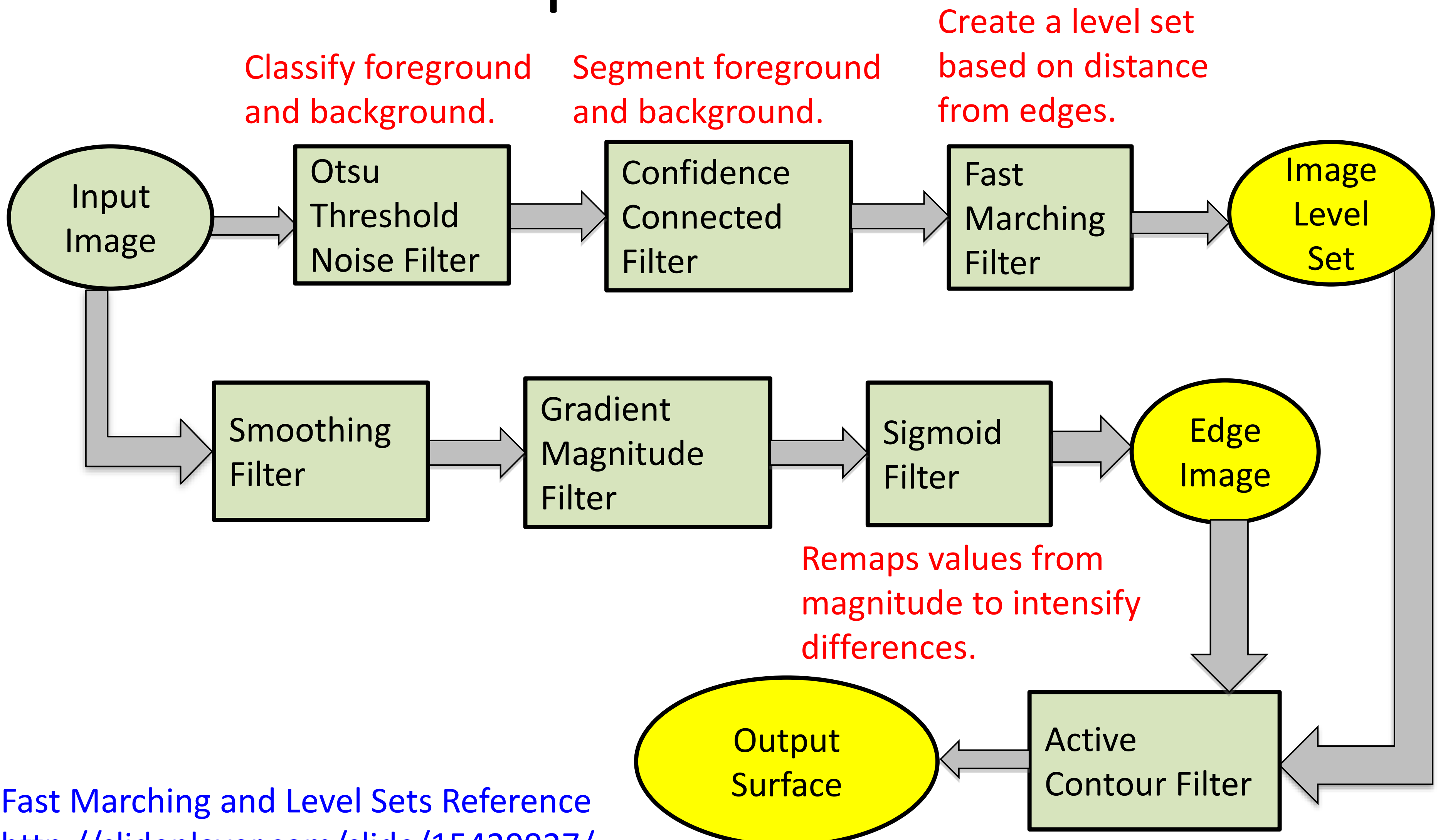
Sara Rolfe's Work from High Resolution 3D Scan Data



Chick embryo

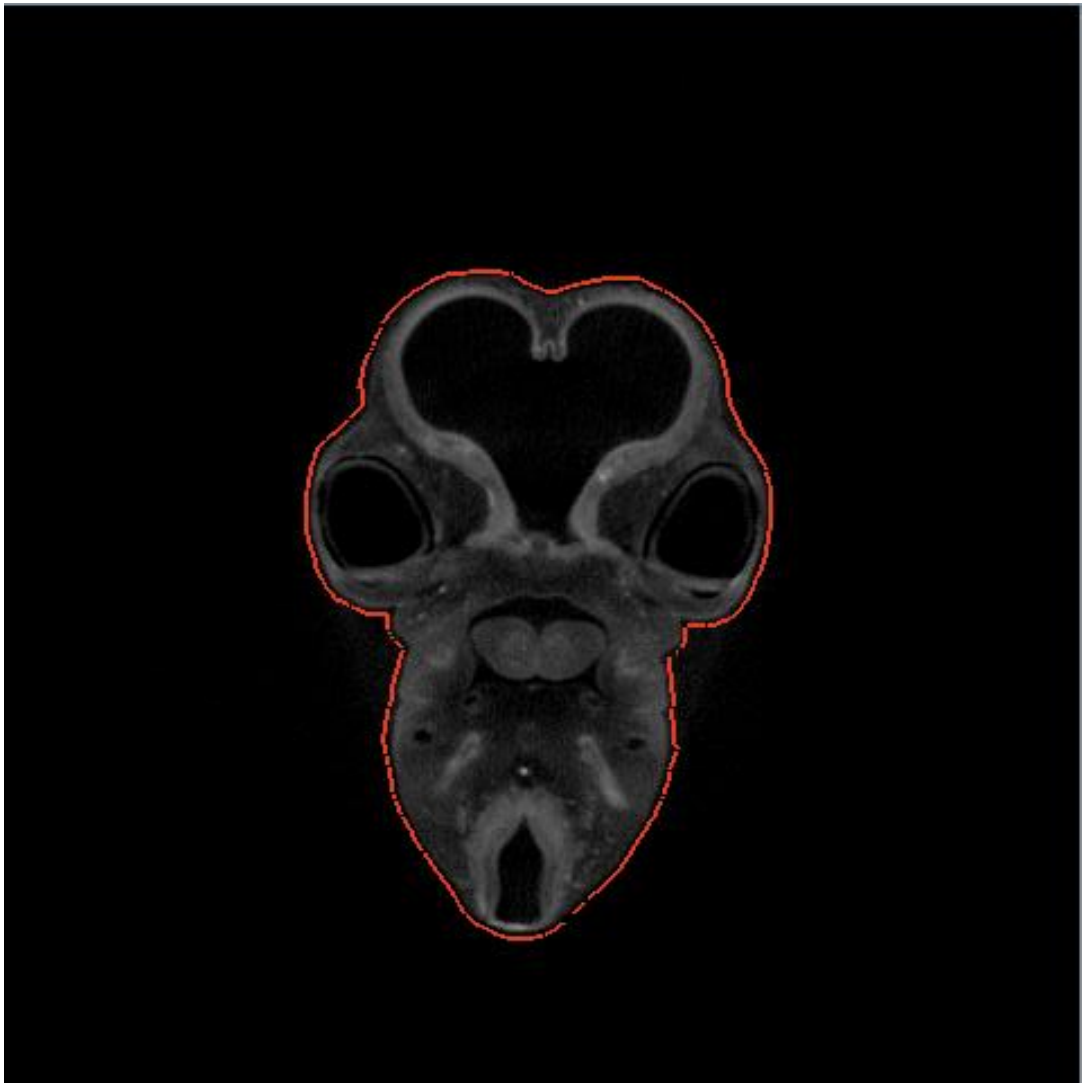
2D image slices

Geodesic Active Contour Implementation

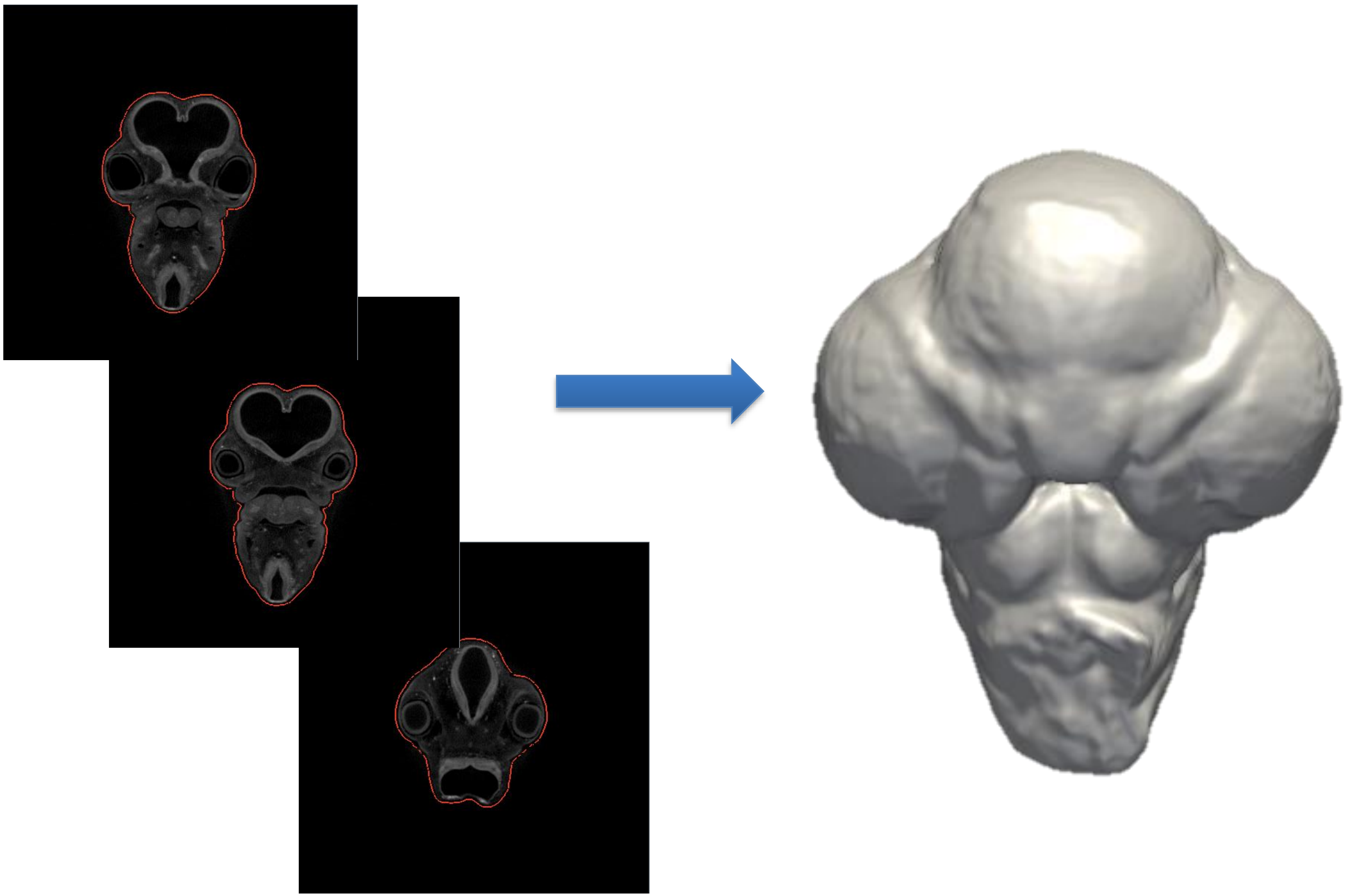


Fast Marching and Level Sets Reference
http://slideplayer.com/slide/15429927/

2D Example



3D Surface Generation

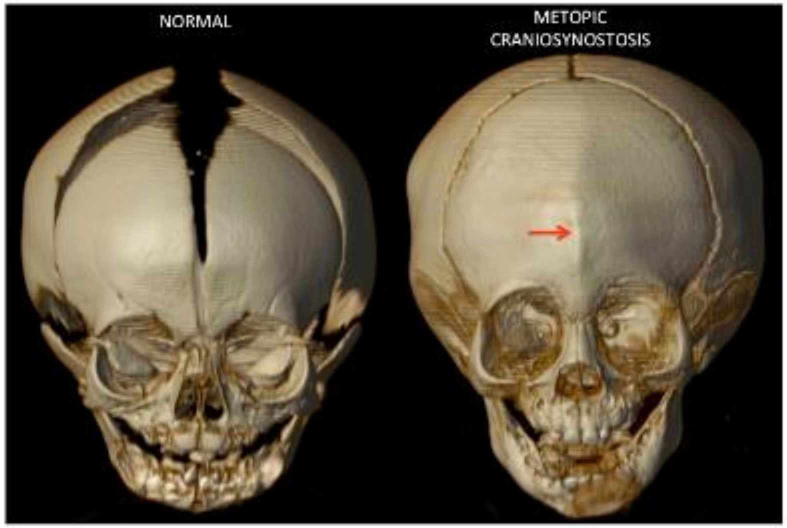


DICOM Standard

- DICOM stands for Digital Imaging and Communications in Medicine.
- It is a standard for **storing and transmitting** medical images, enabling the integration of medical imaging devices and communication systems from multiple manufacturers.
- It has been widely adopted by hospitals and is making inroads into smaller applications like doctors’ and dentists’ offices.
- It is used worldwide to store, exchange and transmit medical images.

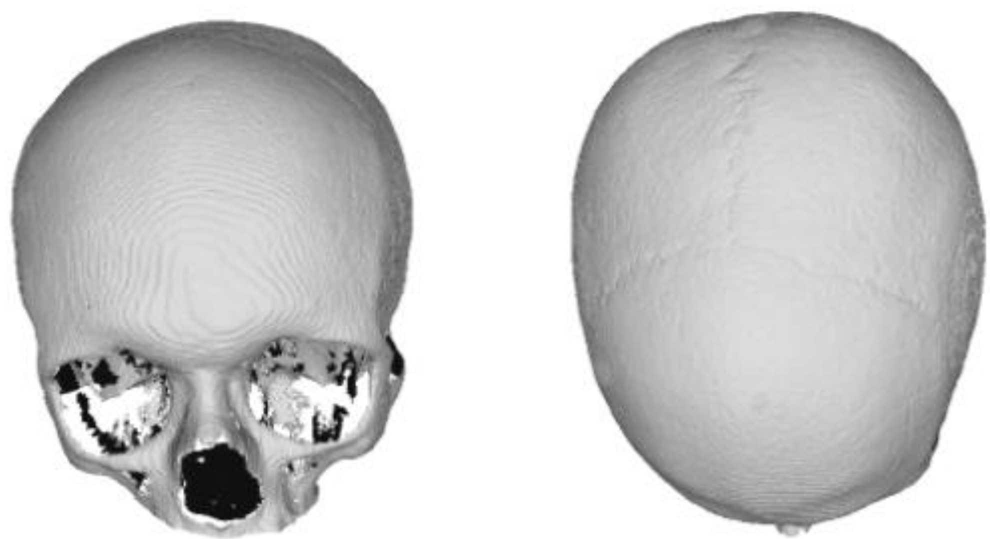
Shu Liang used DICOM images to construct 3D meshes of childrens' skulls

- **Craniosynostosis** is a condition in which one or more of the fibrous sutures in an infant (very young) skull prematurely fuses by turning into bone (ossification), thereby changing the growth pattern of the skull.



She converted DICOM CT images to skull meshes using a tool called Osirix

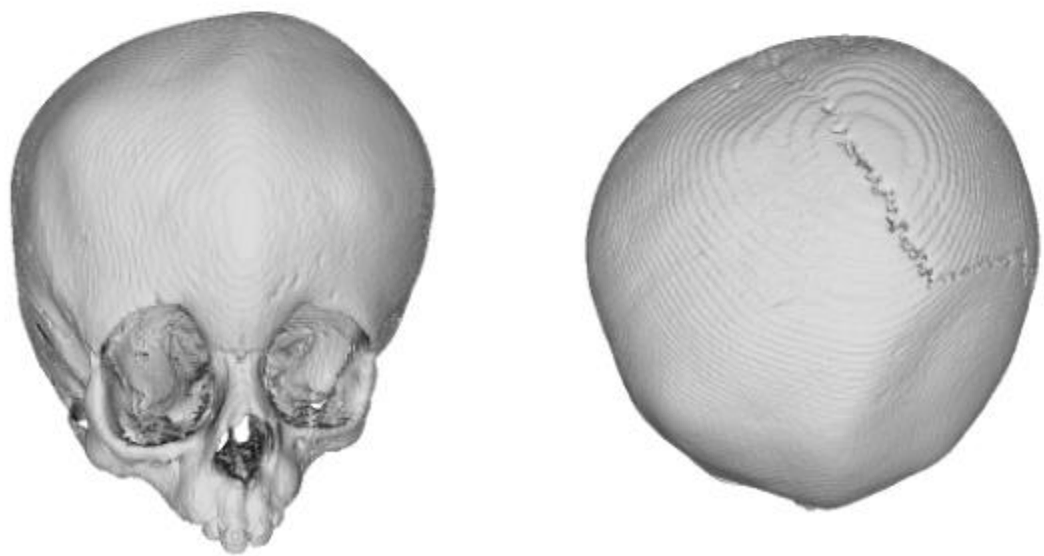
Skull Mesh



Normal Skull

Abnormal Skull

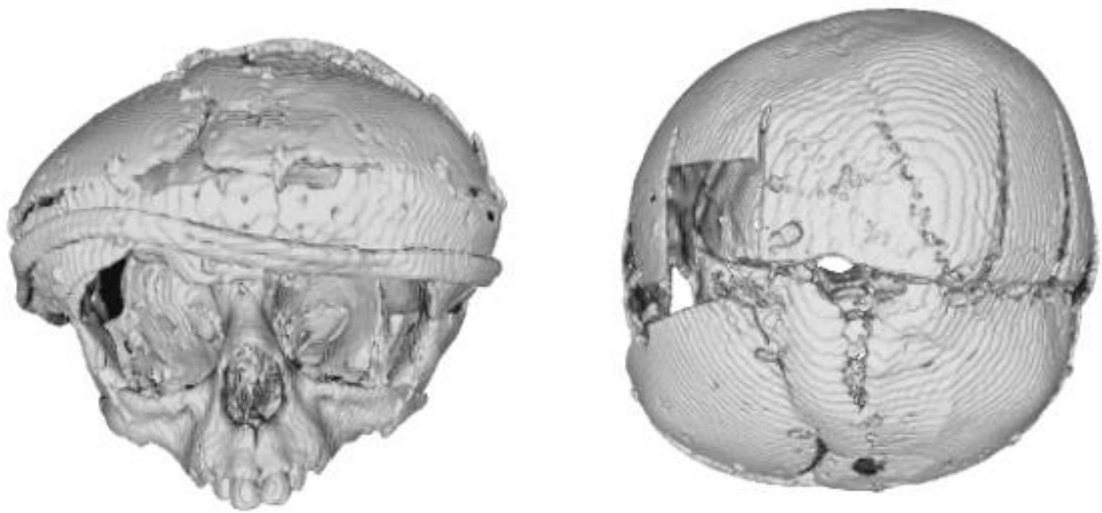
Skull Mesh



Before Surgery

Right after Surgery

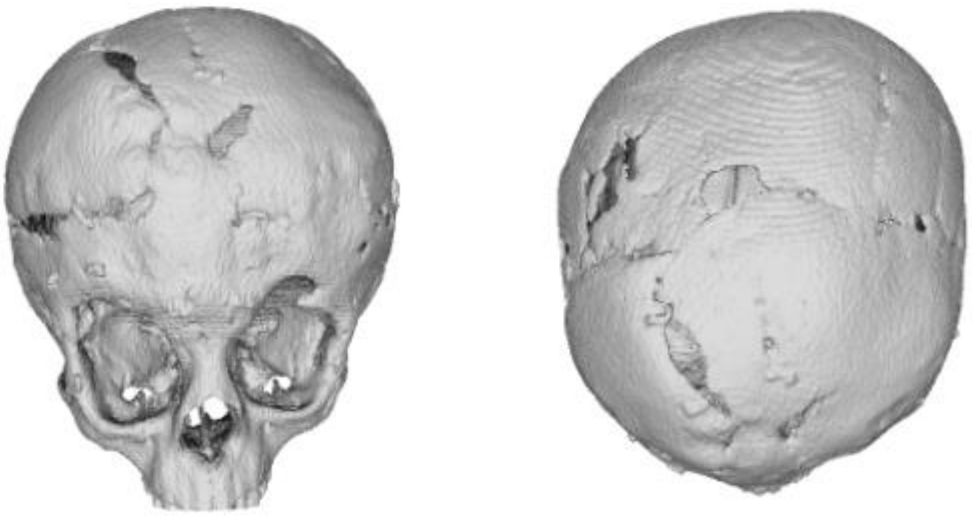
Skull Mesh



Right After Surgery

1-2 Years After Surgery

Skull Mesh



1-2 years After Surgery

Did it work?

Motivation

- Once the contours of an object are found, constructing the 3D model is a well-solved process in graphics.
- Osirix is a freeware program available to the public on the Apple Inc. Website. Biomedical Visualizers can use this software to visualize anatomical data sets and extract visual information for reference.
- Matlab has a function called meshgrid that does this in voxel space.
- Python has something similar.
- So, it's the correct FINDING of organs that's still the hard part.

Knowledge-Based Organ Identification from CT Images

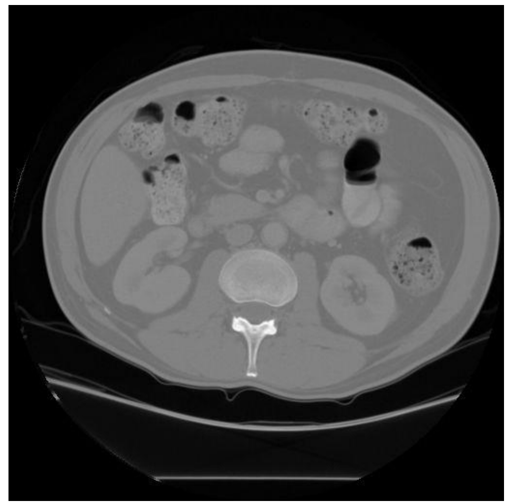
Masahara Kobashi and Linda Shapiro
Best-Paper Prize in
Pattern Recognition
Vol. 28, No. 4
1995

Motivation

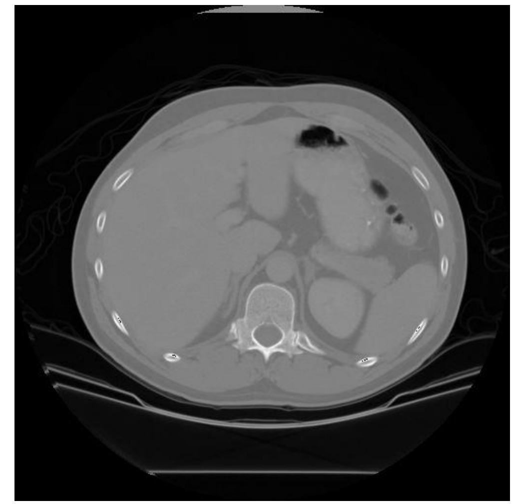
- The extraction of structure from CT volumes of cancer patients is an important first step in the creation of patient-specific models that can be used by treatment planning software to deliver maximal dosage to the tumor and minimal dosage to critical anatomical structures.
- Even today, no automatic techniques have been successful enough to replace the standard manual methods of outlining the organs.
- The goal of this work was to develop a knowledge-based recognition system that utilizes knowledge of anatomy and image processing to extract the organs from CT volumes.

3 CT Slices of the Abdomen

kidney.jpg



g006.jpg



e030.jpg

Where are the kidneys, liver, spleen, aorta, spine?

Major Features of the System

1. dynamic thresholding controlled by feedback

2. the use of negative shape constraints that

3. progressive landmarking that extracts organs in order of predicted success and uses already-extracted organs to help locate others

Difficulties in Segmenting CT Images

1. Regions produced by gray-tone-based segmentation procedures do not correspond to organs.
2. There are very few shape invariants for organs.
3. The absolute gray tones for each organ vary widely over difference instances.
4. There is no precise, objective ground truth for performance evaluation (in our study).

Observations

- Two different organs can have the same or very close gray tones in CT images

- Most human organs have few computable and stable shape invariants.

Shapes of a kidney in different CT slices.

More Observations

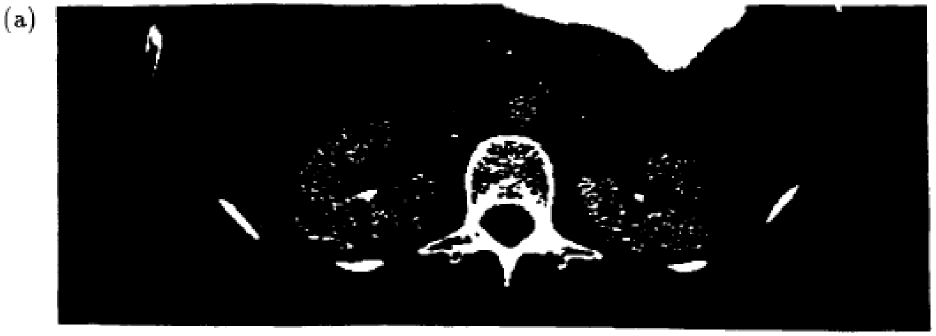
- Each organ has a fairly stable vertical and horizontal location.
- The ordering of organs by their gray tones is fairly stable, even though their absolute gray tones vary widely.
- Each biological substance has a relatively narrow range of gray tones.
- But CT image analysis is simpler than many outside-world computer vision domains.
- And there are relatively small numbers of objects in each image.
- There are some very stable landmarks: spine and aorta.

Specific Organ Properties to Use

1. position in the ordering of gray tones among organs
2. relevant gray-tone range
3. height of gray-tone cliff (related to range of thresholds)
4. location in terms of stable landmarks: aorta and spine
5. adjacency with other organs
6. size in terms of expected area in a slice
7. overlap ratio with other slices
8. positive and negative shape constraints

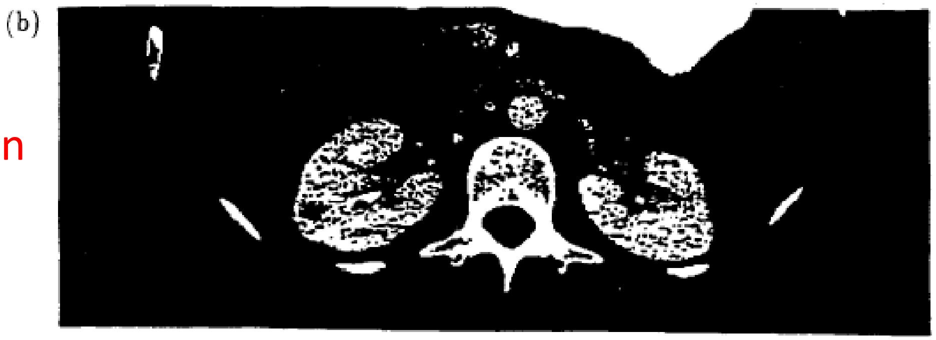
Idea of the Dynamic Thresholding

too high



(a) results of thresholding at the initial (highest) threshold for kidneys

3 steps down



(b) at 3 steps, the kidneys become detectible

too far

(c) at 11 steps, both kidneys connect with other organs

Steps of the Procedure

1. Set the initial threshold to the high end of the relevant gray tone range for the organ of interest.

   From the second iteration on, this threshold will be reduced by a constant value (10 was used) in each iteration.

   If the threshold reaches the low end of the range with no candidates, other methods are invoked.

Steps

2. Threshold the image with the current threshold.

3. Perform connected components to produce a set of regions.

4. AREA CHECK: Check if there is a region of acceptable size in the search area for the organ of interest. If not, go back to step 1.

5. LOCATION CHECK: Check if any candidate regions satisfy the location condition for the organ of interest. If so, record them, else go back to step 1.

Steps

6. SHAPE CHECK: Check if there is among the candidates one that satisfies the positive shape constraints (for the aorta and spine) or the negative shape constraints (for the rest).

   Negative shape constraints include
   - abnormal size
   - abnormal extension
   - vertical and horizontal lengths
   - vertical/horizontal ratio

Concept of a Negative Shape Constraint: Shapes that are NOT Kidney

Fig. 2. Concept of negative shape constraints. Clearly these shapes are not of kidney's. Each of the above three shapes is formed by connecting a kidney with other organs/tissues. Such connections take place if two low a threshold is used in thresholding.

Steps

7. OVERLAP CHECK: check if there is a candidate region that satisfies the overlap condition with an already-segmented adjacent slice. Else go to step 1.

   The minimum required overlap is 50% of the smaller region.

8. COLLISION CHECK: Check if there is a candidate region that does not collide with other recognized organs. Else go to step 1.

9. CHOOSE BEST: Choose the best candidate region.

Steps

10. SLOPE CHECK: Check the change in area with change in threshold. Look for the flattest part of the curve that has acceptable area. Choose the midpoint as the threshold.

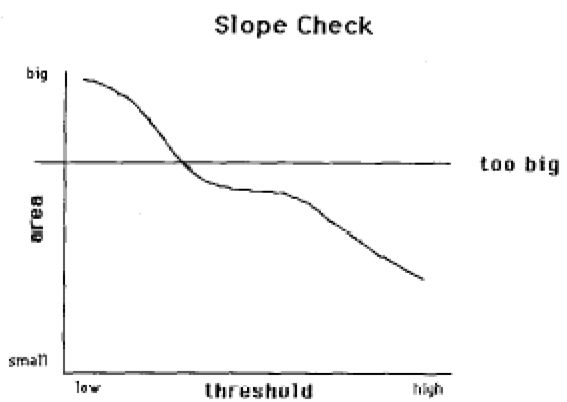


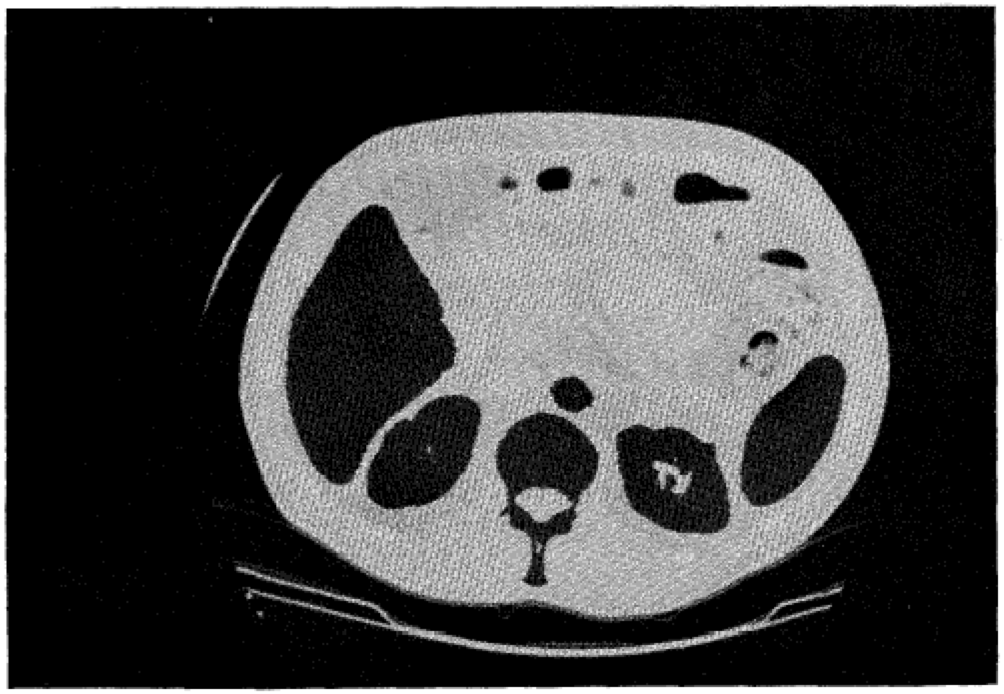
Fig. 4. The slope check test.

Steps

11. MORPHOLOGICAL OPERATIONS:
    - Close with a disk of 3
    - Open with a disk of 5
    - Extract the regions that satisfies the conditions
    - Close the extracted region with a disk of 3

    The result is output as the organ of interest.

Some Results: Labeled as Grade A, B, or C

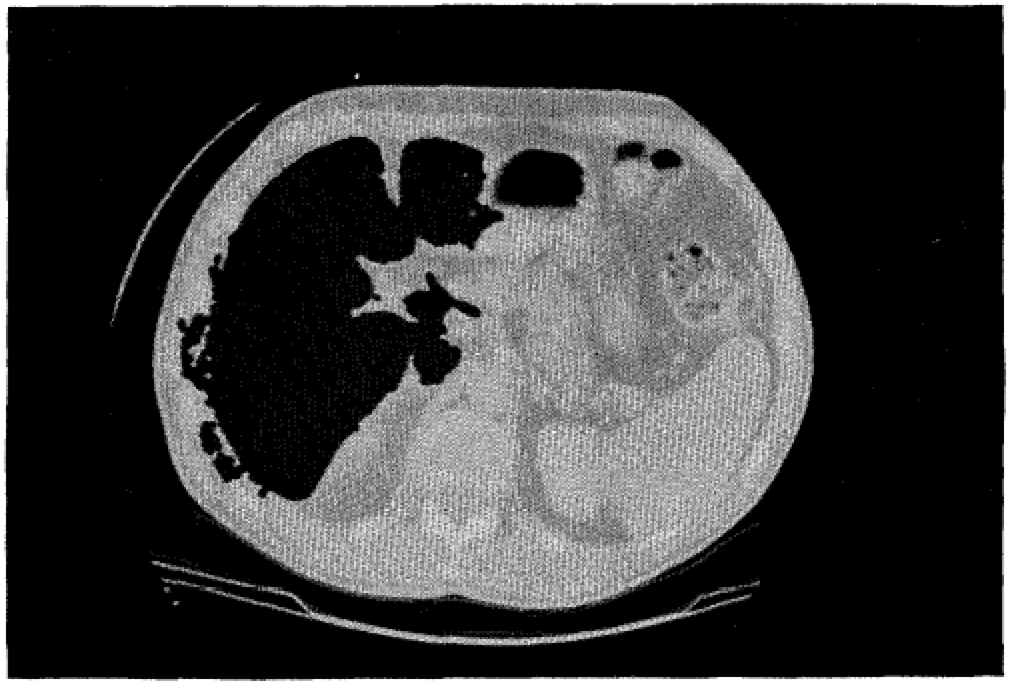


(b)

Fig. 5. Grade A extraction of all organs. (a) Original image. (b) Homogeneous dark regions are kidneys, liver (leftmost), spleen (rightmost), aorta (round one in the center) and a part of spine.

Grade A: Comparable to human dosimetry within a 5 pixel mismatch.

Some Results: Labeled as Grade A, B, or C

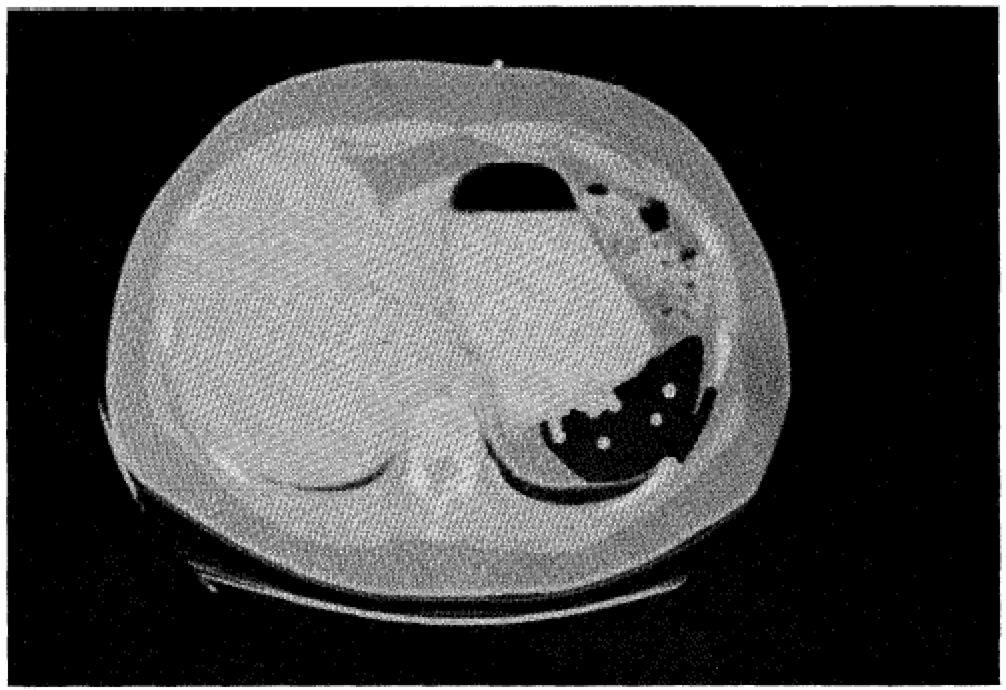


(b)

Fig. 6. Grade B extraction of liver. (a) Original image. (b) Homogeneous dark region is the extracted liver.

Grade B: Worse than A, but at least 70% correct.

Some Results: Labeled as Grade A, B, or C

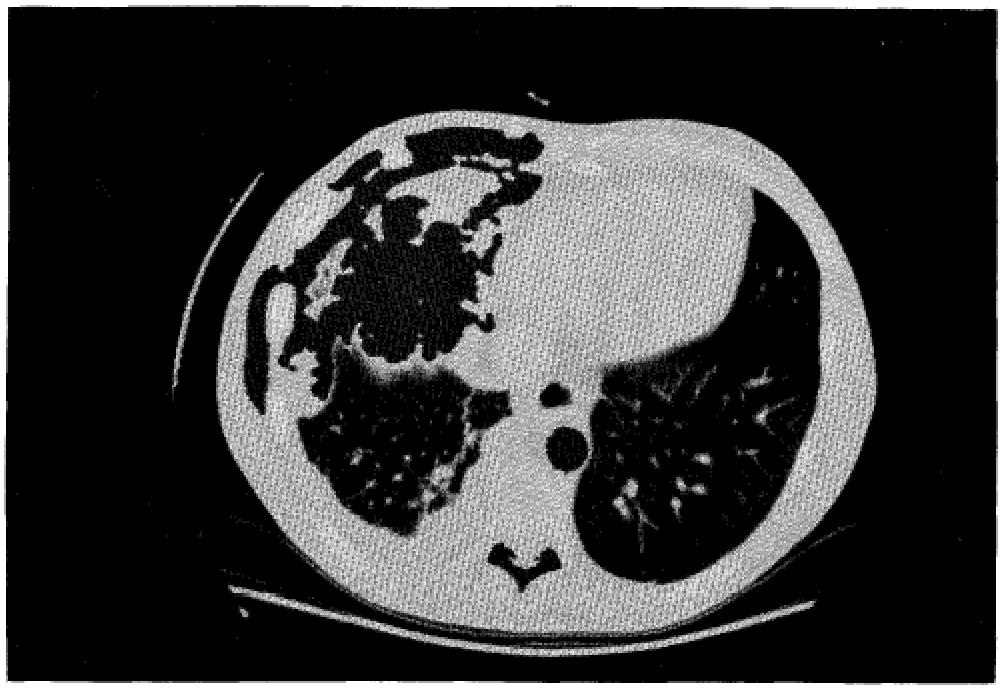


(b)

Fig. 7. Grade B extraction of spleen. (a) Original image. (b) Homogeneous dark region is the extracted spleen.

Grade B Spleen

Some Results: Labeled as Grade A, B, or C

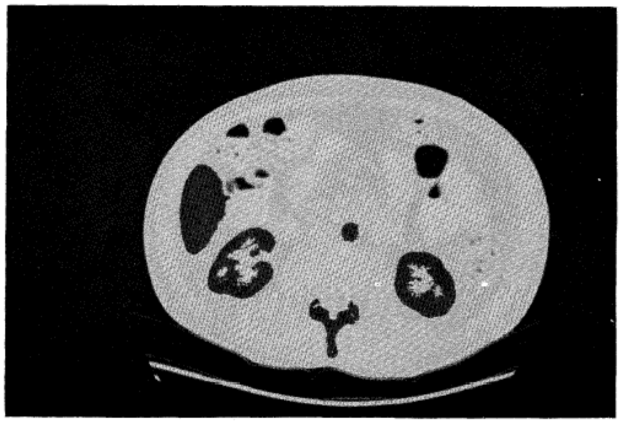


(b)

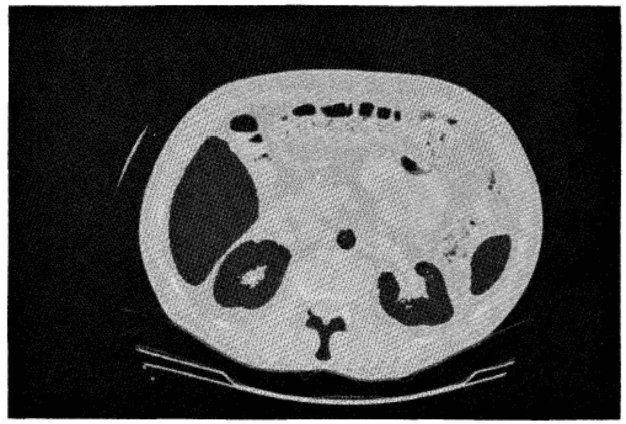
Fig. 8. Grade C extraction of liver. (a) Original image. (b) Homogeneous dark region is the extracted liver.

Grade C: Less than 70% correct.

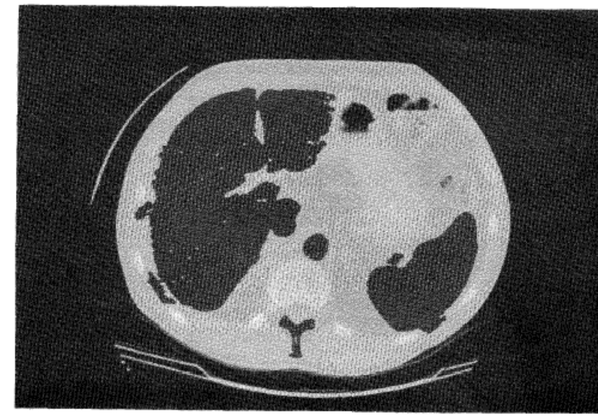
Extraction from 3 Slices



low-level slice



mid-level slice



higher-level slice

Comparison

	Grade A	Grade B	Grade C
Kidneys	85%	0%	15%
Spleen	70%	6%	23%
Liver	52%	31%	17%

Possible Course Project

- Design and implement a semi-automatic system that finds and segments organs from CT or other images and produces 3D meshes from the slices of each organ.

- There are other methods in the literature now.

- There are public data sets, and we have a new private data set we're working on.