Research and development of CT, MRI, SPECT and PET images segmentation software for automatic detection and extraction of brain tumors using ITK, VTK, Qt

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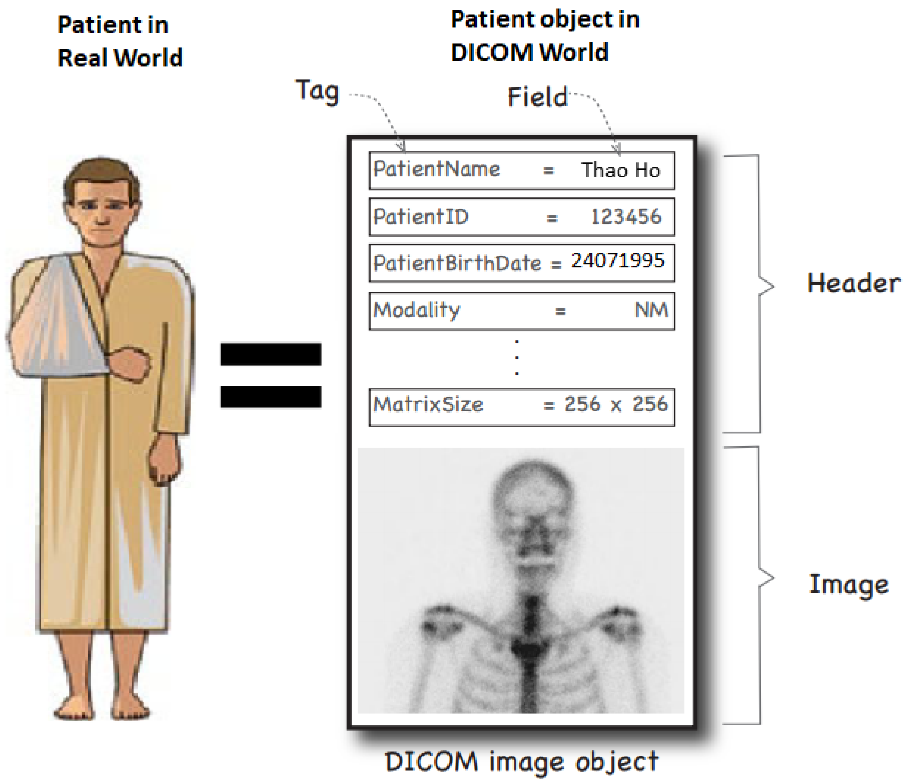
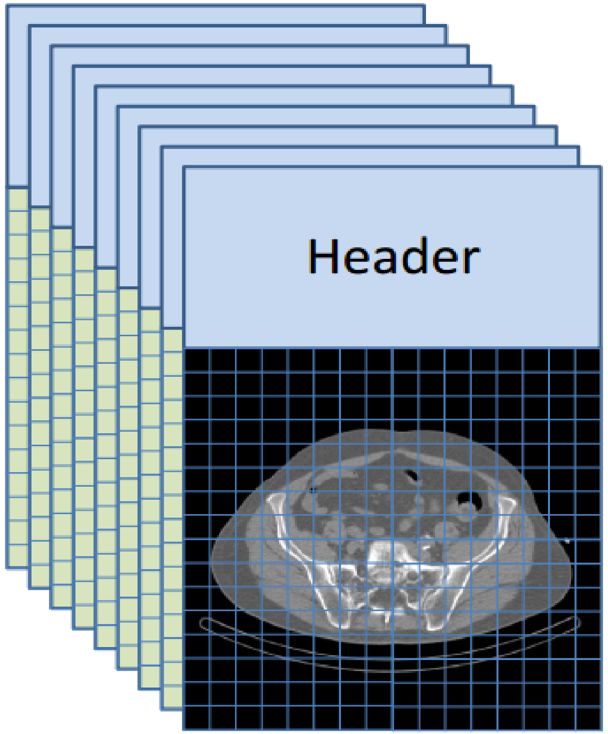
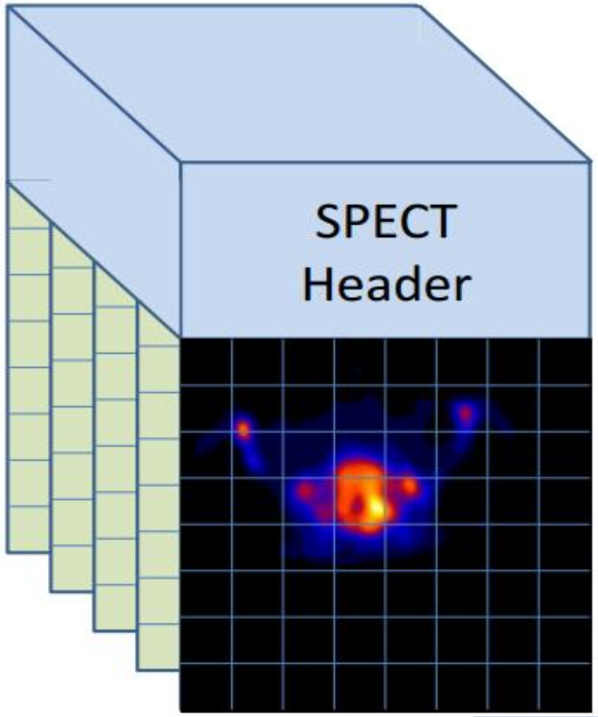
I.
Introduction
&
Motivation

What is DICOM?



What does a DICOM file look like?





- ***CT, MRI***

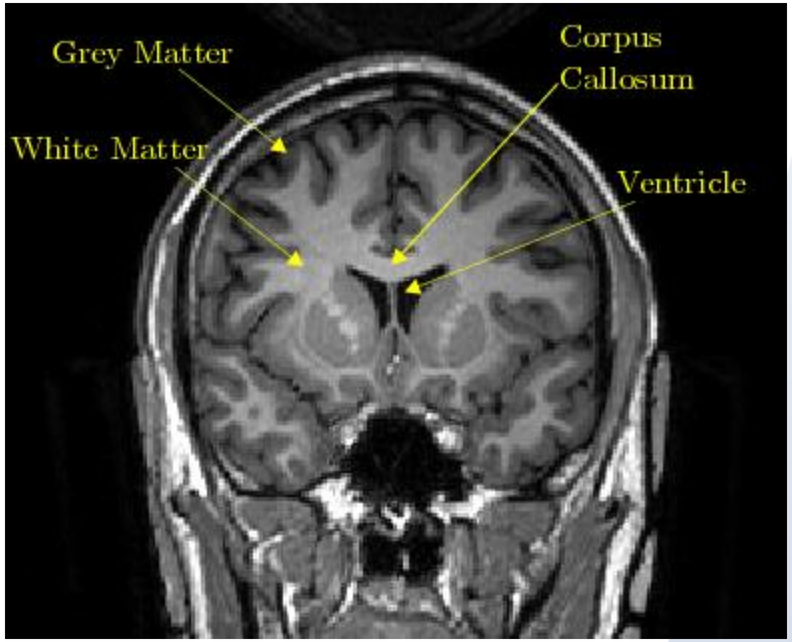
1 file = 1 slice. Each file includes a header and image data.

- ***SPECT, PET***

1 file for one header and all image data.

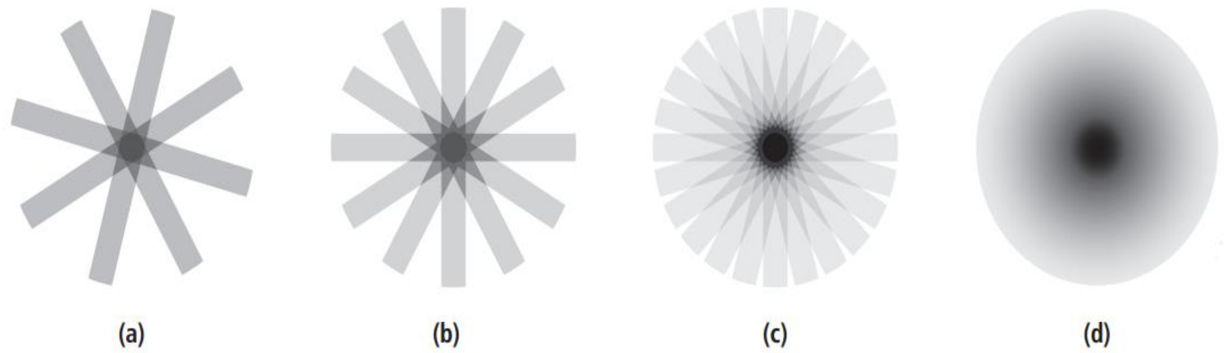
Brain diseases

- The difficulty in brain tumors segmentation lies in their irregularities in terms of shape, size, and location.
- Brain images include four areas: white matter, gray matter, cerebrospinal fluid and background. These areas have small HU index: gray matter: 35-45 HU, substance: 20-30 HU, cerebrospinal fluid: 0-10 HU, so the detection of edges for these areas is difficult.
- The state of medical image data (brain images) lacks association and dispersion; historical calculation and data reuse are not available; the demand for doctors has not met the demand for diagnosis.
- The accuracy depends on the knowledge and skills of the doctors.
- Currently there are many approaches used in many studies to distinguish the biological boundaries of DICOM images.



Artifacts:

- **Aliasing Artifact or Streaks:** These appear as dark lines which radiate away from sharp corners. It occurs because it is impossible for the scanner to take enough projections of the object.
- **Ring Artifact: T**he most common mechanical artifact, the image of one or many 'rings' appears within an image. This is due to a detector fault.
- **Noise Artifact:** This appears as gaining on the image and is caused by a low signal to noise ratio. This occurs more commonly when a thin slice thickness is used or when the kV or mA is too low.
- **Motion Artifact:** blurring, caused by patient movement.
- **Beam Hardening:** It occurs when there is more attenuation in the center of the object than around the edge. → This is easily corrected by filters.



In Vietnam:

➢Hospitals in Vietnam are equipped with many modern equipments: SPECT, MRI, PET, PET/CT, SPECT/CT,…

➢Many commercial software packages are available for processing and analyzing medical images such as **eFilm, 3D-Doctor, DICOMWorks, BrainSuite, Syngo, AVIA, Volumetrix Suite**,…Cons:

❑ **Exclusive from manufacturers (Siemens, Philips, GE, Toshiba, ...)**→In the case of processing two images obtained from two devices of different vendors, these software are not supported.

❑ **High price**

In the world:

Many groups are developing their own image processing software that is independent of the vendors and contains many advanced features, such as: **OsiriX; TIGRE Toolbox; MicroDICOM, RadiAnt DICOM Viewer, ITK-Snap**

II.
Experiment
&
Methodology

1. Proposing image segmentation method to extract brain tumors.

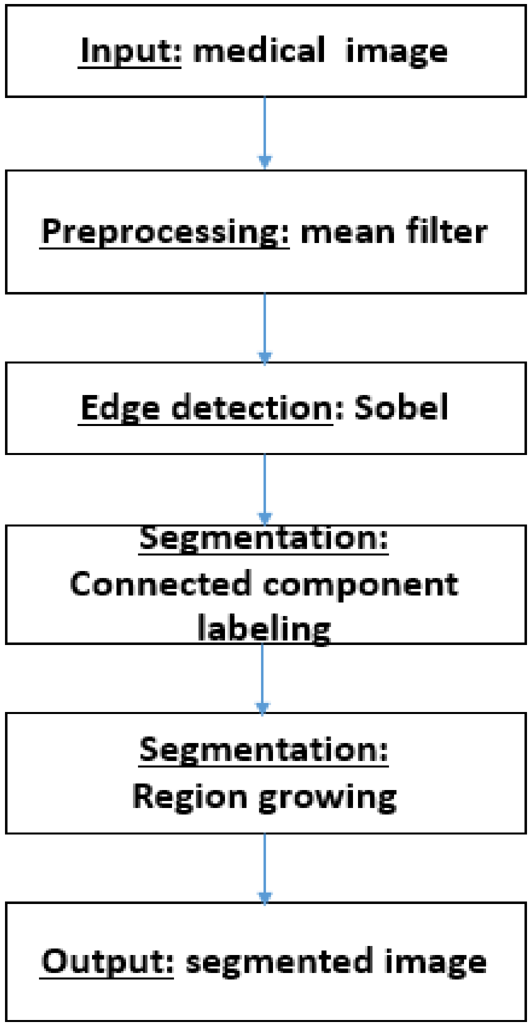


Figure 1: *Flowchart of the proposed method*

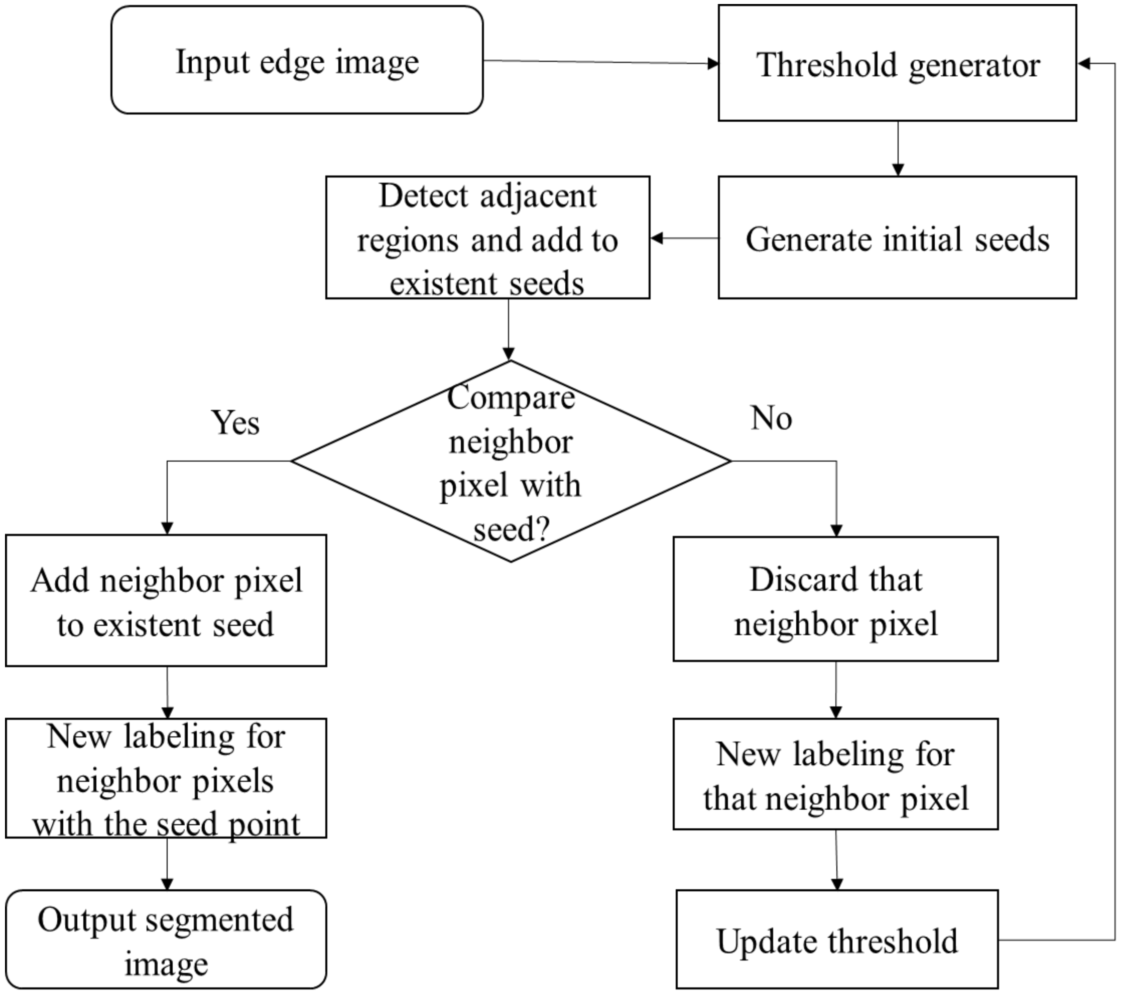


Figure 2: *Proposed image segmentation algorithm*

MSE and PSRN

In order to choose the suitable filters for proposed method, mean square error (MSE) (1) and the peak signal to noise ratio (PSNR) (2) indicators are used.

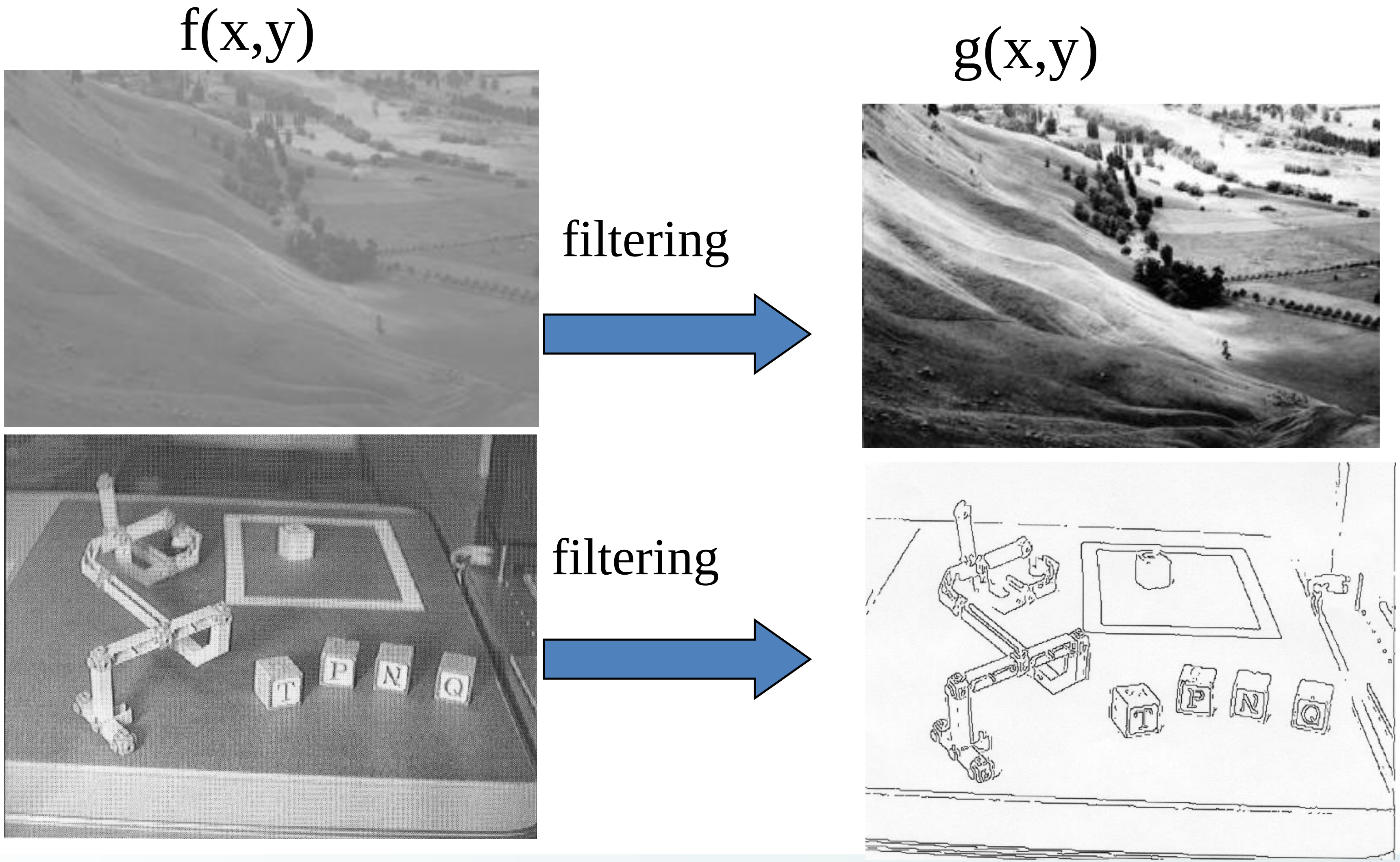
- MSE evaluates the similarity between borders obtained from computation and reality.
- PSNR calculations the peak signal to noise ratio between two corresponding pixels.

$$MSE = \frac{1}{NM} \sum_{i=1}^{N} \sum_{j=1}^{N} [f(i,j) - f'(i,j)]^2 \qquad (1)$$

$$PSNR = 10 log \frac{255^2}{MSE} \qquad (2)$$

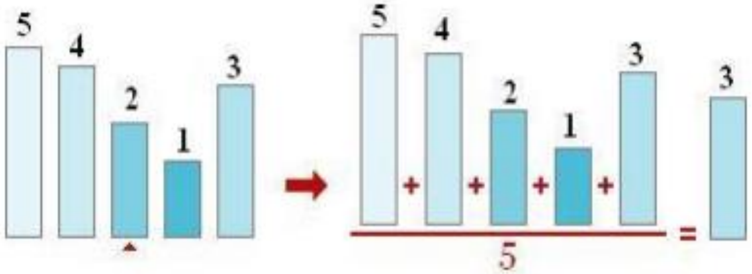
- ❑ This is used for two-dimensional images of the size M.N where f(i,j) and f'(i,j) are the original image and the restored image respectively. The higher of PSNR and lower of MSE, the better the quality of the segmentation.

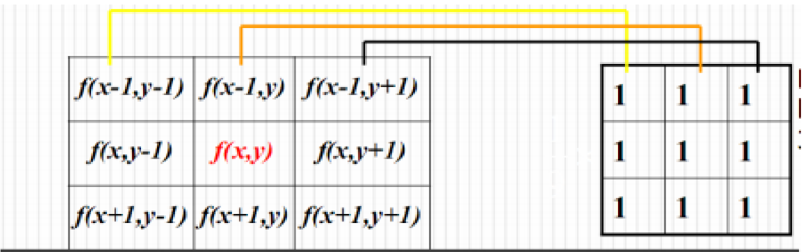
What is image filtering?



Prerpocessing (Mean filters)

$$H = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$





$$g(x,y) = \frac{1}{9}[f(x-1,y-1) + f(x-1,y) + f(x-1,y+1) + f(x,y-1) + f(x,y) + f(x,y+1) + f(x+1,y-1) + f(x+1,y) + f(x+1,y+1)]$$

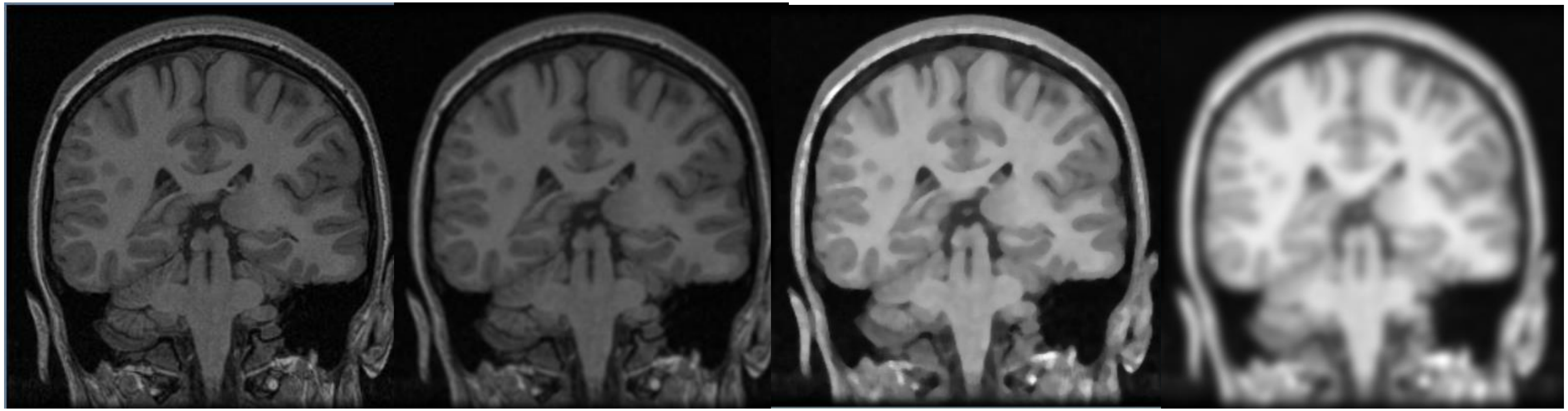
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	90	90	90	90
0	0	0	90	90	90	90
0	0	0	90	90	90	90
0	0	0	90	0	90	90
0	0	0	90	90	90	90
0	0	0	0	0	0	0
0	0	90	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

	0	10	20	30	30	30	20	10	
	0	20	40	60	60	60	40	20	
	0	30	60	90	90	90	60	30	
	0	30	50	80	80	90	60	30	
	0	30	50	80	80	90	60	30	
	0	20	30	50	50	60	40	20	
	10	20	30	30	30	30	20	10	
	10	10	10	0	0	0	0	0	
[redacted]									

Result

*Input : .dcm



Input Mean filter Median filter Gaussian blur

(.png)

Sobel method

Edge detection method:

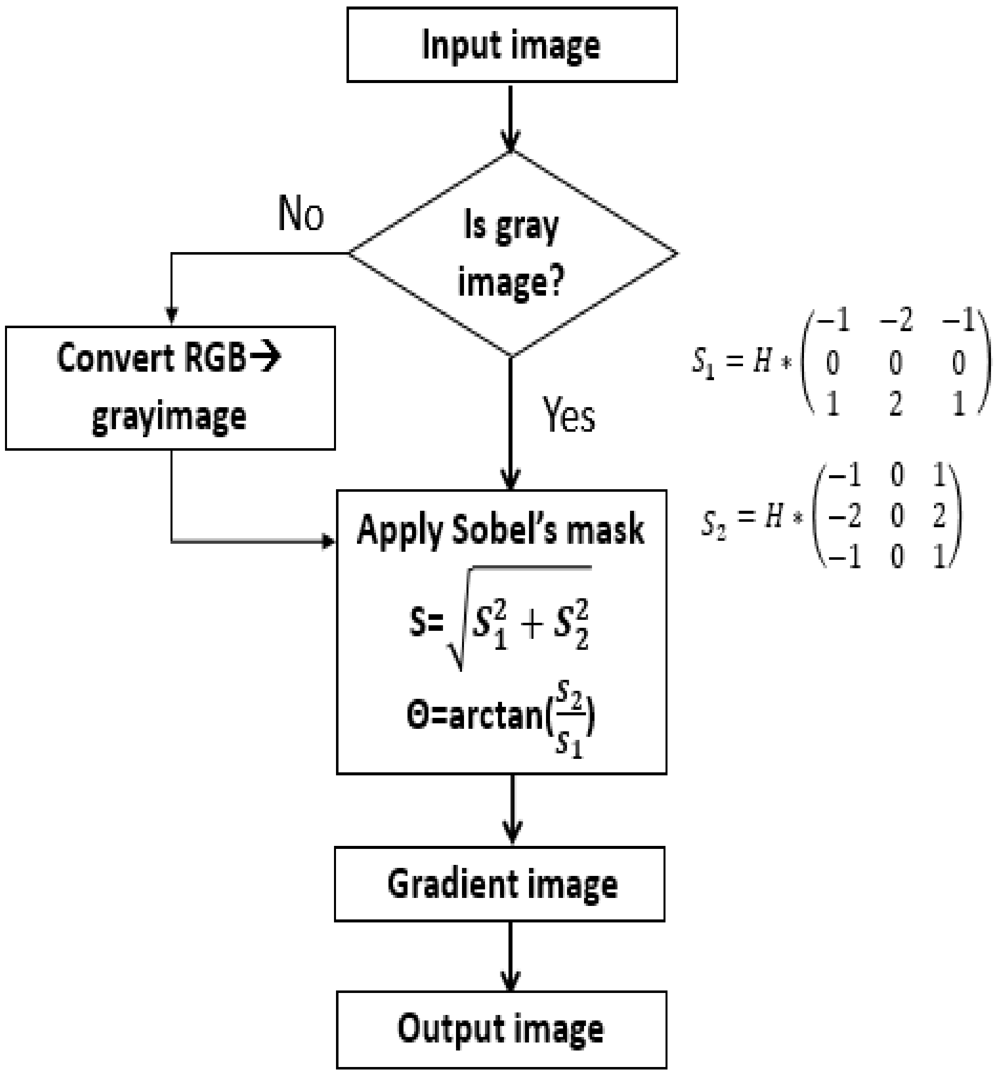
* **Direct:** find the edge based on the variation in the brightness value (grayscale) of the image. Mainly based on the technique of taking the derivative:

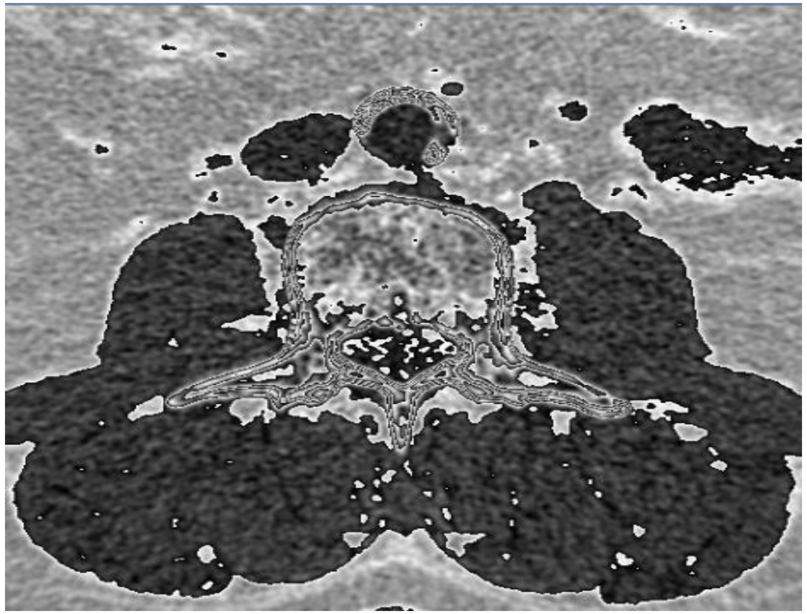
– Gradient method: Calculates the estimate of the gradient by using a smoothing and computation to determine the position of the edge (by finding the maximum and minimum values for the first derivative of the image).

– Laplace method: Secondary derivative to find edge.

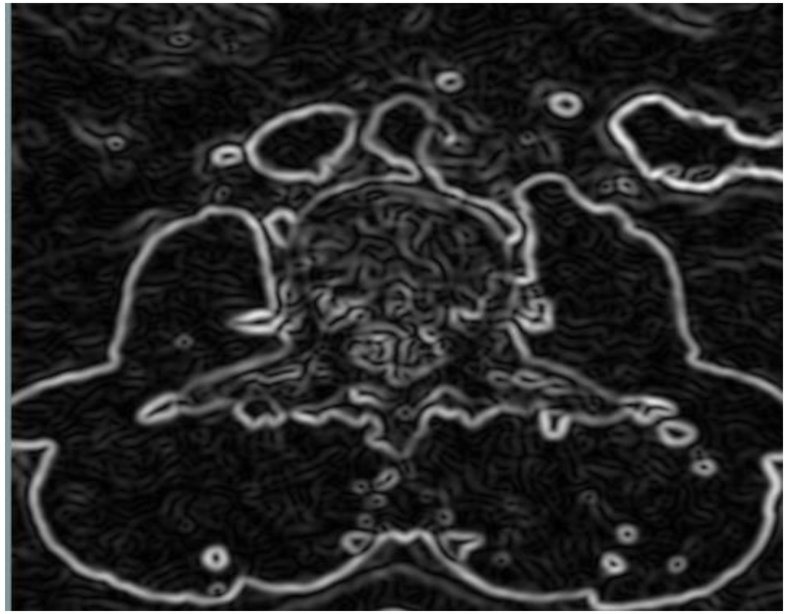
* **Indirect:** split the image into regions, the boundary between the regions is called edge.

→ Role: The boundary separates gray areas (colors). In contrast, use the image areas to find the separator.

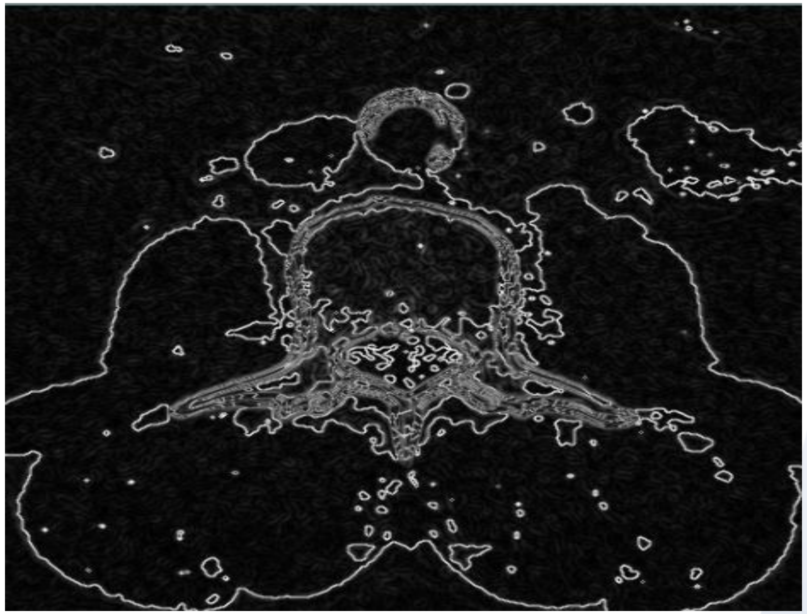




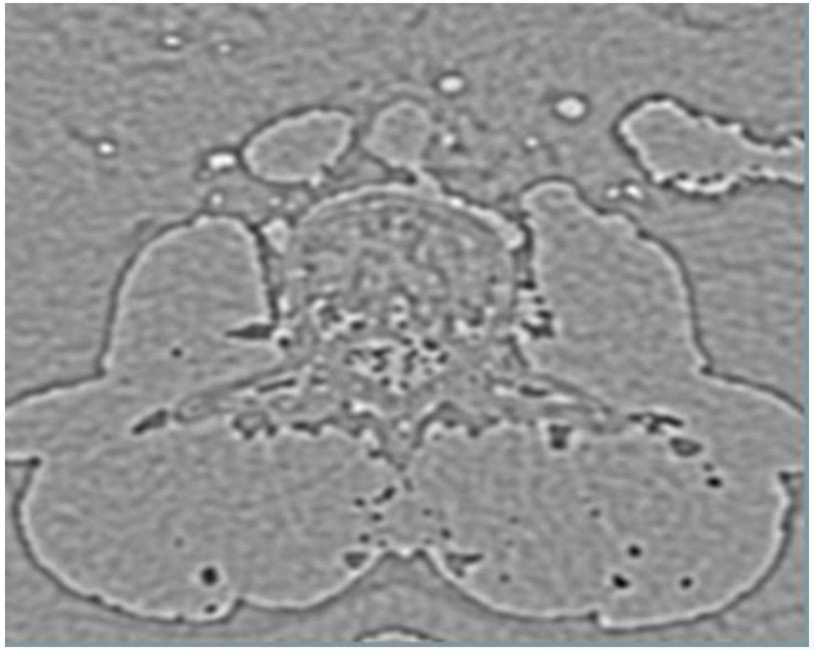
raw



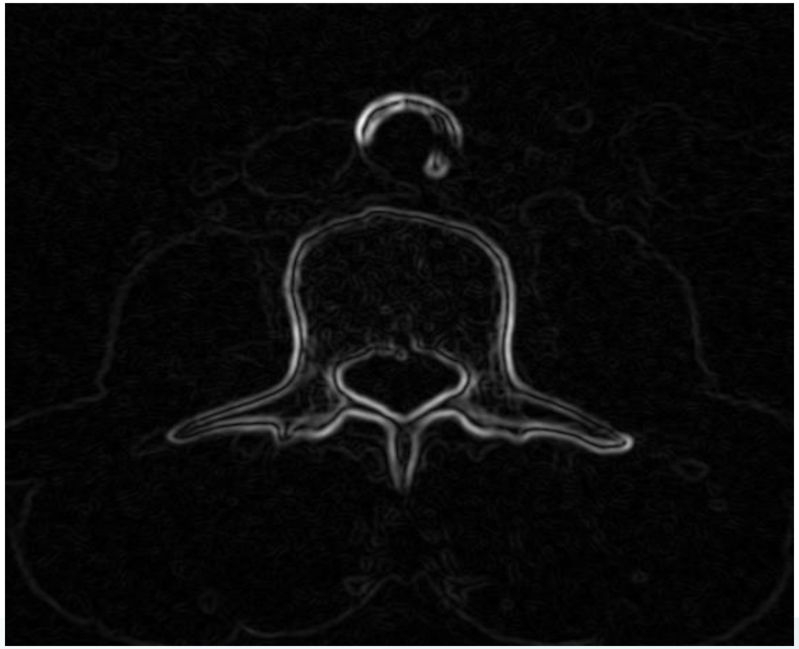
Gradient



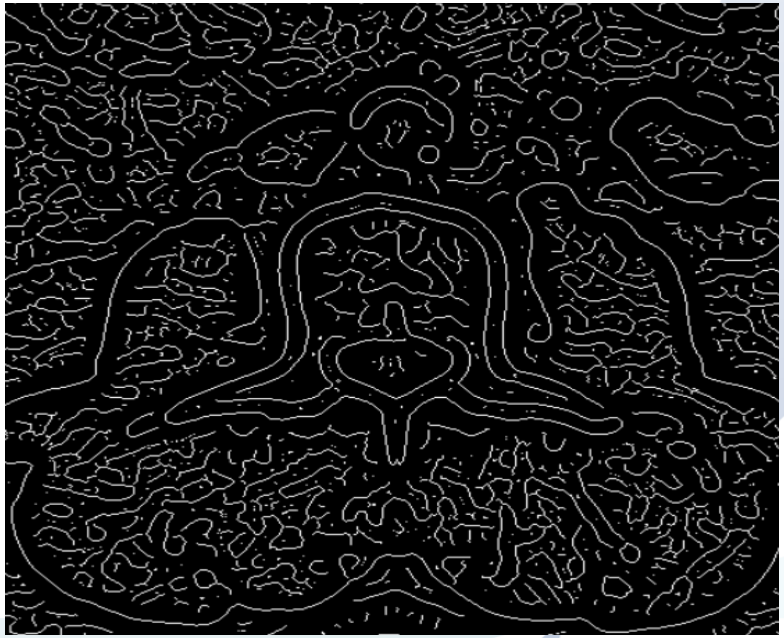
Gradient+ gauss



Laplace



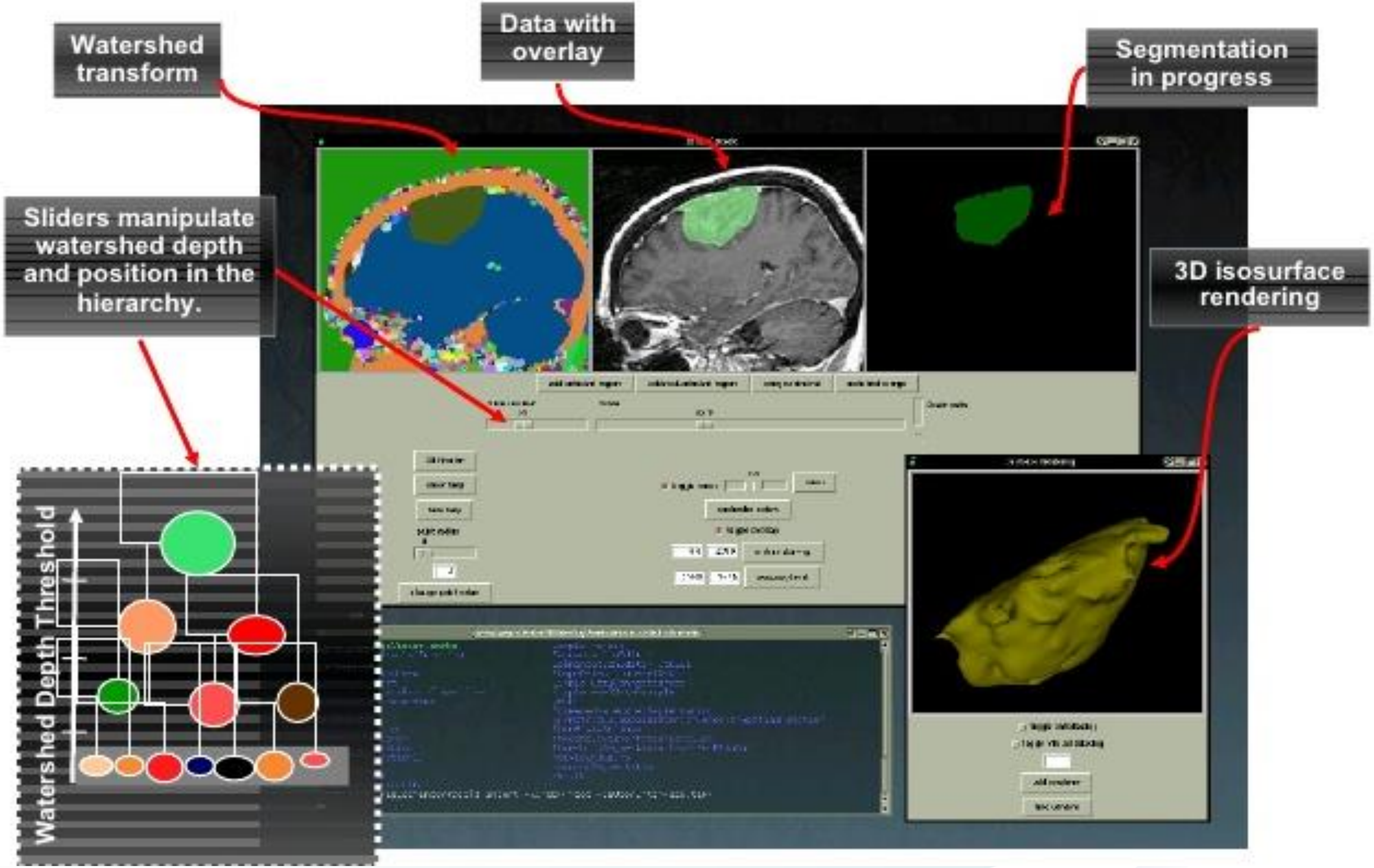
Sobel



Canny

III.
Results

Segmentation Editor



Segmentation results

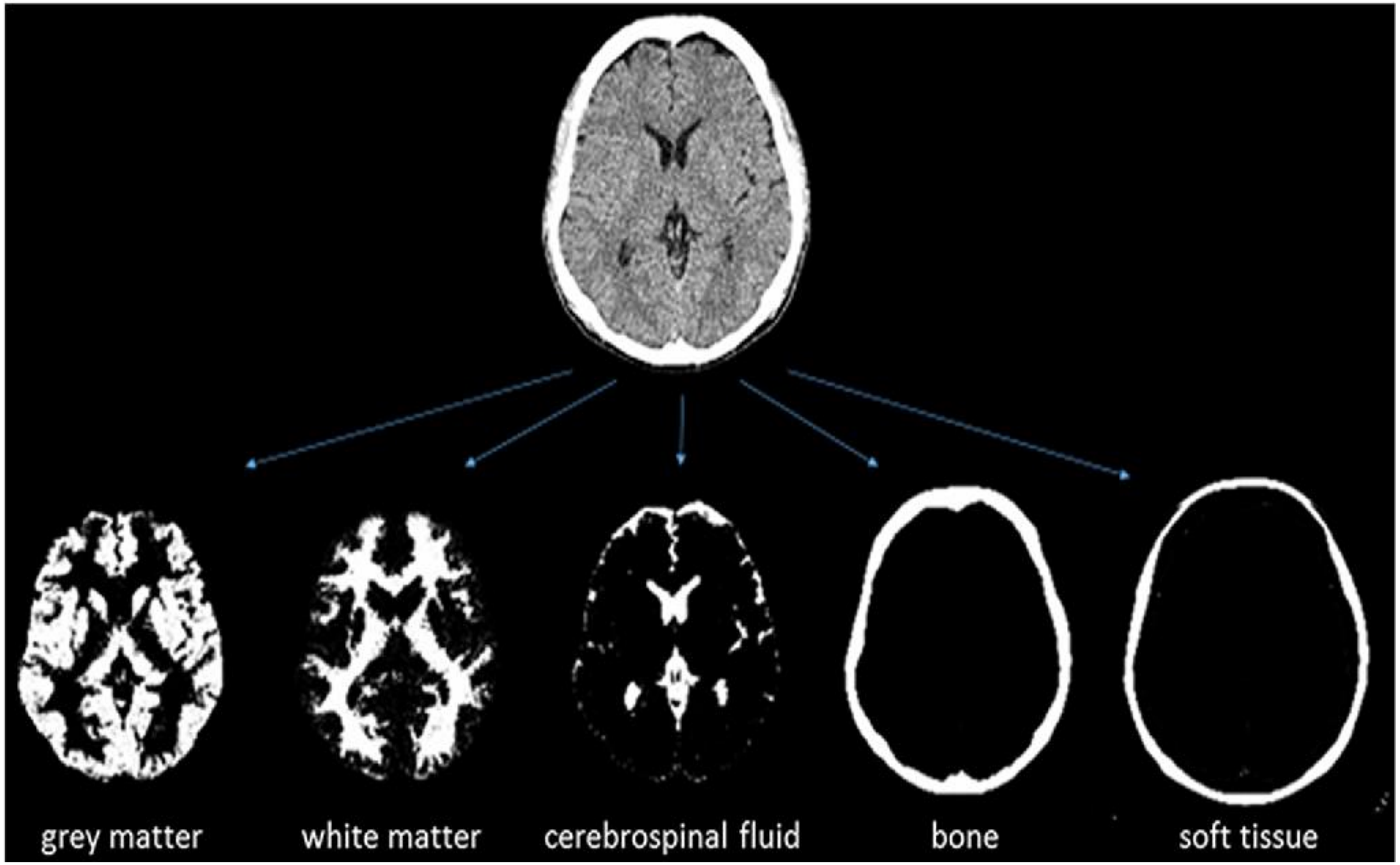
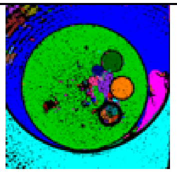
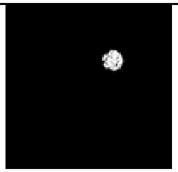
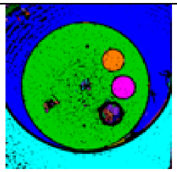
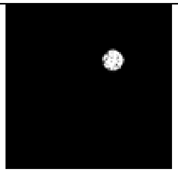
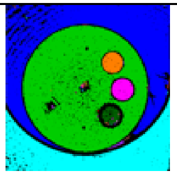
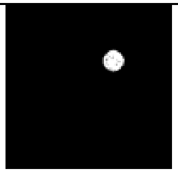
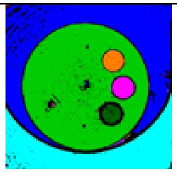
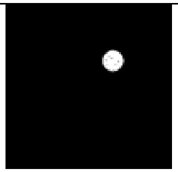
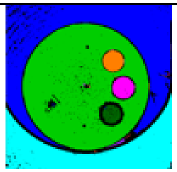
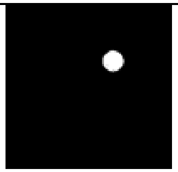
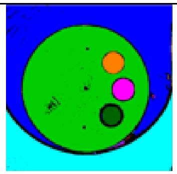
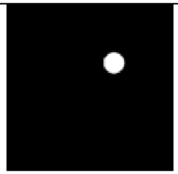
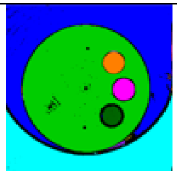
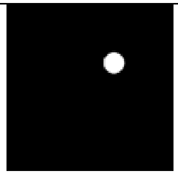
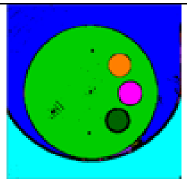
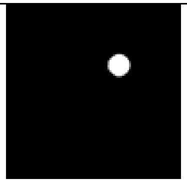
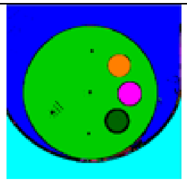
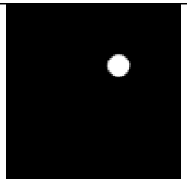
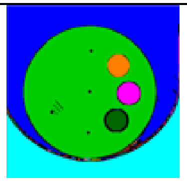
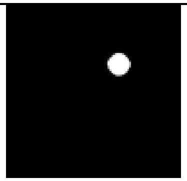
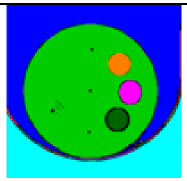
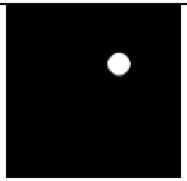
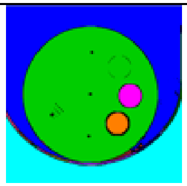
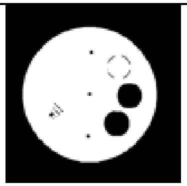


Fig 15. CT segmentation, automatically segments CT images into gray matter, whitematter, cerebrospinal fluid, bone,and soft tissue.

No.	The output image	Threshold value	Extration output image	Standard area of phantom	Caculated area (pixel)
1		*7*		9113	*7473*
2		*8*		9113	*7979*
3		*9*		9113	*8252*
4		*10*		9113	*8315*
5		*11*		9113	*8529*
6		*14*		9113	*8811*
7		***15***		**9113**	***9098***
8		*16*		9113	*9278*
9		*20*		9113	*9456*
10		*25*		9113	*9622*
11		*30*		9113	*9689*
12		*31*		9113	Unknown

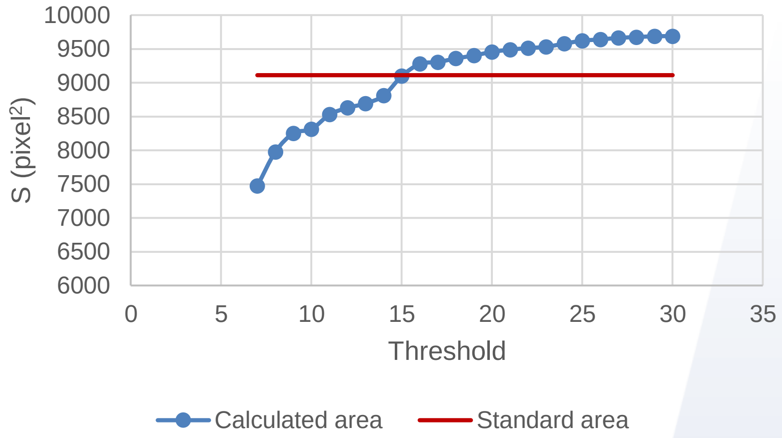


Figure 5: The graph shows the change of area by threshold.

Seed point	d(mm)	R (mm)	d(px)	$S(px^2)$
(297,145)	28.96	14.48	108.72	9284
(328,227)	29.07	14.54	109.87	9480
(291,307)	28.85	14.43	107.91	9146

Table 2: Results of seed points, area of 3 round holes extracted within the threshold range of 8 to 30. The results of the three areas on the phantom are 9284 pixels^2, 9480 pixels^2, and 9146 pixels^2, roughly the same as the area recorded on the phantom 9113 pixels^2. Accurate rates are 98.12%, 95.96% and 99.64%, respectively.

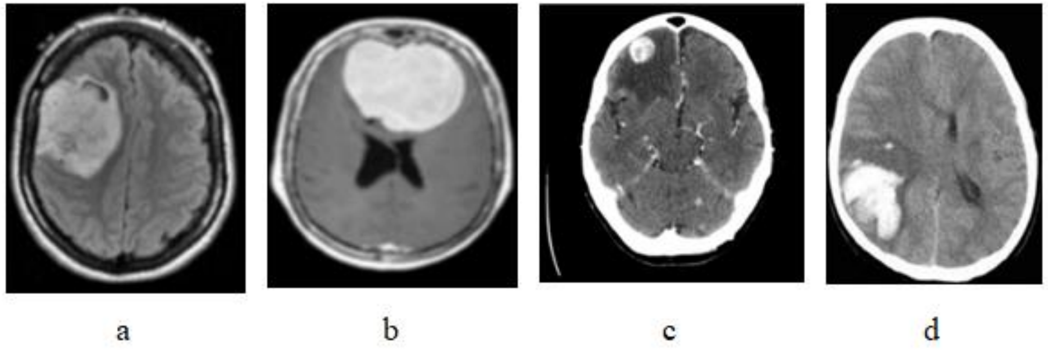


Figure 3.7. Preprocessing mean filter

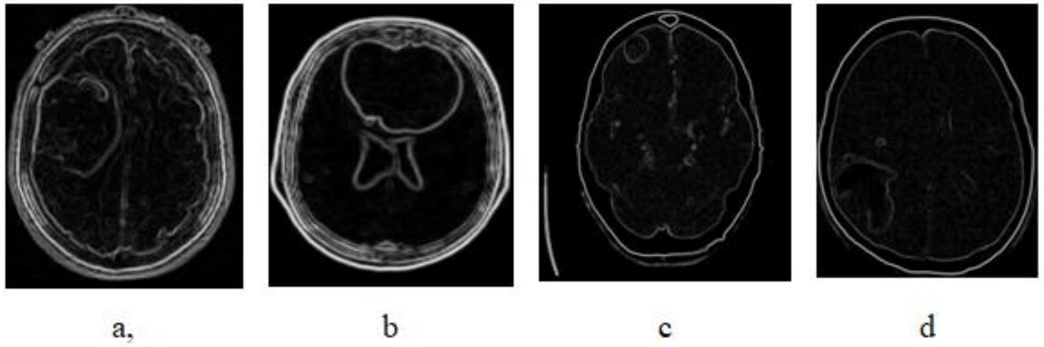


Figure 3.8. Sobel edge detection.

Table 3: Area of the extracted tumor

Images	Original size (pixel)	Area in pixel	Area of tumor	Mean (%)
Image 1	205 x 246	50430	10174	95.34
Image 2	409 x 537	219633	32829	92.75
Image 3	480 x 480	230400	1552	93.32
Image 4	441 x 521	229761	9257	91.39

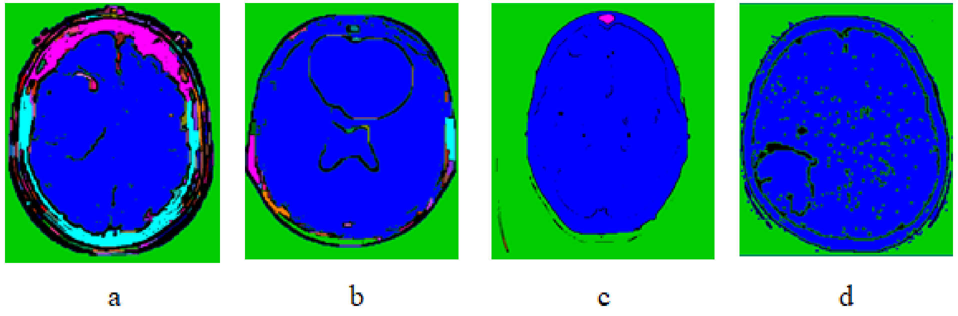


Figure 3.9. Connected component without using Sobel.

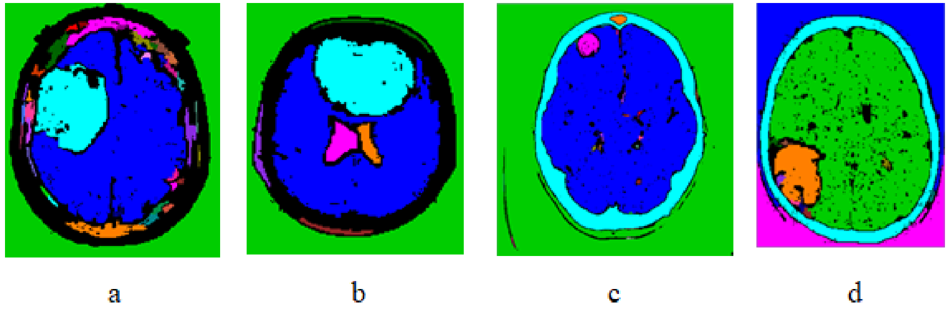


Figure 3.10. Connected component using Sobel.

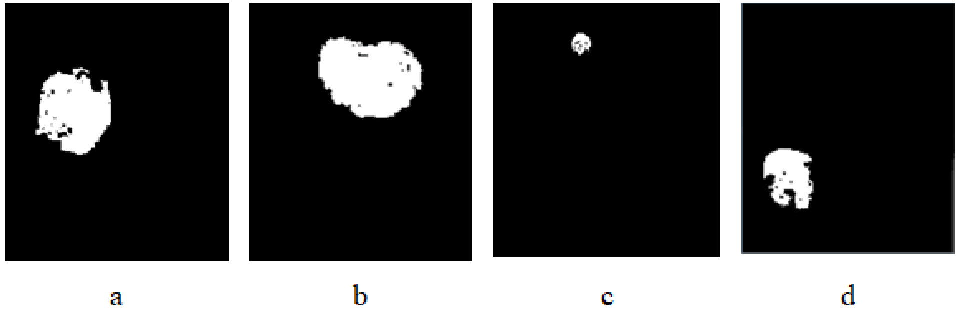


Figure 3.11. Segmented images after using region growing.

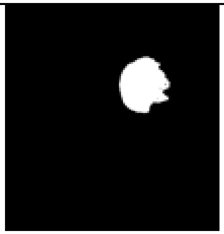
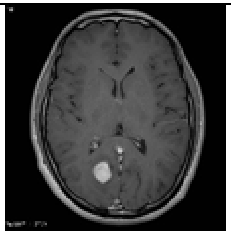
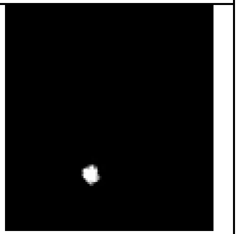
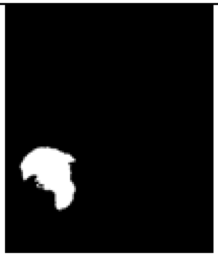
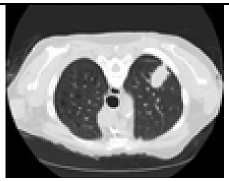
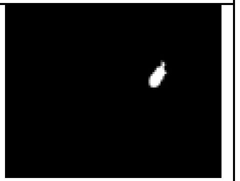
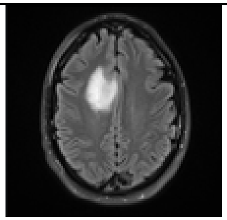
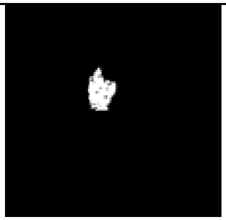
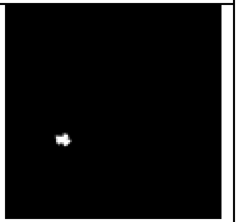
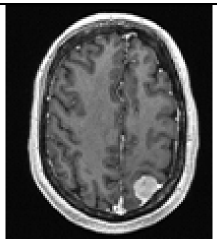
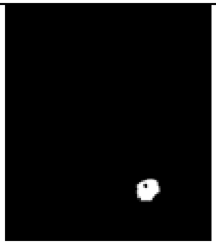
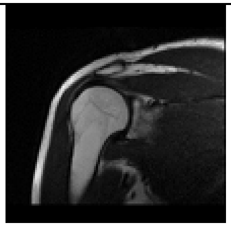
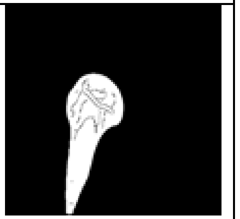
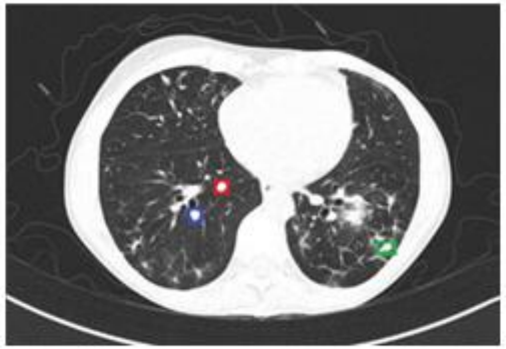
No.	Image	Confident connectecd	No.	Image	Confident connectecd
1		 238-137	5		 217-427
2		 99-354	6		
3		 196-202	7		
4		 307-391	8		

Table 4: Results of brain tumor extraction 1, 2, 3, 4, 5 and lung tumor 6, tumor in liver 7 and extraction of interest area 8 of region growing method.



a, Lung image with 3 locations suspected of tumor being marked

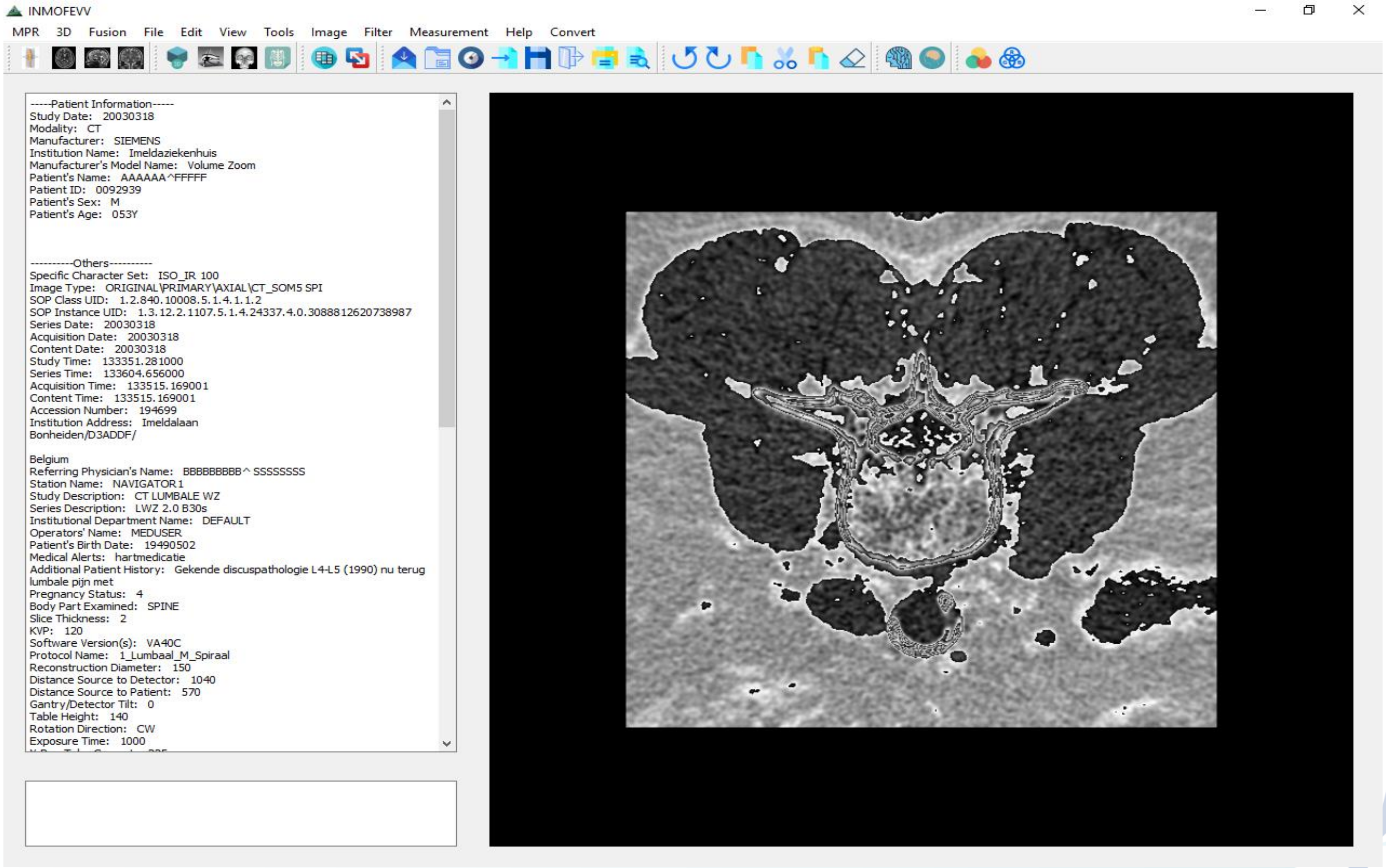
b, Extract the first tumor (red)

c, Extract the second tumor (red)

d, Extract the third tumor (green)

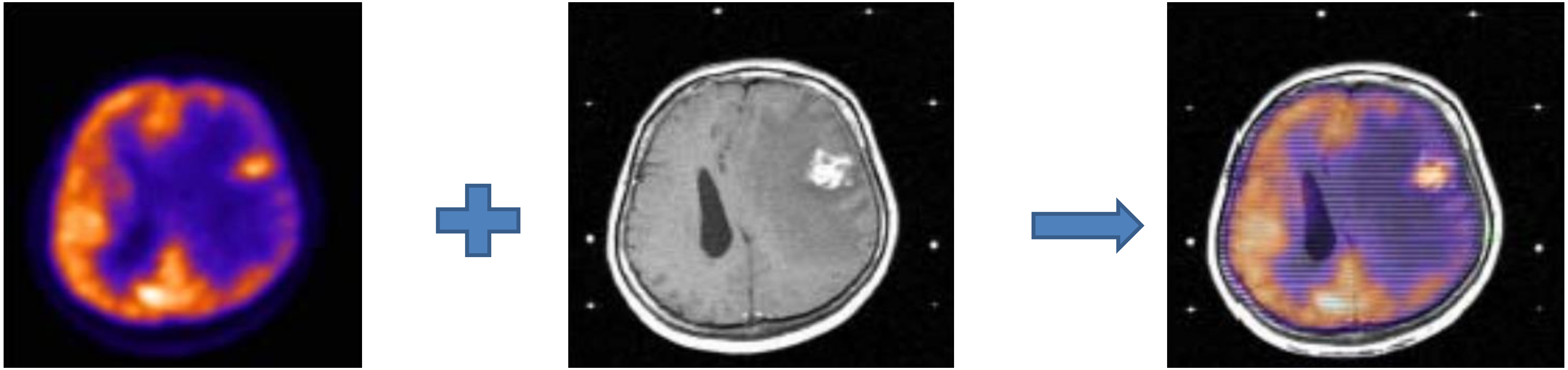
Figure 3.13. The results of extracting large and small brain tumors use the proposed fragmentation method on lung images.

2. POCTA Software

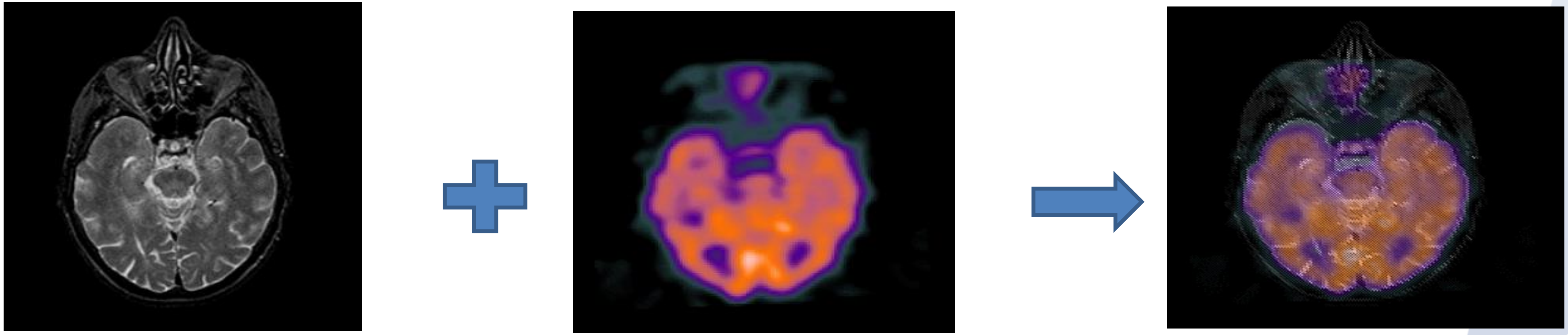


Fusion

PET+MRI

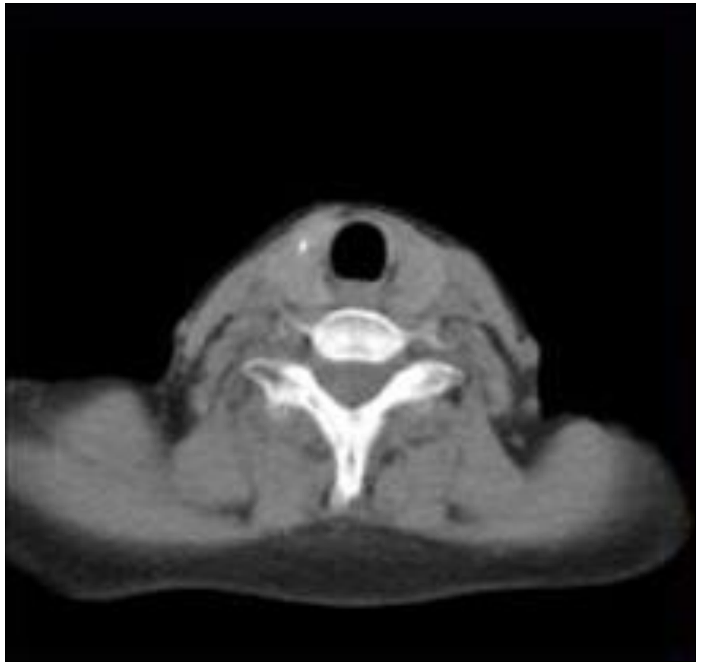


MRI+SPECT

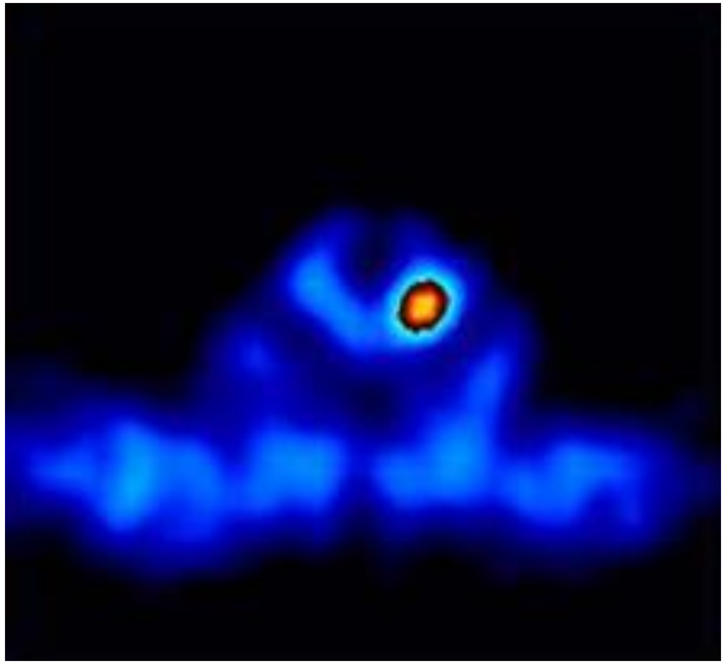


- **Development of SPECT and CT ;PET and CT fusion tools to produce SPECT/CT, PET/CT images (anatomical and functional images) →** This leads to a more accurate determination of the location, volume and mass of brain tumors and lesions in relation to surrounding tissues, overcoming the disadvantages of fusion with <u>different positions and doses</u>.

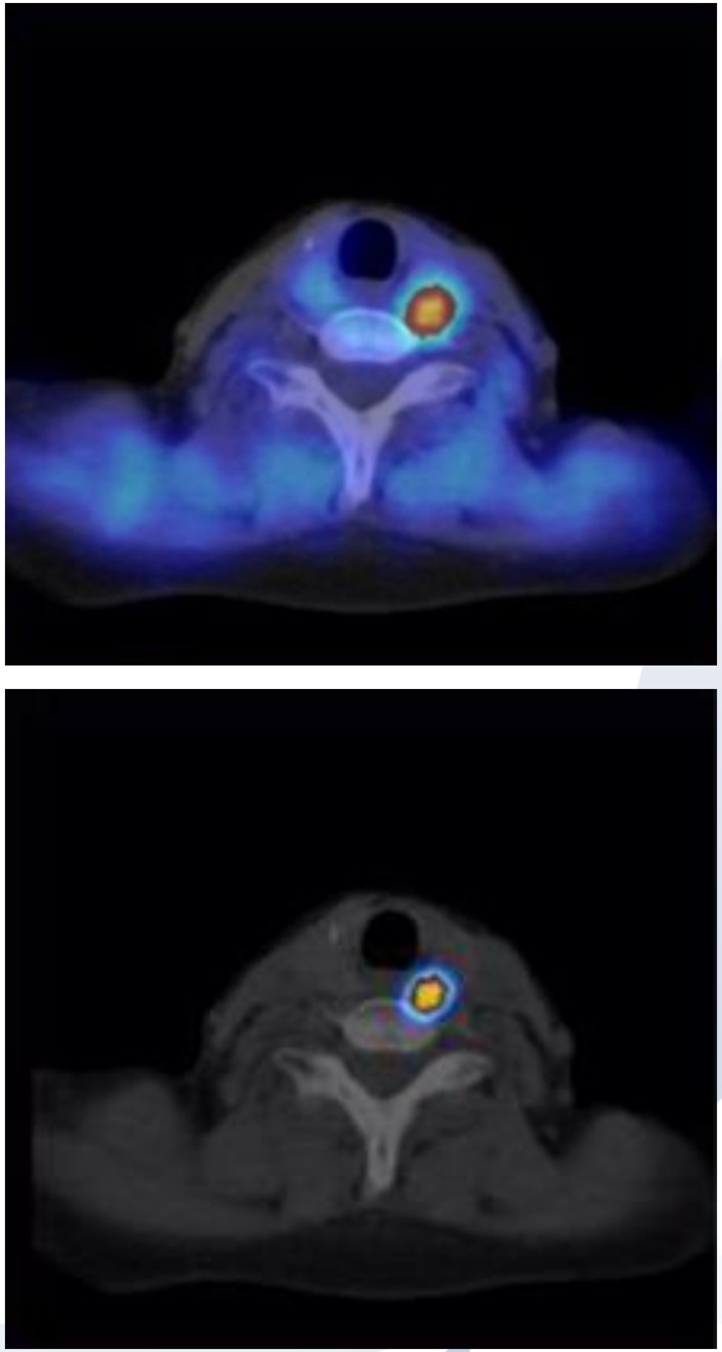
Fusion



CT

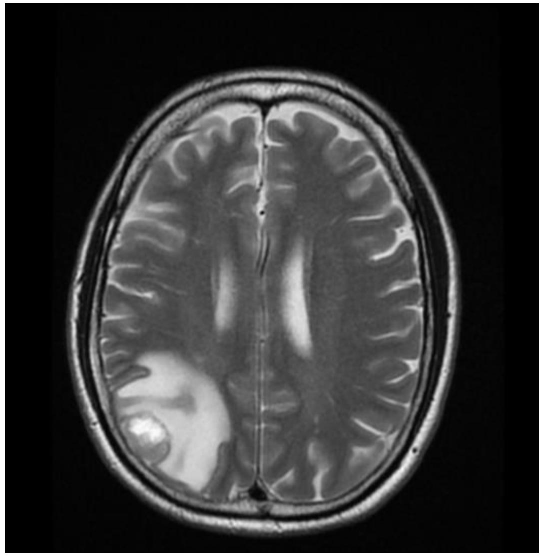


SPECT

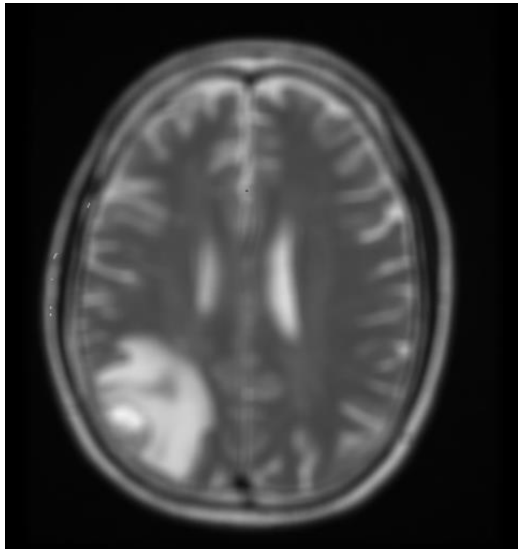


SPECT-CT

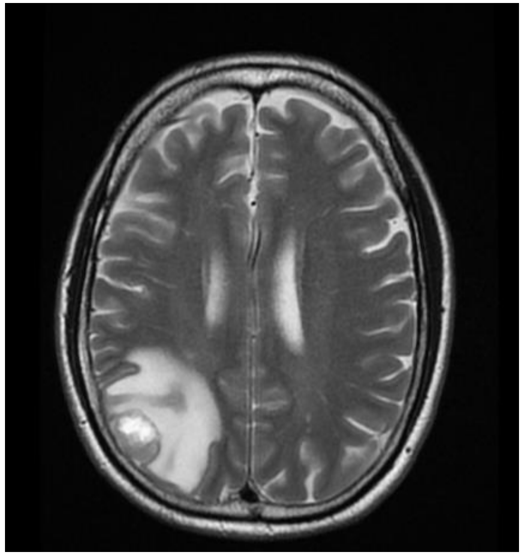
Filters



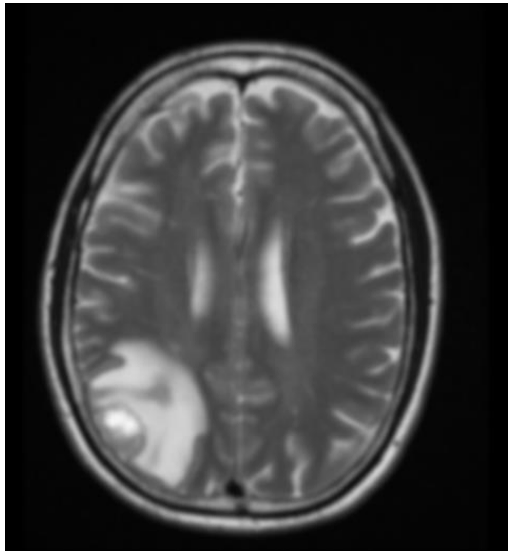
Raw



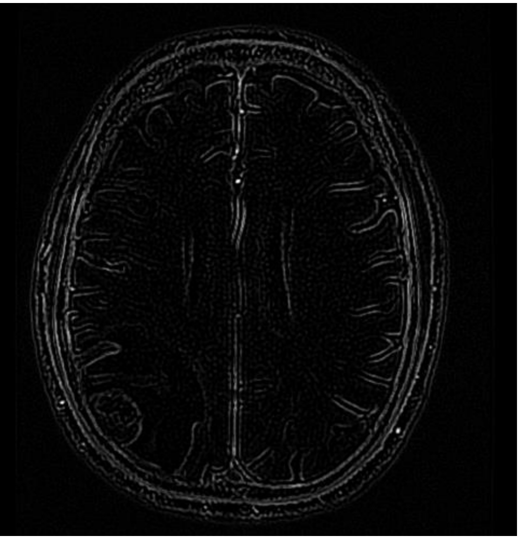
meadian



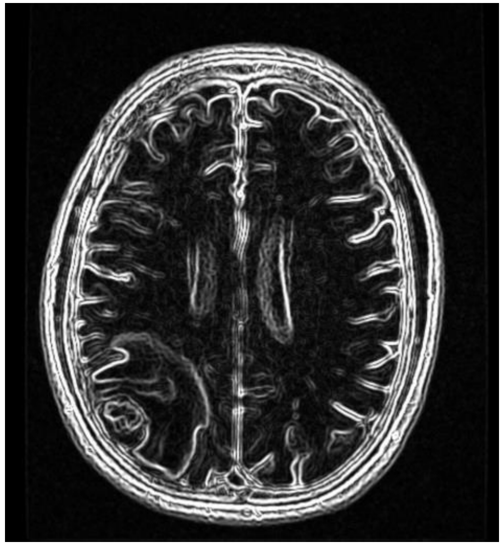
laplace



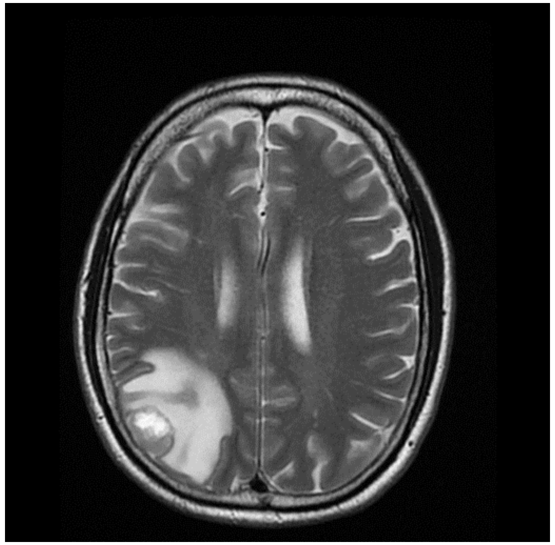
Laplace of gauss



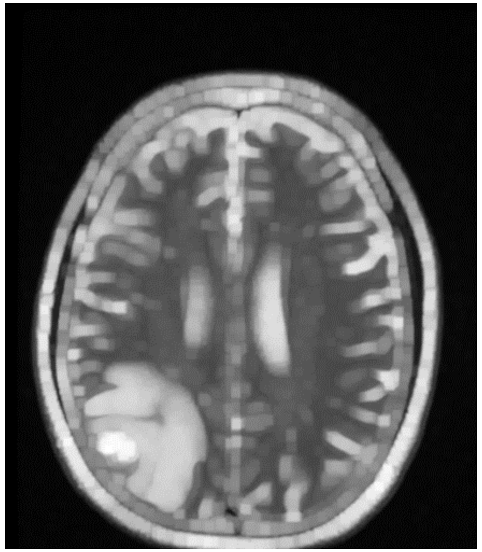
canny



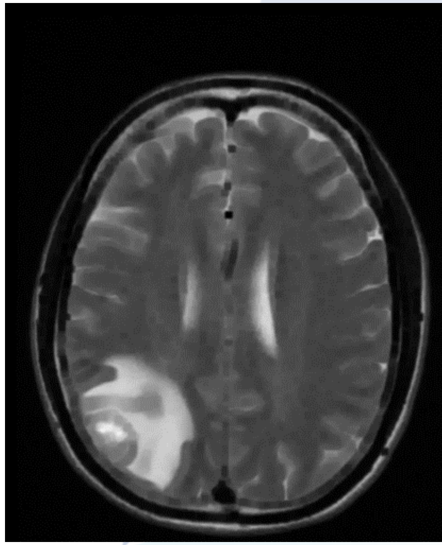
sobel



sharpen

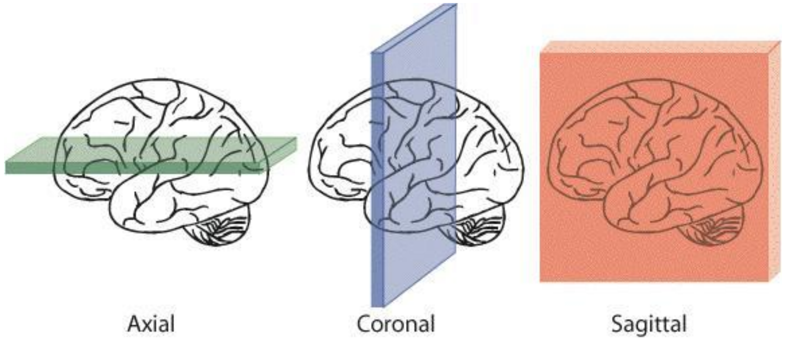


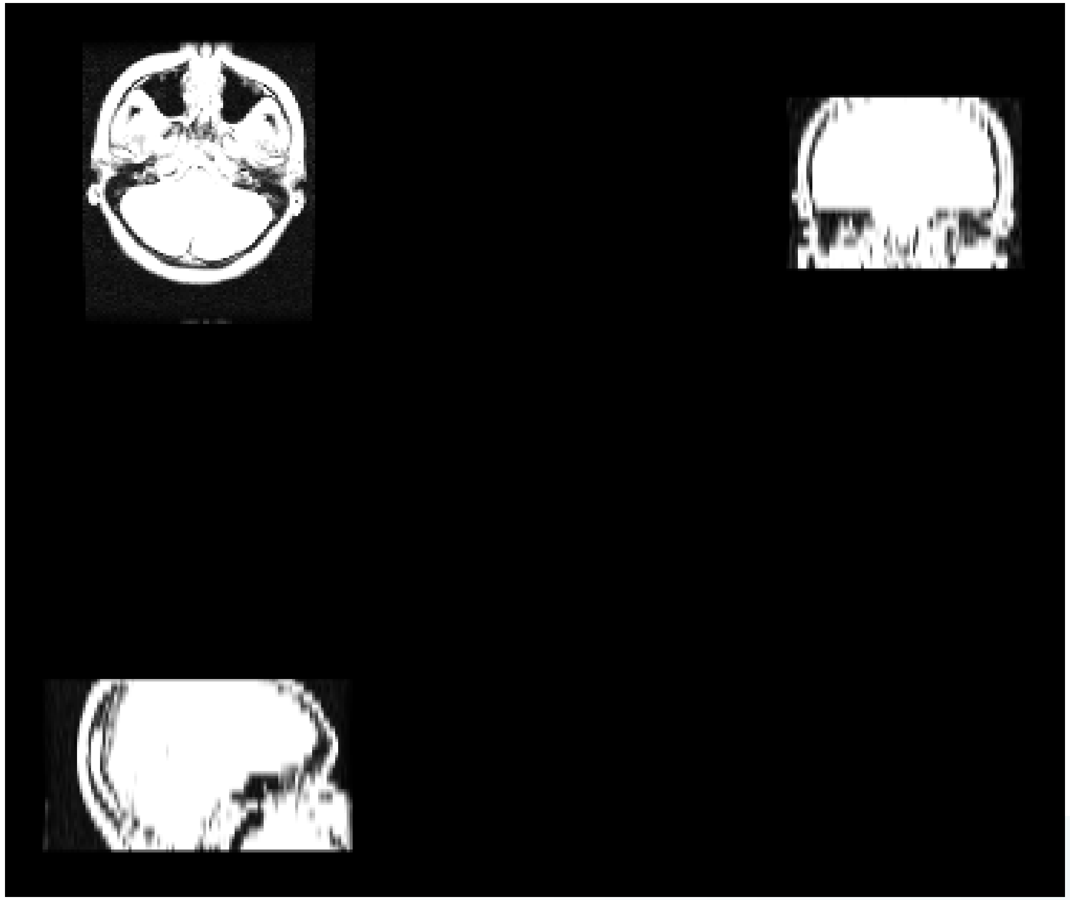
dilation

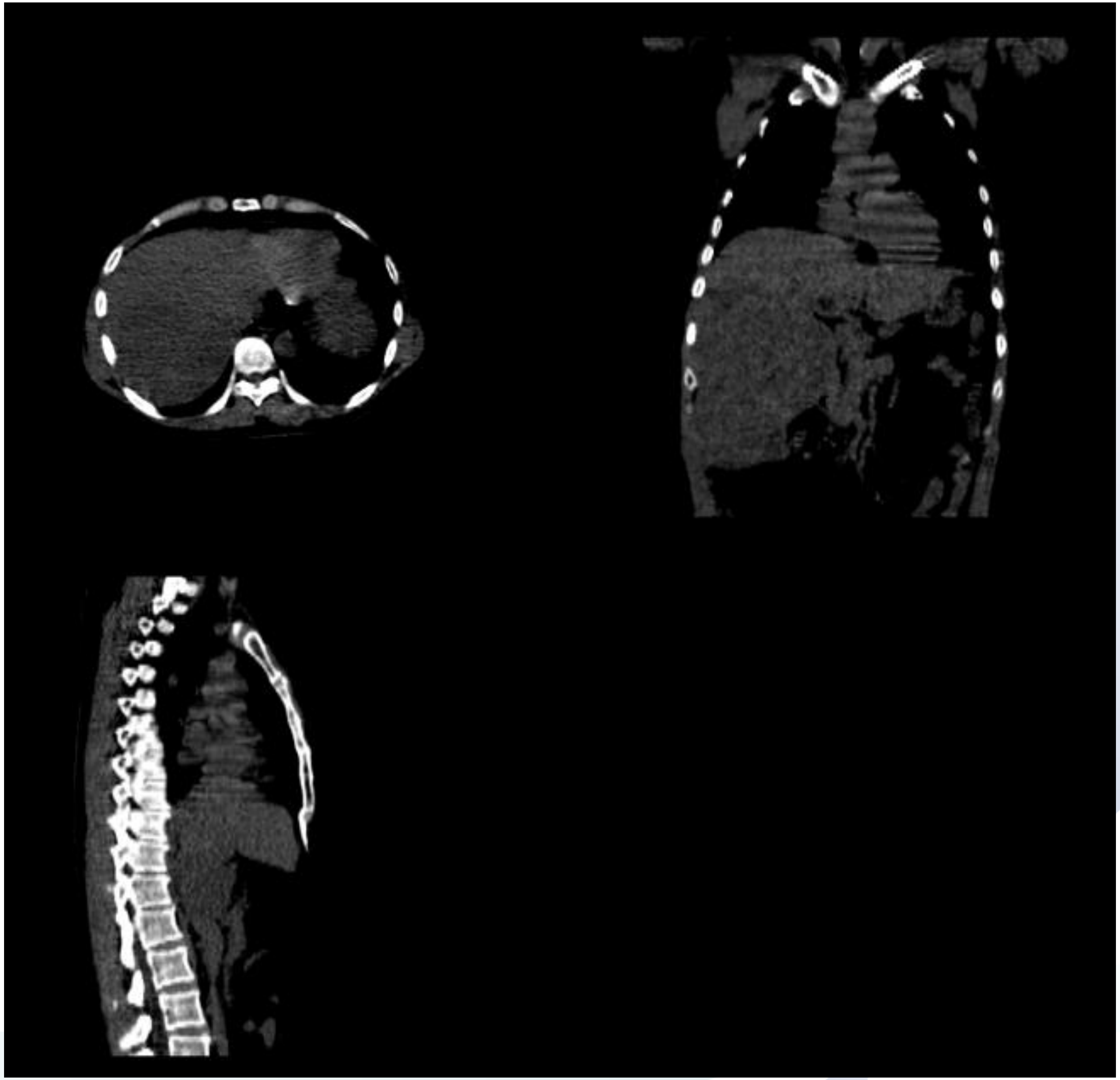


Erosion

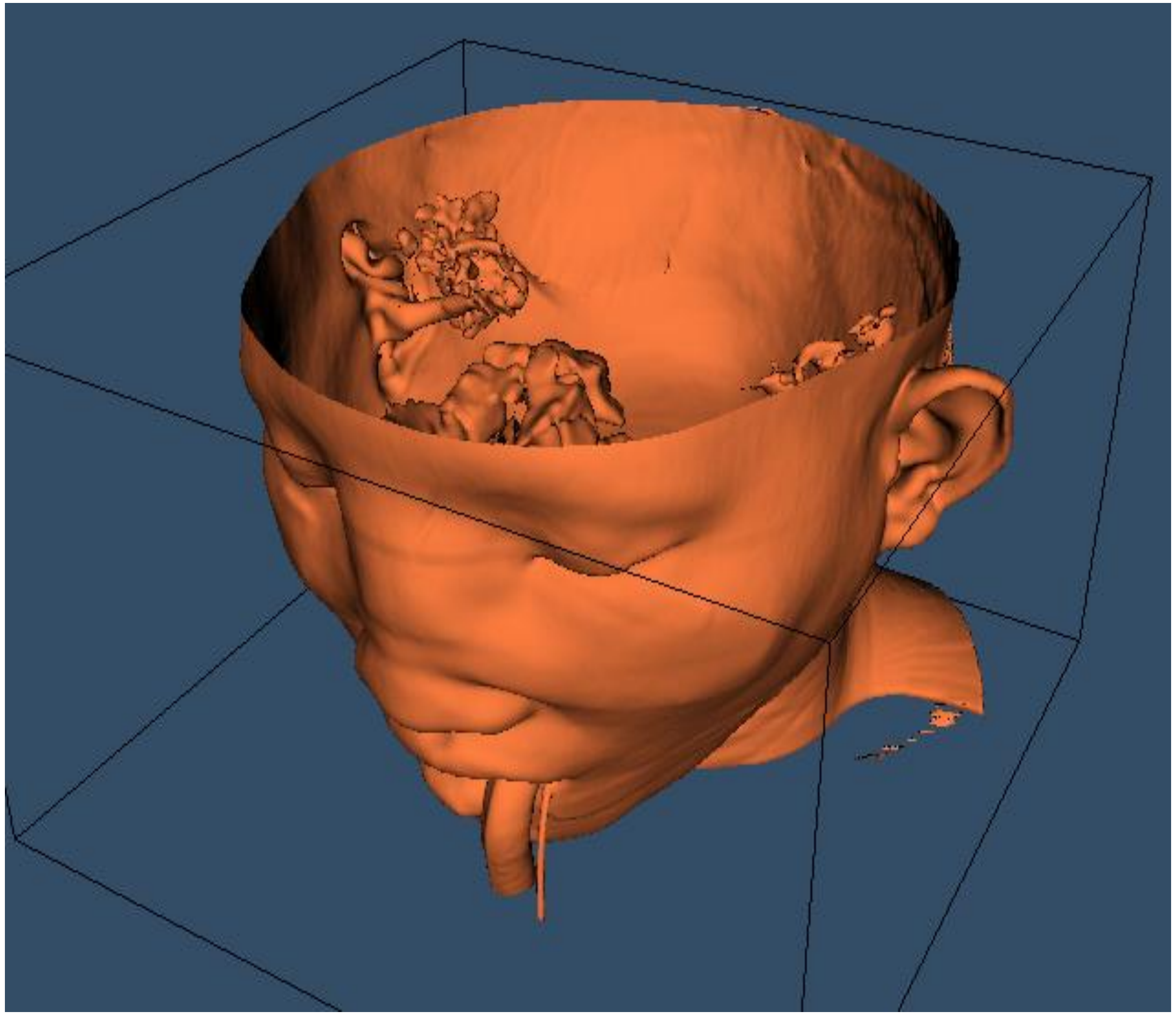
Multiplanar reconstruction (MPR)

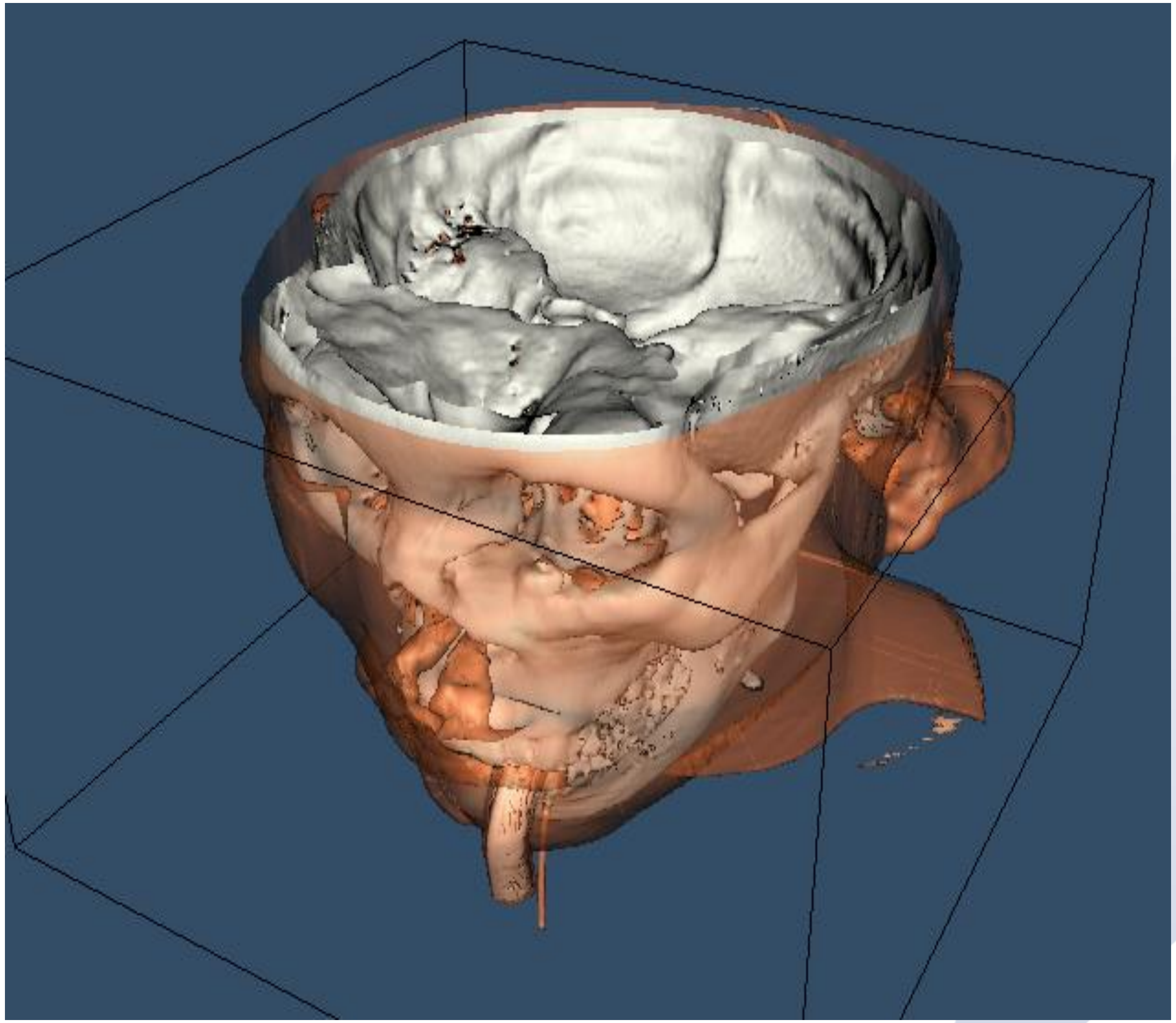






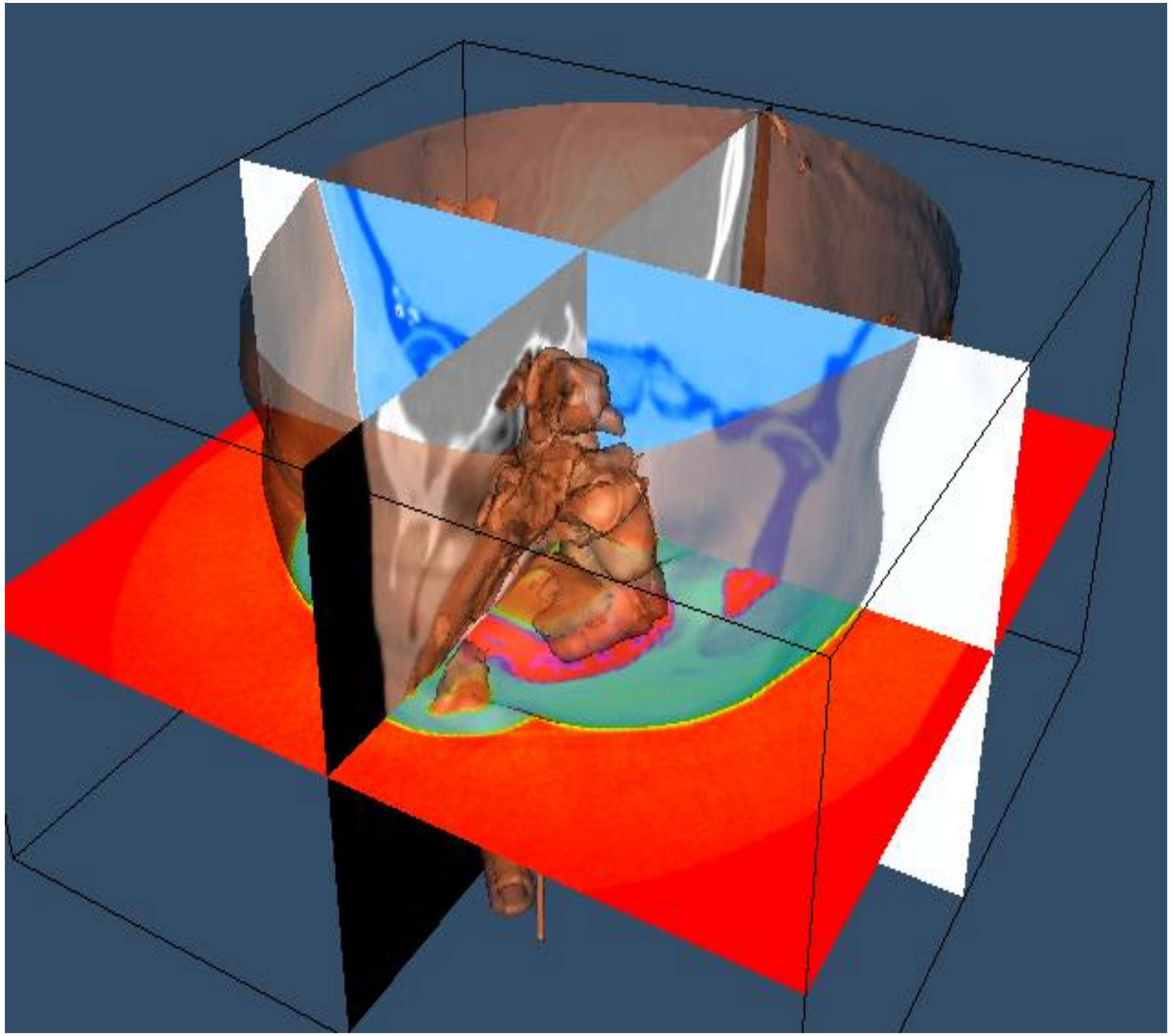
3D Reconstruction

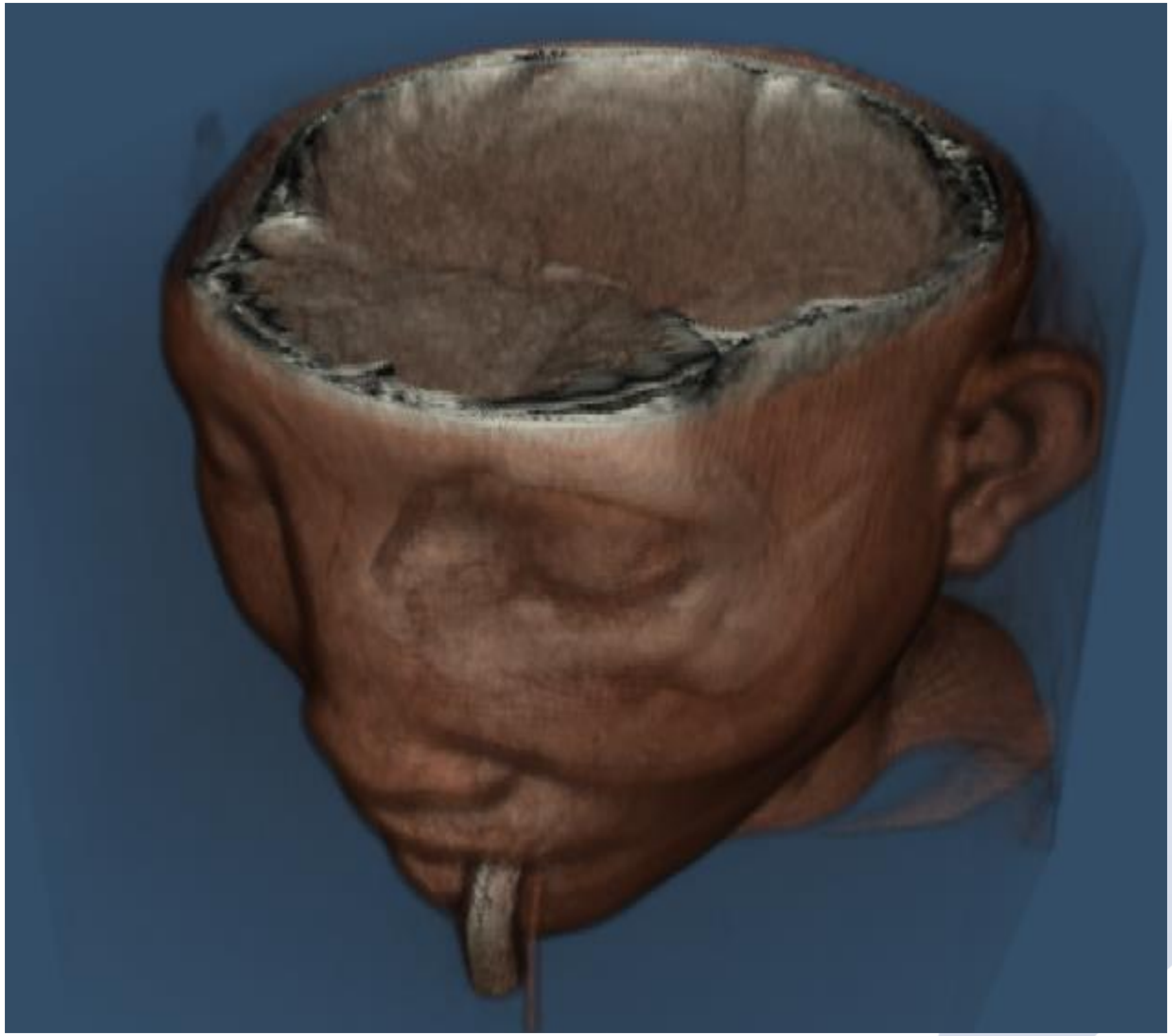




→ Reads a volume dataset, extracts an isosurface that represents the skin and displays it.

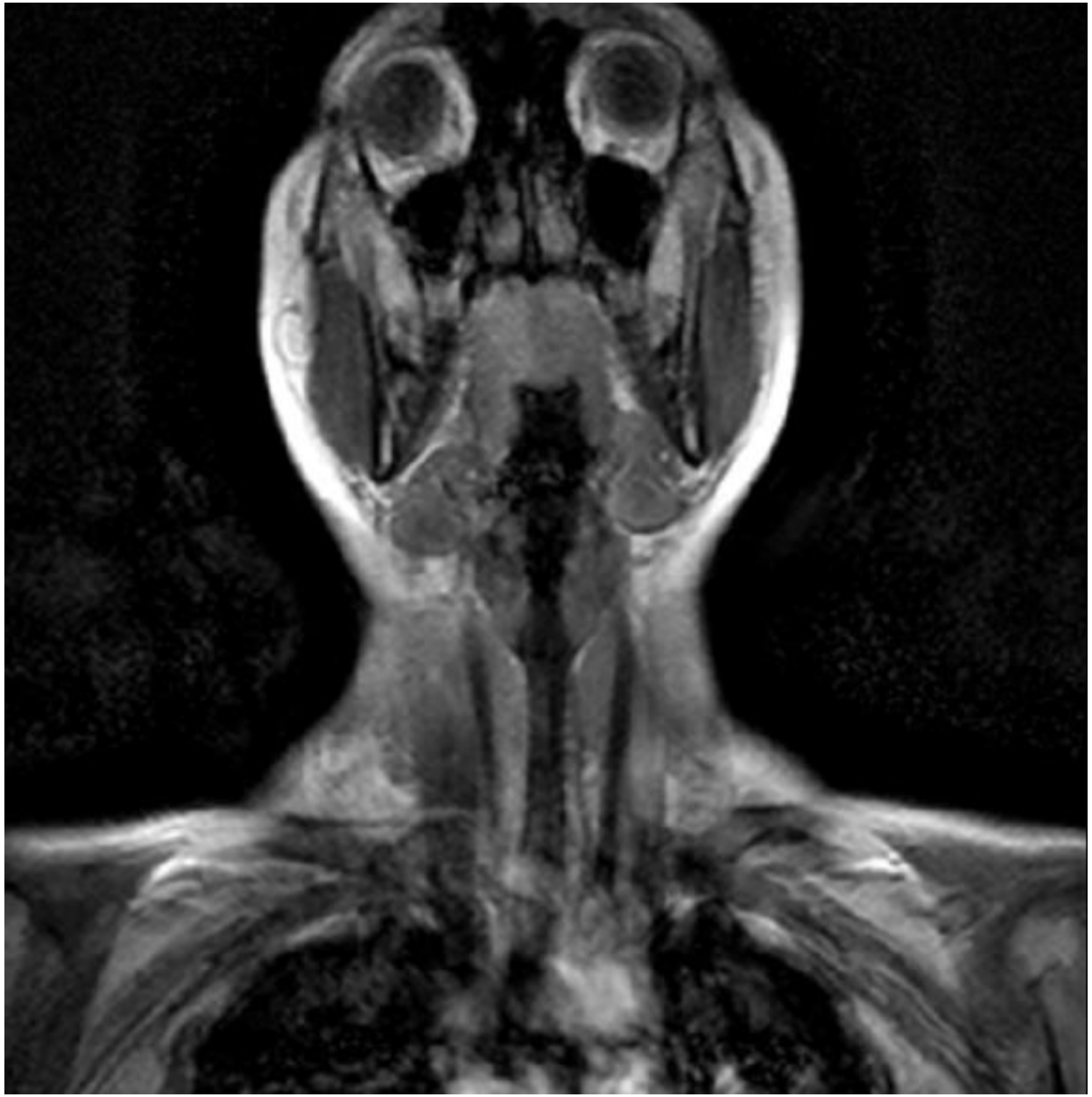
→ Reads a volume dataset, extracts two isosurfaces that represent the skin and bone, and then displays them; clearly shows the high density bones

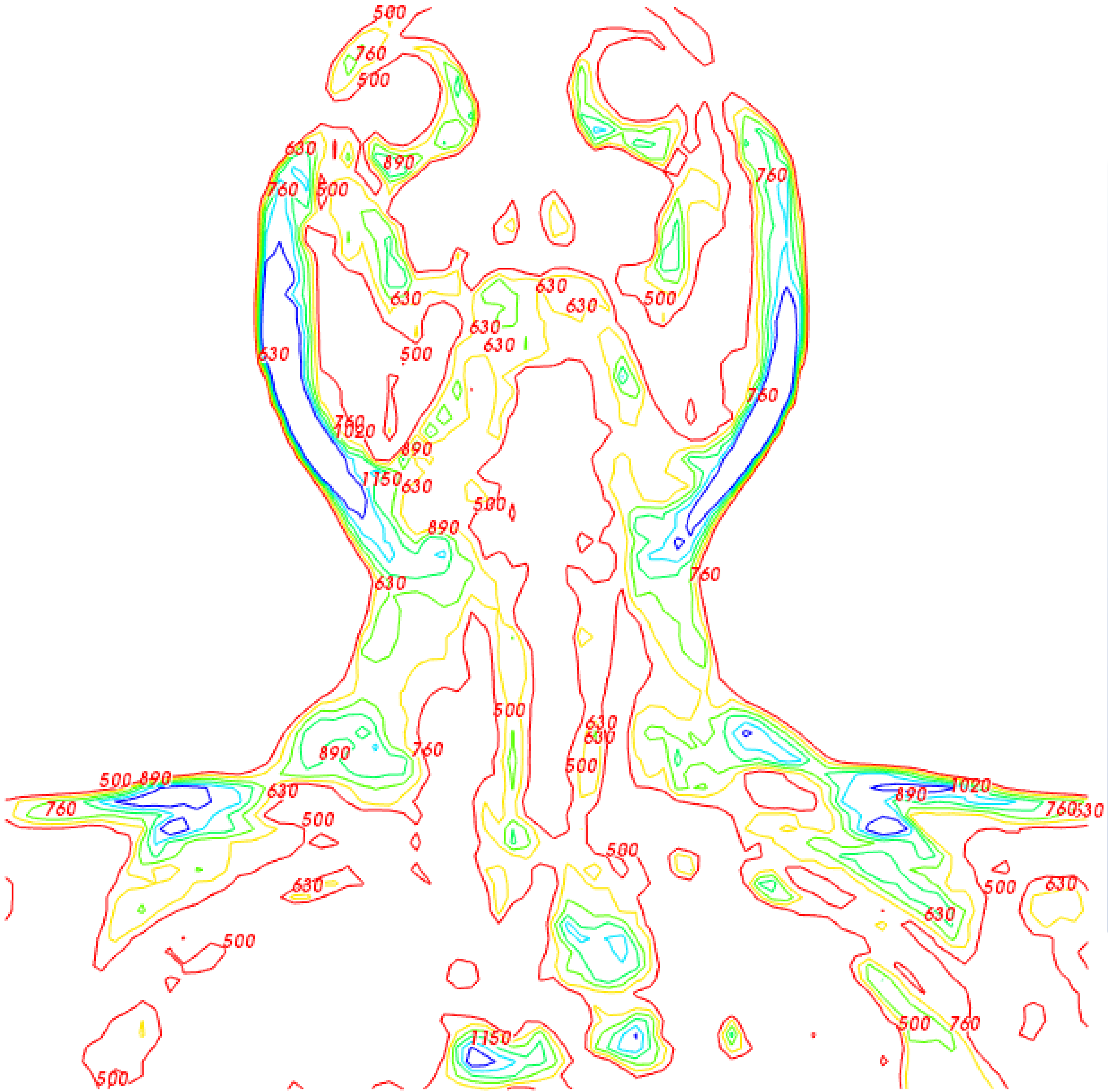




→ Reads a volume dataset, extracts two isosurfaces that represent the skin and bone, creates three orthogonal planes (sagittal, axial, coronal), and displays them.

→ Reads a volume dataset and displays it via volume rendering.





→ Calculate material distribution, describe the distribution of contour lines.

IV.
Conclusions

Conclusions

- Description of medical image processing software POCTA with features: filters, fusion, 3D reconstructions,…
- Proposed a process of segmentation of brain images and expand for other lesions using ITK and VTK, → This is an important step for calculating the correct dose on the tumor later.
- In the future, we will focus on studying new algorithms more optimally and finishing the POCTA software with featuring enhancement, segmentation (by AI, big data), 3D reconstruction obtained from different medical equipment.

THANKS YOU FOR YOUR ATTENTION!