



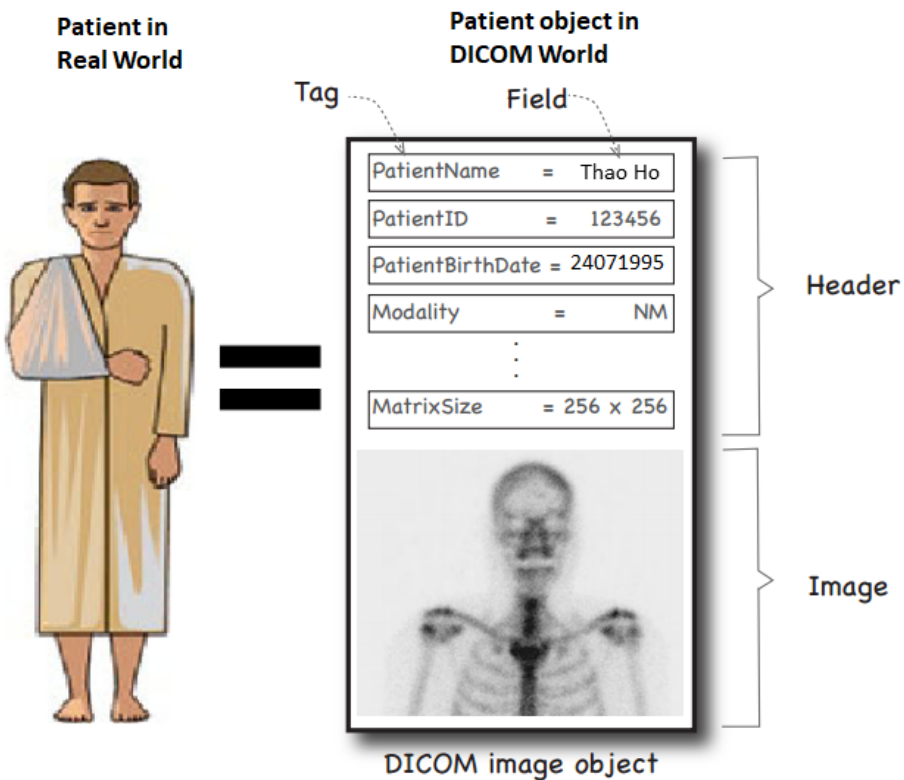
# Research and development of CT, MRI, SPECT and PET images segmentation software for automatic detection and extraction of brain tumors using ITK, VTK, Qt

**Speaker: Ho Thi Thao**

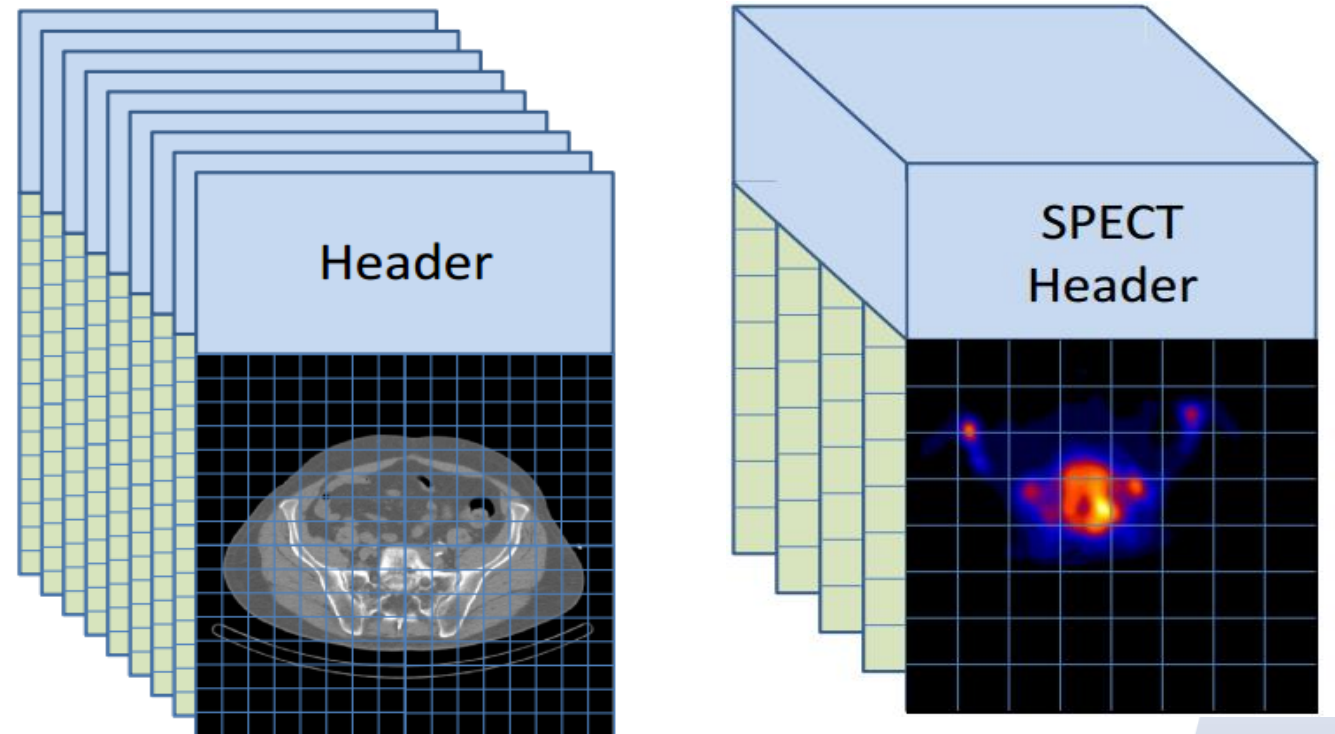
**Rencontres du Vietnam, July, 2019**

# **I. Introduction & Motivation**

# What is DICOM?



# What does a DICOM file look like?



## ➤ *CT, MRI*

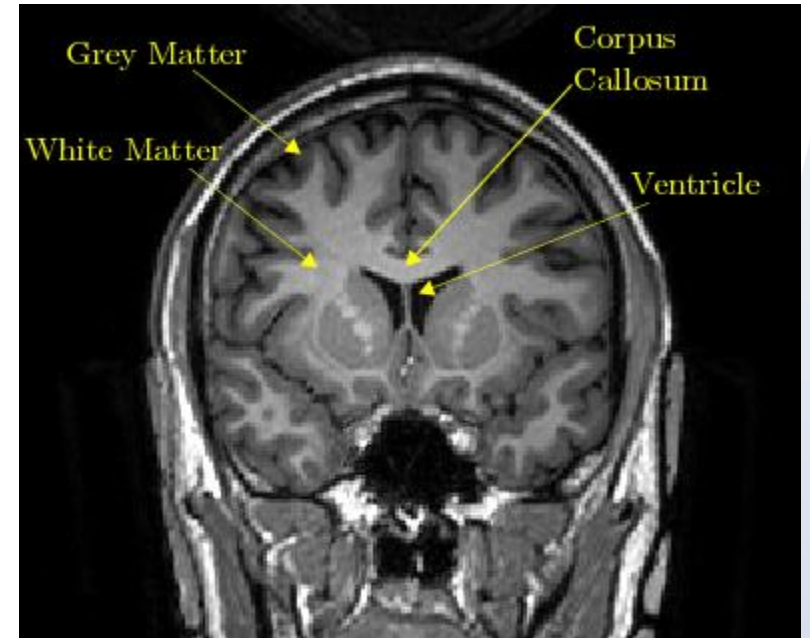
1 file = 1 slice. Each file includes a header and image data.

## ➤ *SPECT, PET*

1 file for one header and all image data.

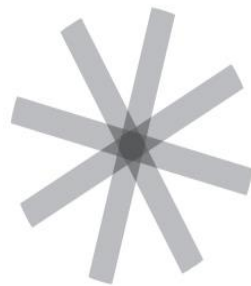
# Brain diseases

- 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:

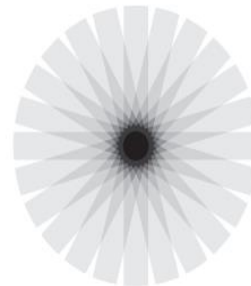
- **Aliasing Artifact or Streaks:** These appear as dark lines which radiate away from sharp corners. It occurs because it is impossible for the scanner to take enough projections of the object.
- **Ring Artifact:** The most common mechanical artifact, the image of one or many 'rings' appears within an image. This is due to a detector fault.
- **Noise Artifact:** This appears as graininess 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.



(a)



(b)



(c)



(d)

## 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**

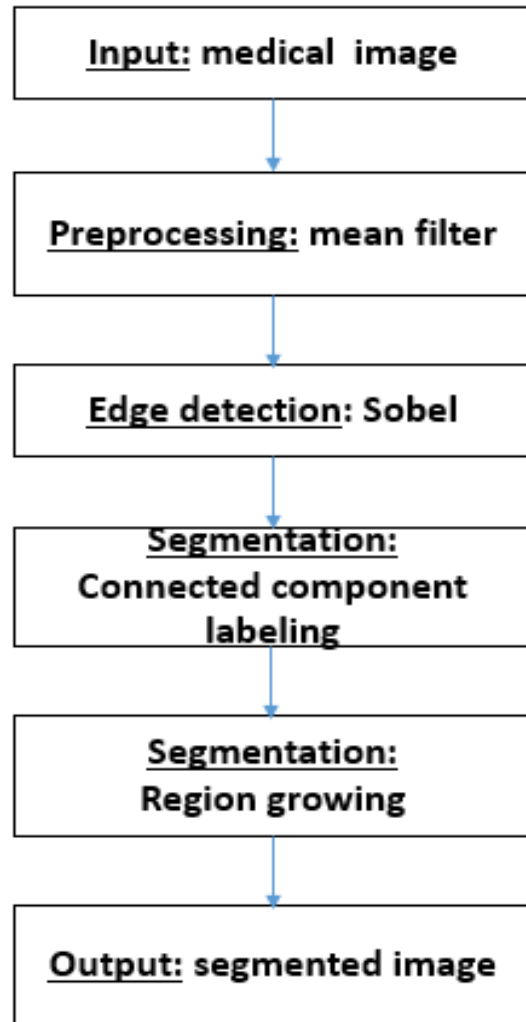


## In the world:

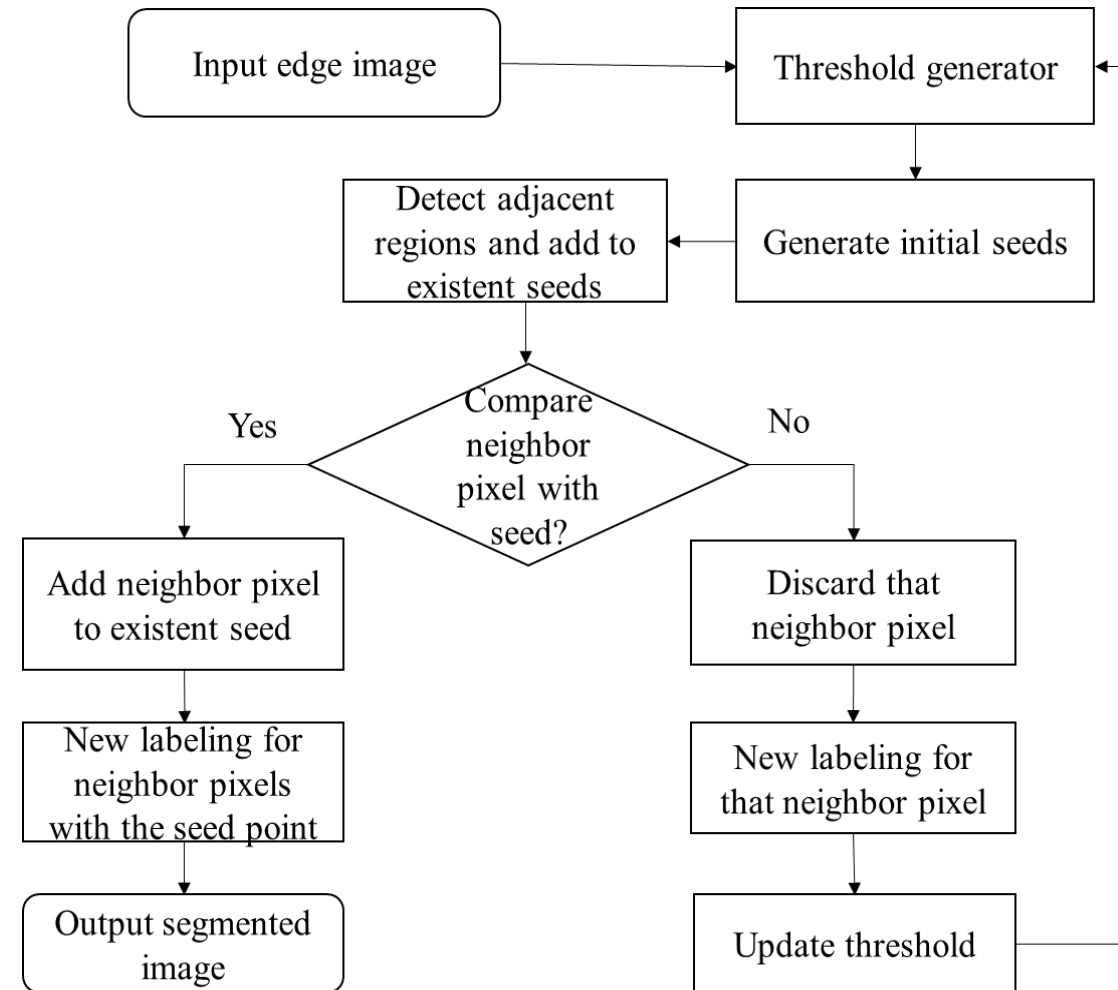
Many groups are developing their own image processing software that is independent of the vendors and contains many advanced features, such as: **OsiriX; TIGRE Toolbox; MicroDICOM, RadiAnt DICOM Viewer, ITK-Snap**

## **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 PSNR

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.

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

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

□ 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?

$f(x,y)$



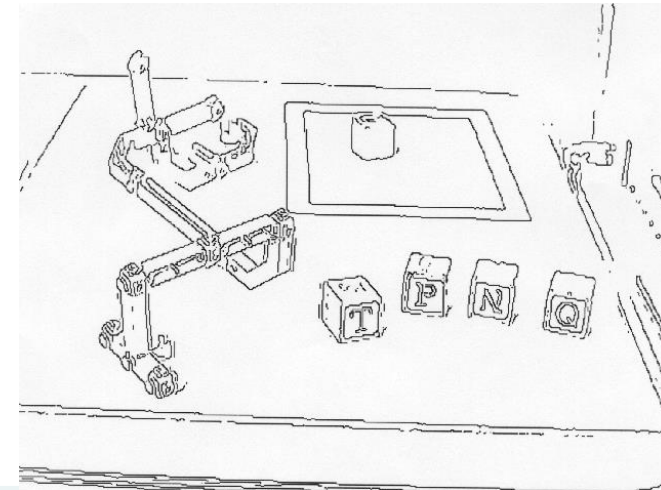
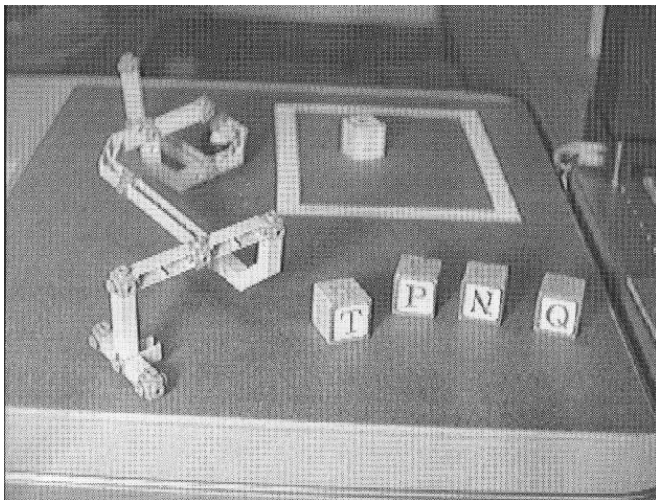
filtering



$g(x,y)$

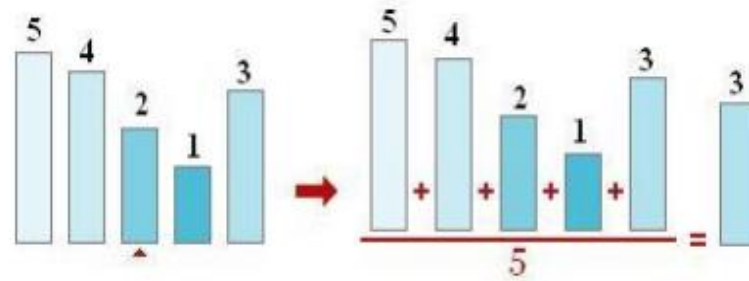


filtering



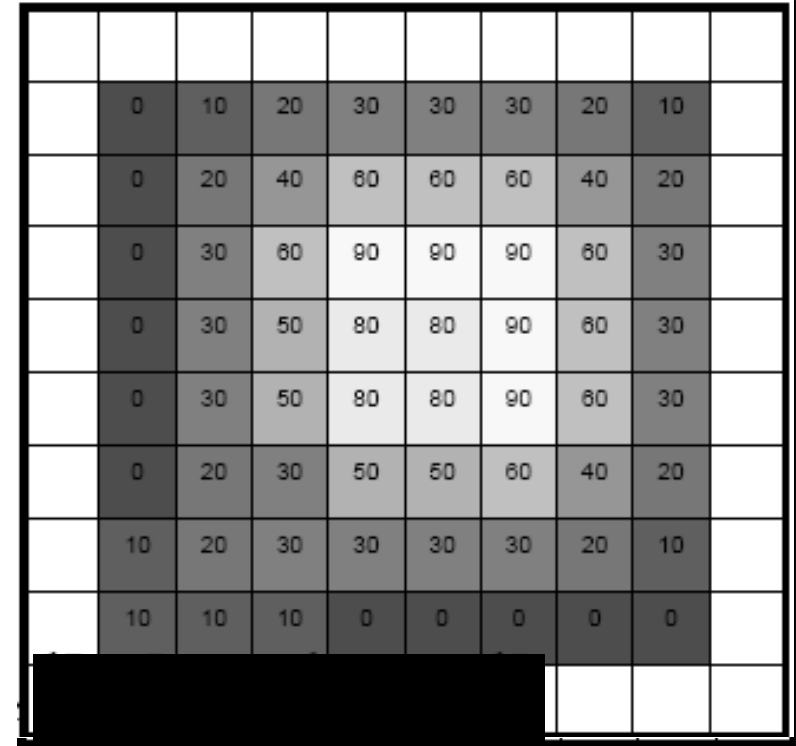
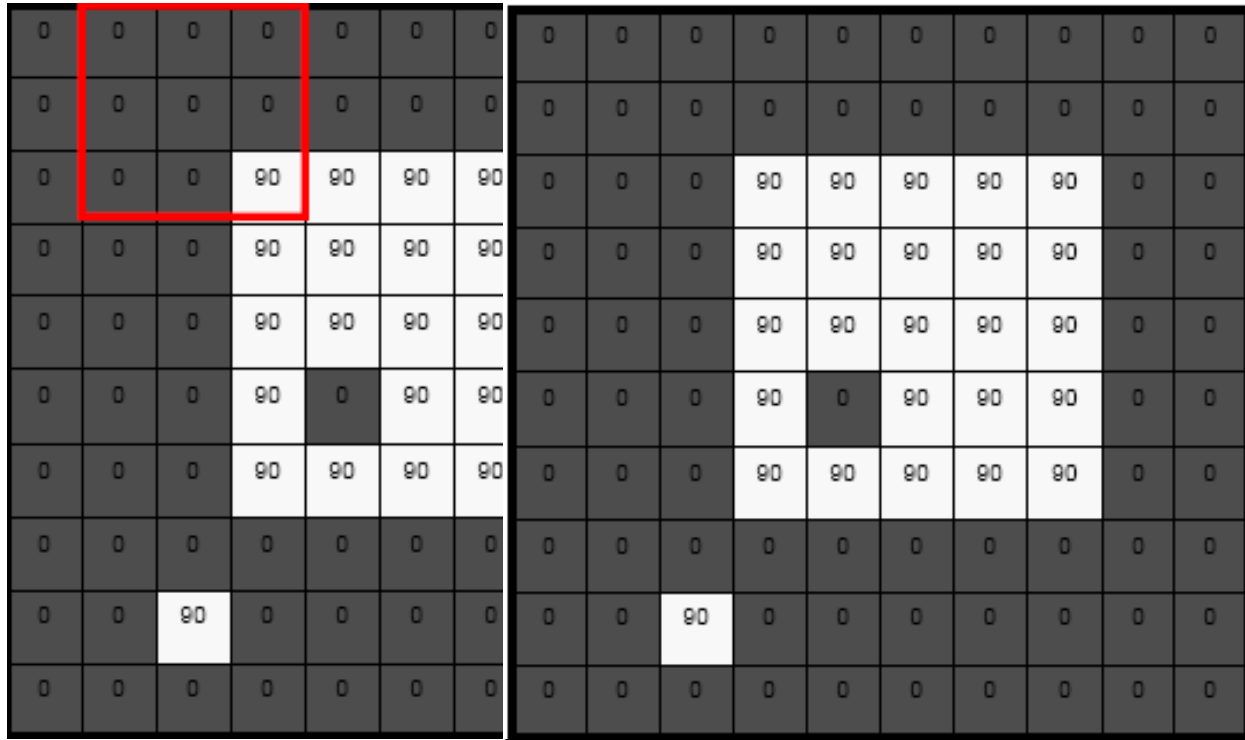
# Prerprocessing (Mean filters)

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



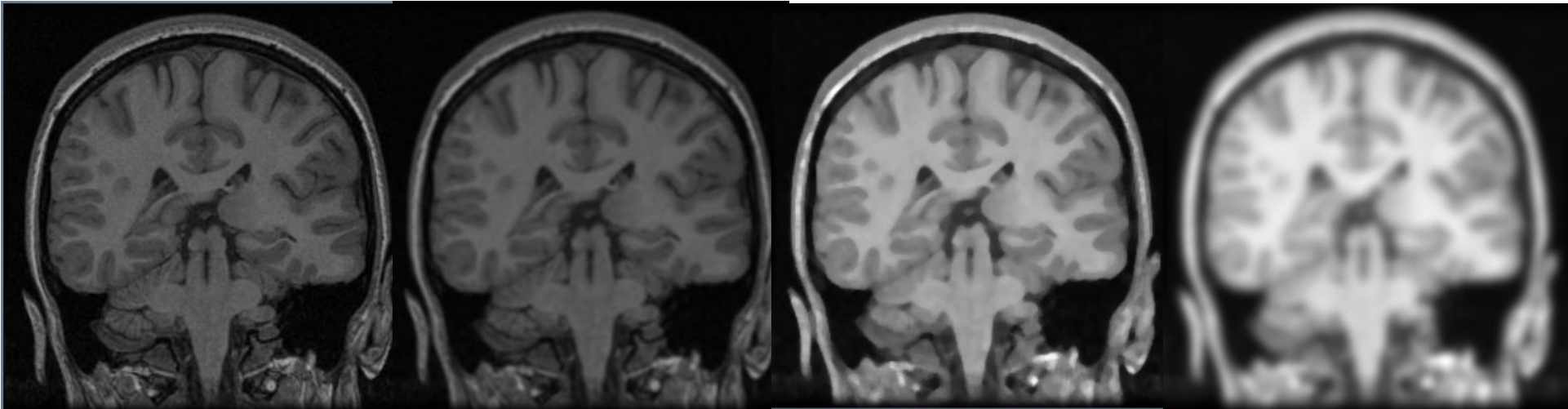
|              |            |              |
|--------------|------------|--------------|
| $f(x-1,y-1)$ | $f(x-1,y)$ | $f(x-1,y+1)$ |
| $f(x,y-1)$   | $f(x,y)$   | $f(x,y+1)$   |
| $f(x+1,y-1)$ | $f(x+1,y)$ | $f(x+1,y+1)$ |

|   |   |   |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 1 | 1 |
| 1 | 1 | 1 |

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


# Result

\*Input : .dcm



Input

Mean filter

Median filter

Gaussian blur



(.png)

# Sobel method

## Edge detection method:

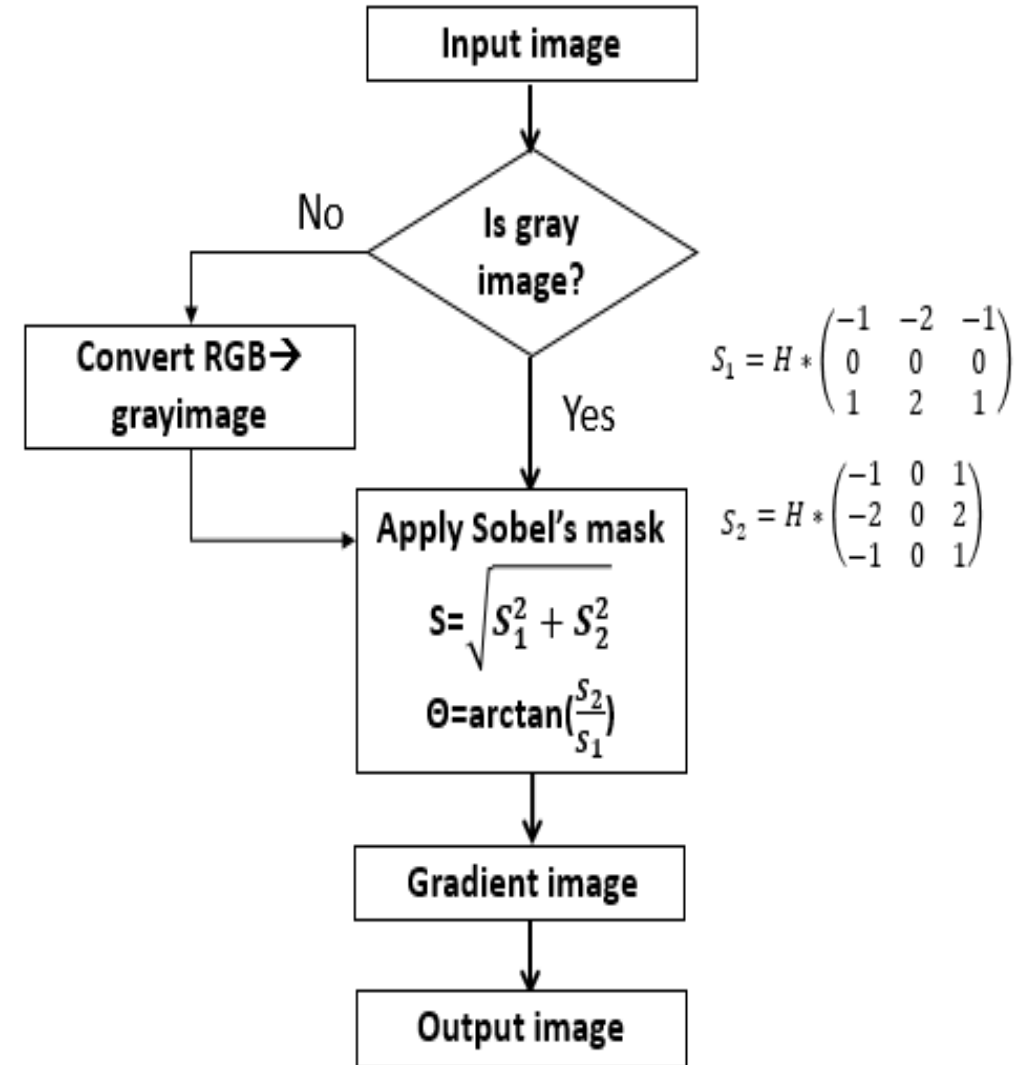
\* **Direct:** find the edge based on the variation in the brightness value (grayscale) of the image. Mainly based on the technique of taking the derivative:

– **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).

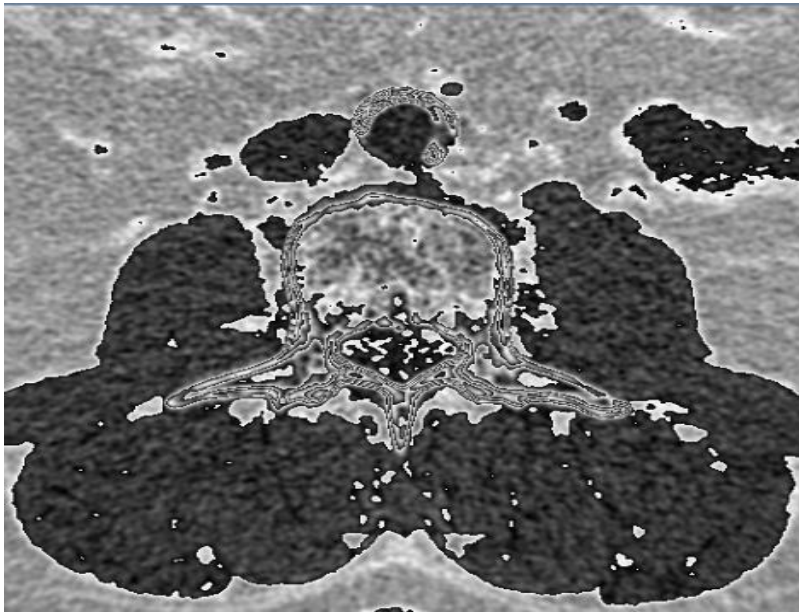
– **Laplace method:** Secondary derivative to find edge.

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

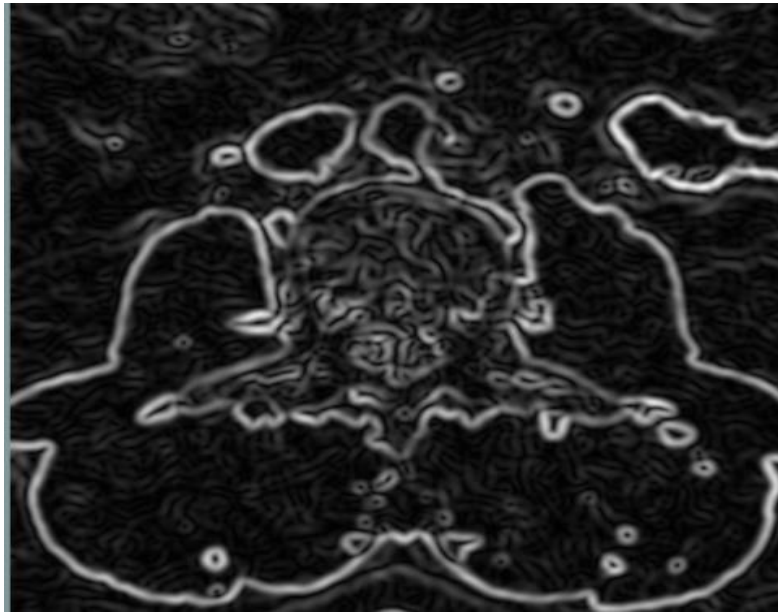
→ Role: The boundary separates gray areas (colors). In contrast, use the image areas to find the separator.



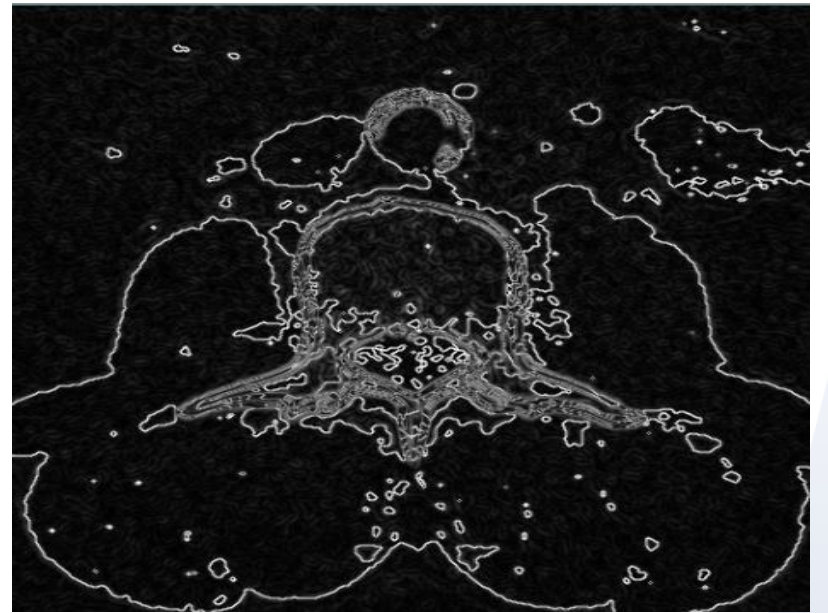




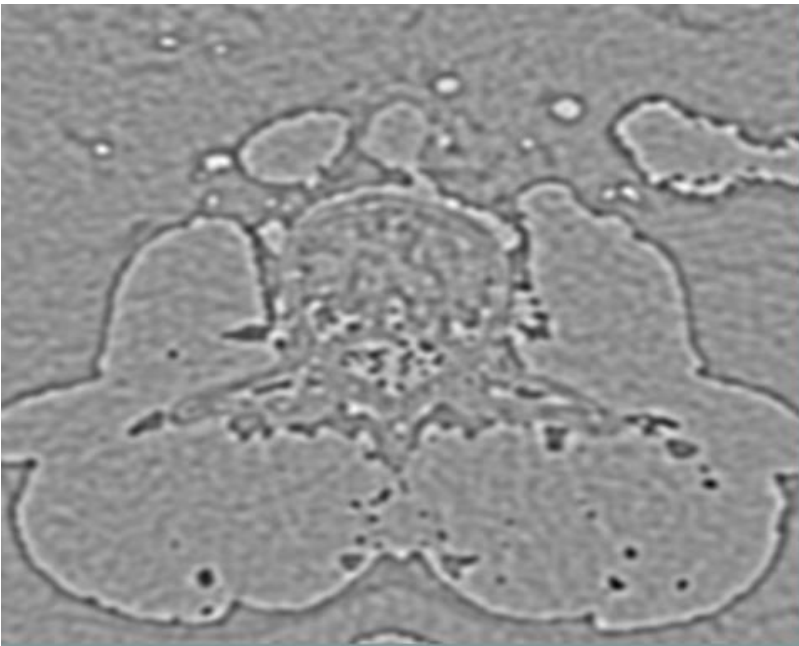
raw



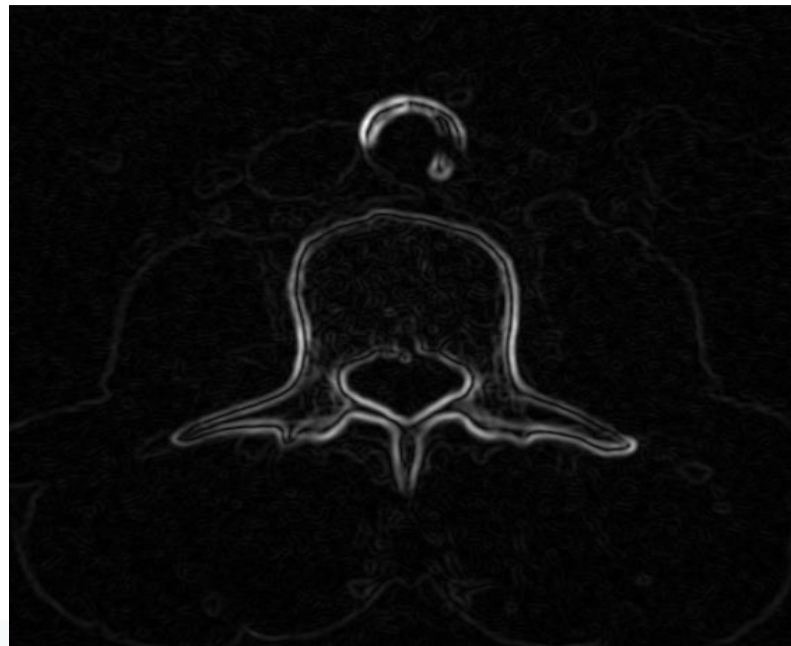
Gradient



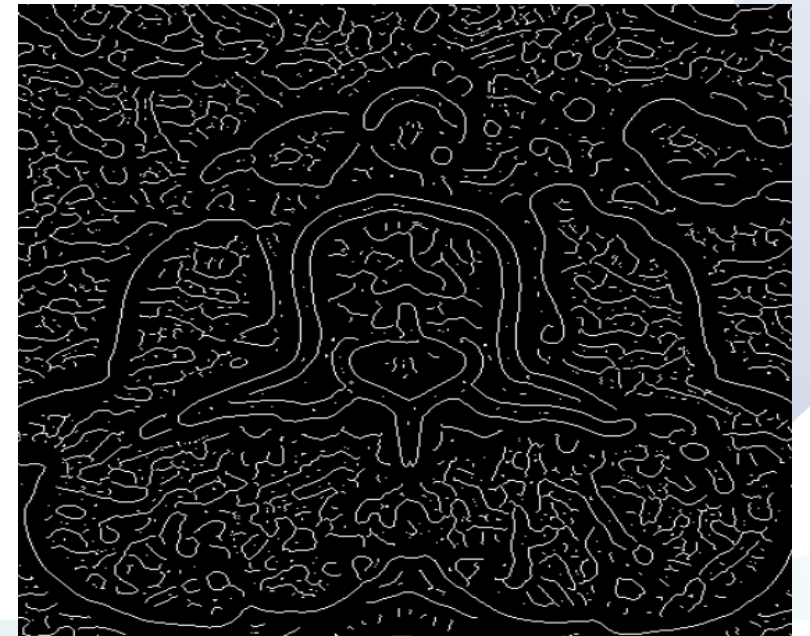
Gradient+ gauss



Laplace



Sobel



Canny

# **III. Results**

# Segmentation Editor

The image shows a screenshot of the Segmentation Editor software interface. The interface is divided into several panels:

- Watershed transform:** A callout box pointing to the leftmost panel, which displays a watershed segmentation of a brain slice with various colored regions.
- Data with overlay:** A callout box pointing to the middle panel, which shows the original MRI slice with a green overlay indicating a specific region of interest.
- Segmentation in progress:** A callout box pointing to the rightmost panel, which shows a green region on a black background, representing the current state of segmentation.
- Sliders manipulate watershed depth and position in the hierarchy:** A callout box pointing to a control panel below the watershed transform panel. This panel includes a vertical axis labeled "Watershed Depth Threshold" and a tree diagram with colored nodes representing the hierarchy of segments.
- 3D isosurface rendering:** A callout box pointing to the bottom right panel, which displays a 3D isosurface rendering of the segmented region in a yellowish-green color.

The central part of the interface contains a control panel with various buttons and sliders, including "add watershed region", "remove watershed region", "merge watershed", "split watershed", "clear watershed", "undo", "redo", "toggle visibility", "toggle color", "toggle opacity", "toggle alpha", "toggle beta", "toggle gamma", "toggle delta", "toggle epsilon", "toggle zeta", "toggle eta", "toggle theta", "toggle iota", "toggle kappa", "toggle lambda", "toggle mu", "toggle nu", "toggle xi", "toggle omicron", "toggle pi", "toggle rho", "toggle sigma", "toggle tau", "toggle upsilon", "toggle phi", "toggle chi", "toggle psi", "toggle omega", "toggle alpha", "toggle beta", "toggle gamma", "toggle delta", "toggle epsilon", "toggle zeta", "toggle eta", "toggle theta", "toggle iota", "toggle kappa", "toggle lambda", "toggle mu", "toggle nu", "toggle xi", "toggle omicron", "toggle pi", "toggle rho", "toggle sigma", "toggle tau", "toggle upsilon", "toggle phi", "toggle chi", "toggle psi", "toggle omega".



# Segmentation results

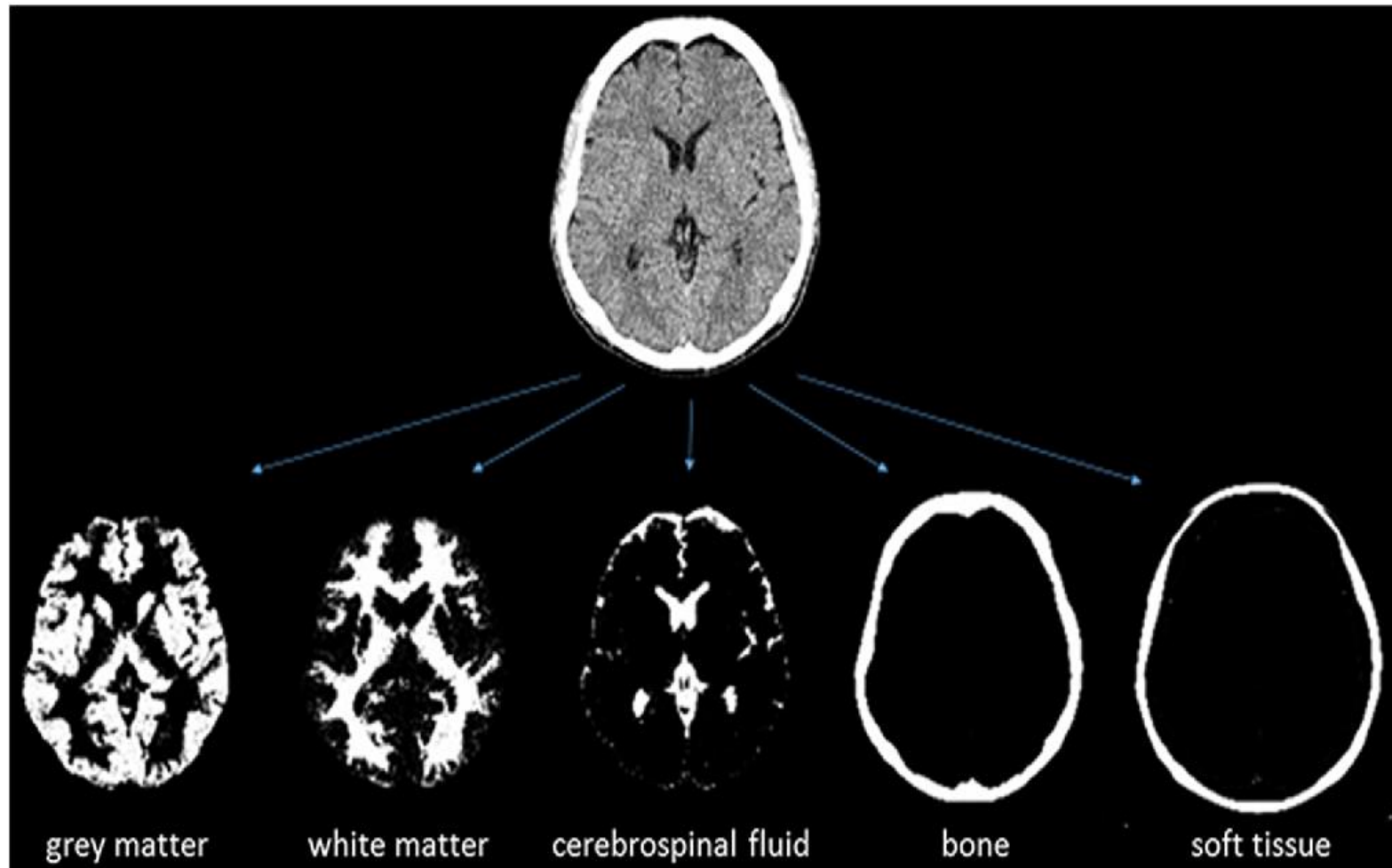
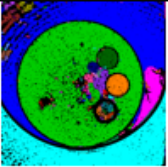
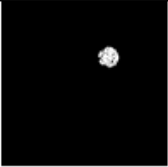
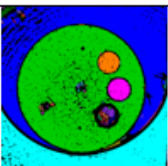
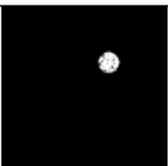
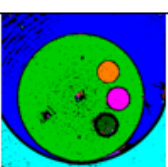
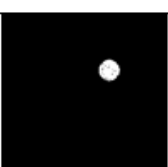

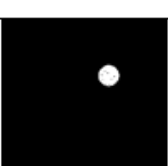

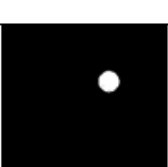

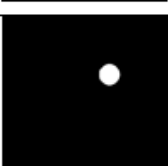


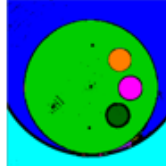
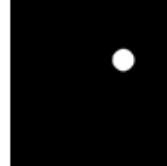
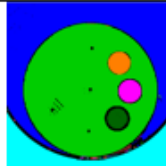
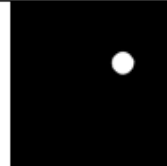
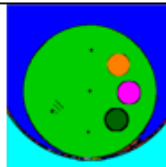
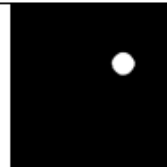
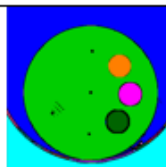
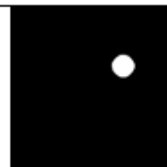

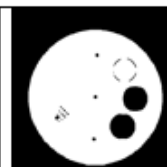
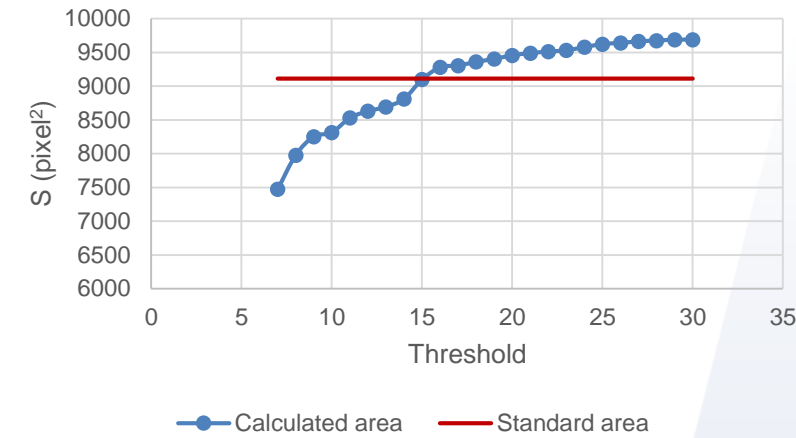


Fig 15. CT segmentation, automatically segments CT images into gray matter, whitematter, cerebrospinal fluid, bone,and soft tissue.

| No. | The output image   | Threshold value | Extraction output image   | Standard area of phantom | Calculated 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 <sup>2</sup> ) |
|------------|-------|--------|--------|---------------------|
| (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<sup>2</sup>, 9480 pixels<sup>2</sup>, and 9146 pixels<sup>2</sup>, roughly the same as the area recorded on the phantom 9113 pixels<sup>2</sup>. Accurate rates are 98.12%, 95.96% and 99.64%, respectively.

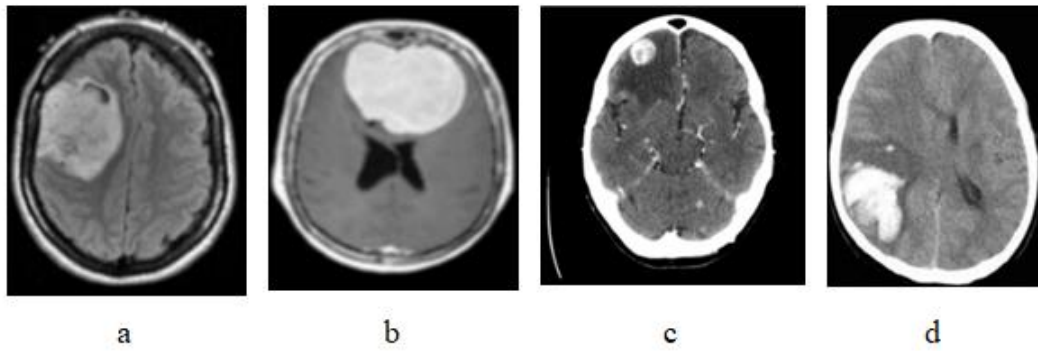


Figure 3.7. Preprocessing mean filter

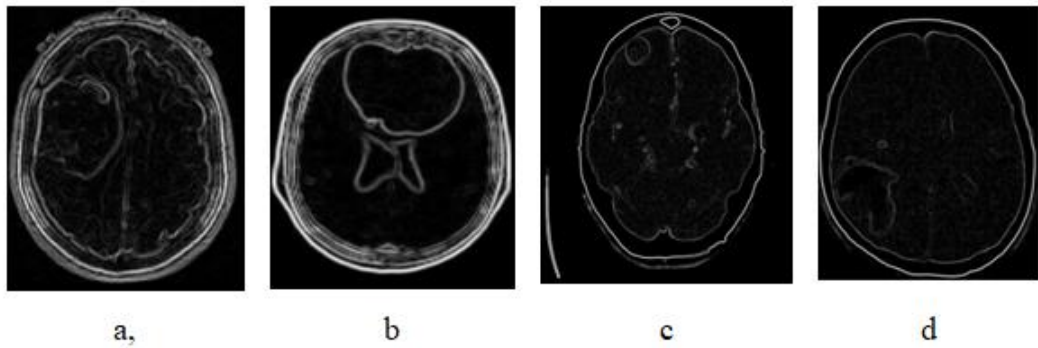


Figure 3.8. Sobel edge detection.

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    |

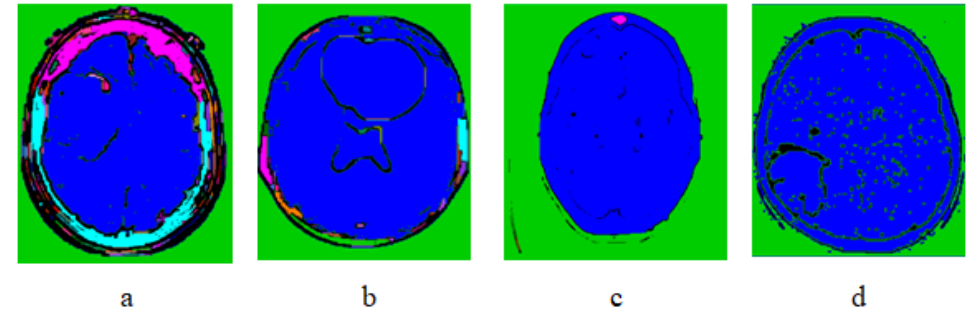


Figure 3.9. Connected component without using Sobel.

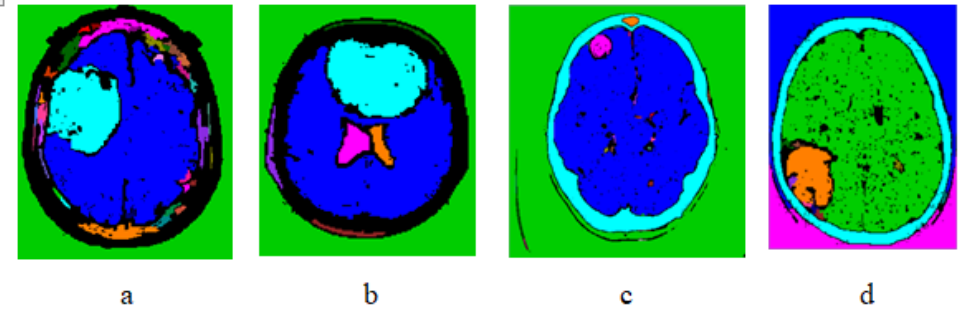


Figure 3.10. Connected component using Sobel.

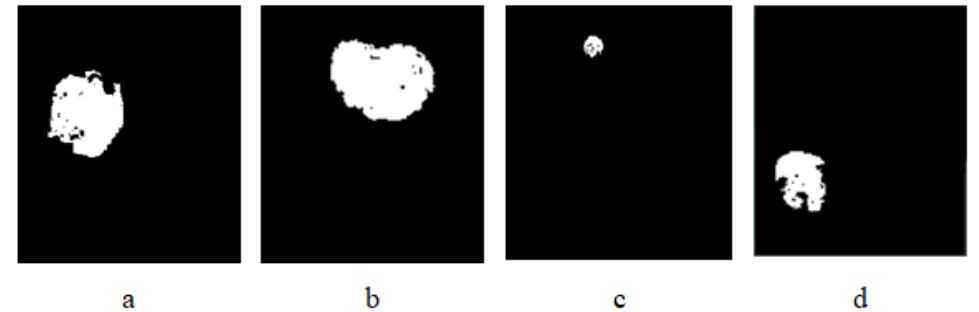
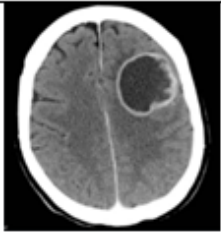

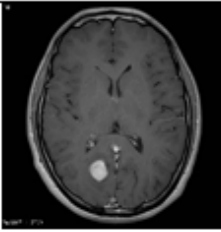

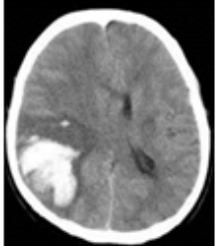



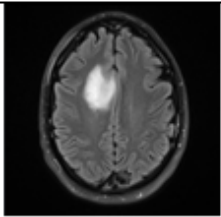
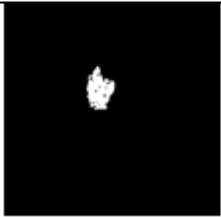
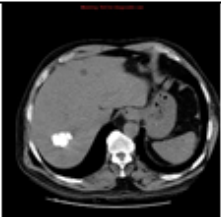

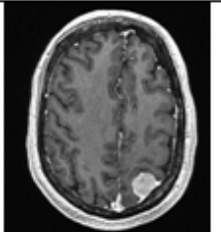
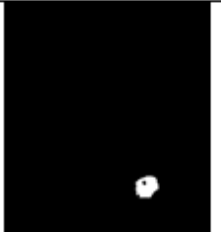
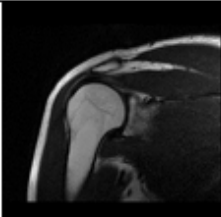

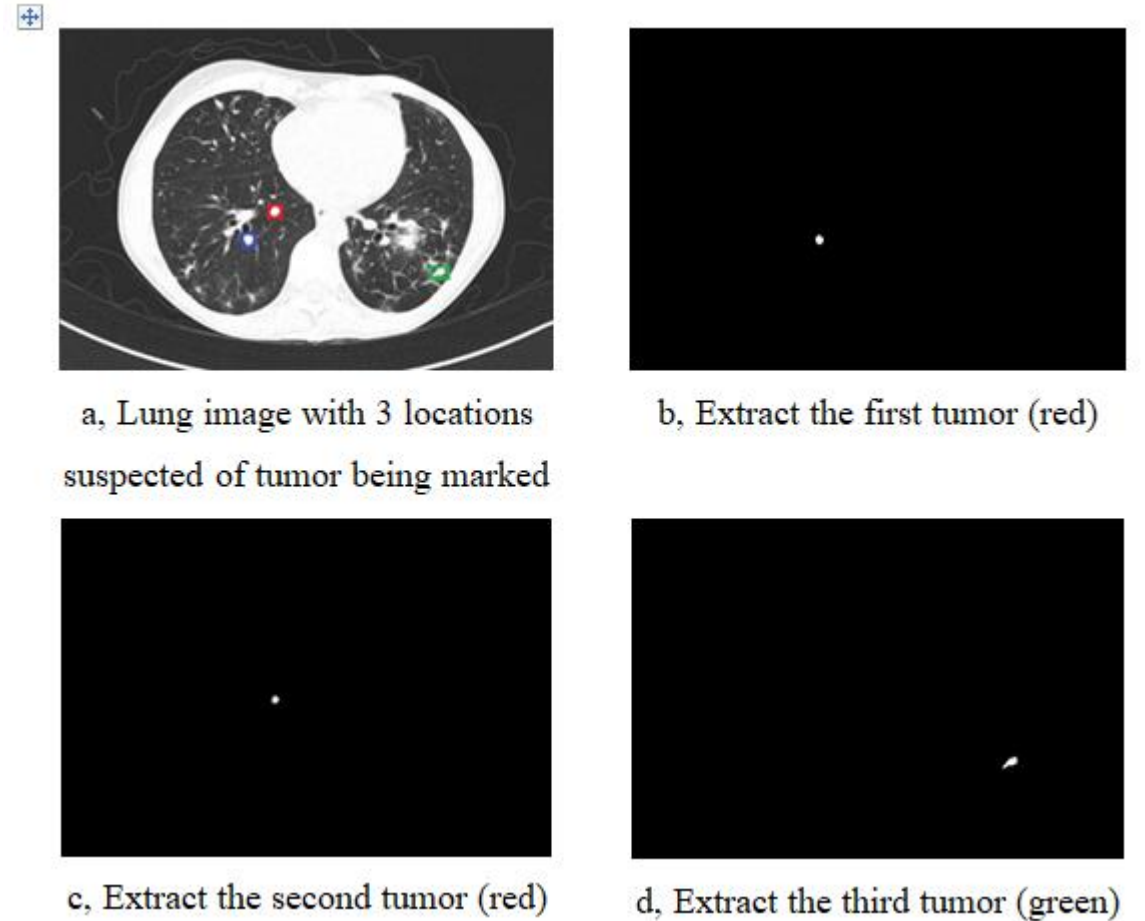


Figure 3.11. Segmented images after using region growing.

| No. | Image  | Confident connected   | No. | Image  | Confident connected   |
|-----|--|---|-----|--|---|
| 1   |   | <br>238-137  | 5   |   | <br>217-427 |
| 2   |   | <br>99-354   | 6   |   |             |
| 3   |   | <br>196-202  | 7   |   |             |
| 4   |  | <br>307-391 | 8   |  |            |



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

**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.



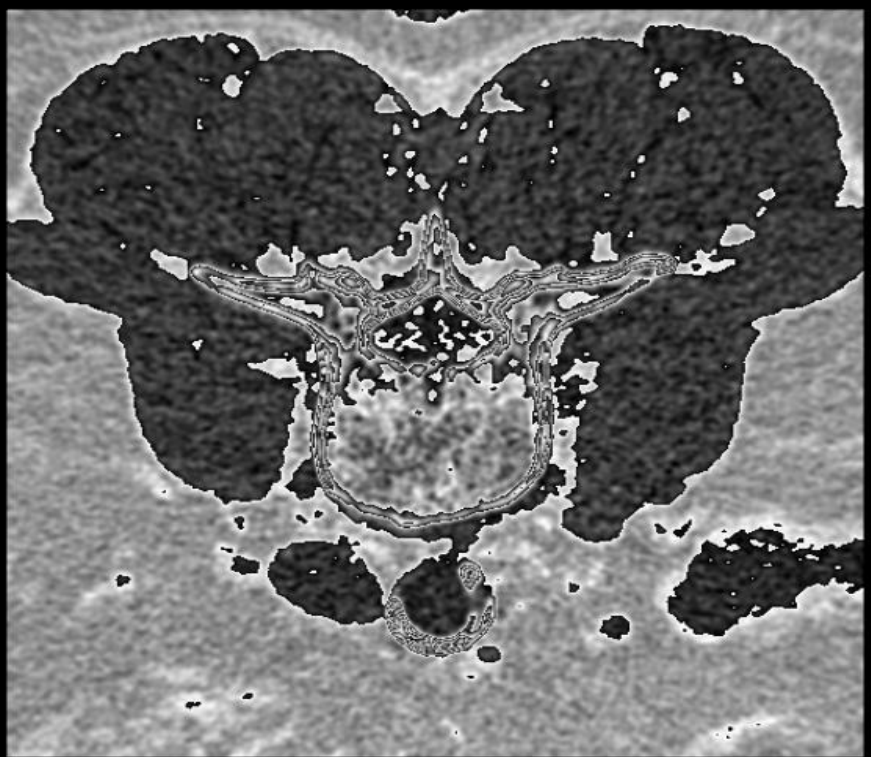
# 2. POCTA Software

INMOFEV

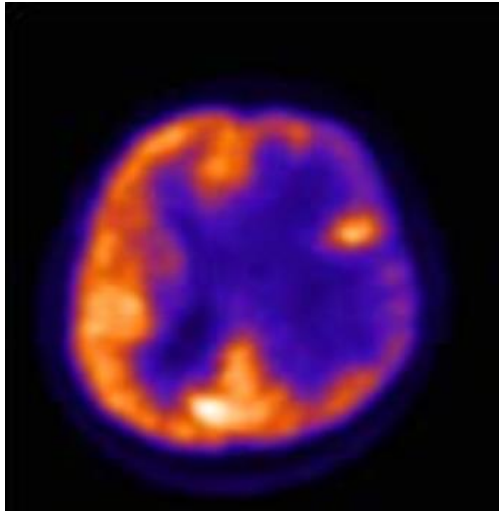
MPR 3D Fusion File Edit View Tools Image Filter Measurement Help Convert

-----Patient Information-----  
Study Date: 20030318  
Modality: CT  
Manufacturer: SIEMENS  
Institution Name: Imeldaziekenhuis  
Manufacturer's Model Name: Volume Zoom  
Patient's Name: AAAAAA^FFFFF  
Patient ID: 0092939  
Patient's Sex: M  
Patient's Age: 053Y

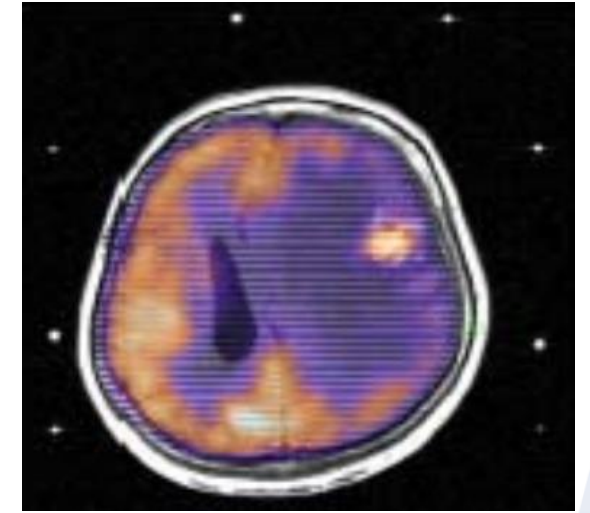
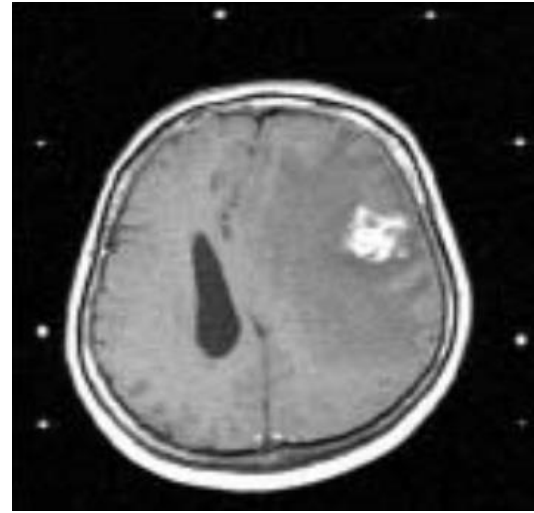
-----Others-----  
Specific Character Set: ISO\_IR 100  
Image Type: ORIGINAL\PRIMARY\AXIAL\CT\_SOM5 SPI  
SOP Class UID: 1.2.840.10008.5.1.4.1.1.2  
SOP Instance UID: 1.3.12.2.1107.5.1.4.24337.4.0.3088812620738987  
Series Date: 20030318  
Acquisition Date: 20030318  
Content Date: 20030318  
Study Time: 133351.281000  
Series Time: 133604.656000  
Acquisition Time: 133515.169001  
Content Time: 133515.169001  
Accession Number: 194699  
Institution Address: Imeldalaan  
Bonheiden/D3ADDF/  
Belgium  
Referring Physician's Name: BBBBBBBB^ SSSSSSSS  
Station Name: NAVIGATOR 1  
Study Description: CT LUMBALE WZ  
Series Description: LWZ 2.0 B30s  
Institutional Department Name: DEFAULT  
Operators' Name: MEDUSER  
Patient's Birth Date: 19490502  
Medical Alerts: hartmedicatie  
Additional Patient History: Gekende discuspathologie L4-L5 (1990) nu terug lumbale pijn met  
Pregnancy Status: 4  
Body Part Examined: SPINE  
Slice Thickness: 2  
KVP: 120  
Software Version(s): VA40C  
Protocol Name: 1\_Lumbaal\_M\_Spiraal  
Reconstruction Diameter: 150  
Distance Source to Detector: 1040  
Distance Source to Patient: 570  
Gantry/Detector Tilt: 0  
Table Height: 140  
Rotation Direction: CW  
Exposure Time: 1000



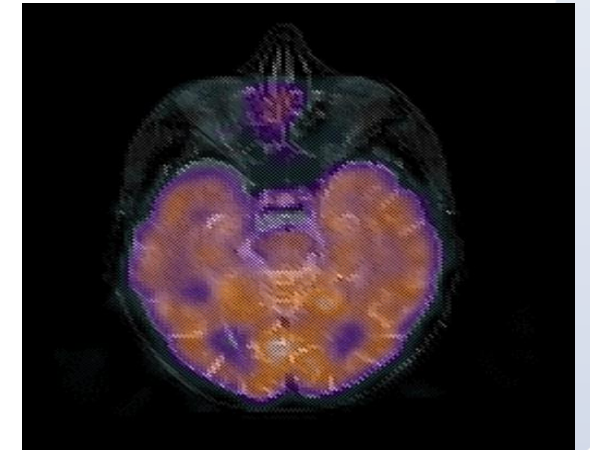
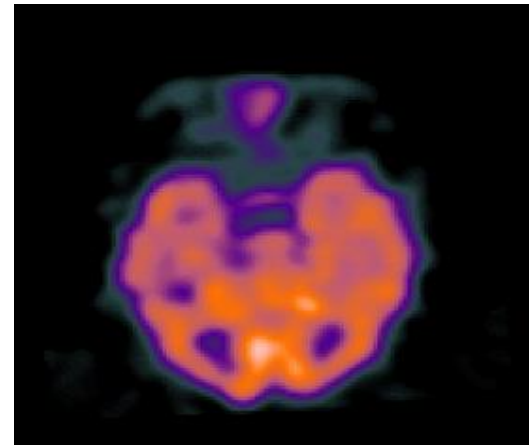
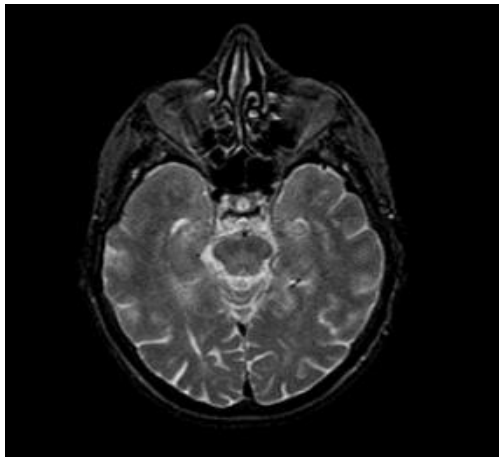
**PET+MRI**



**Fusion**

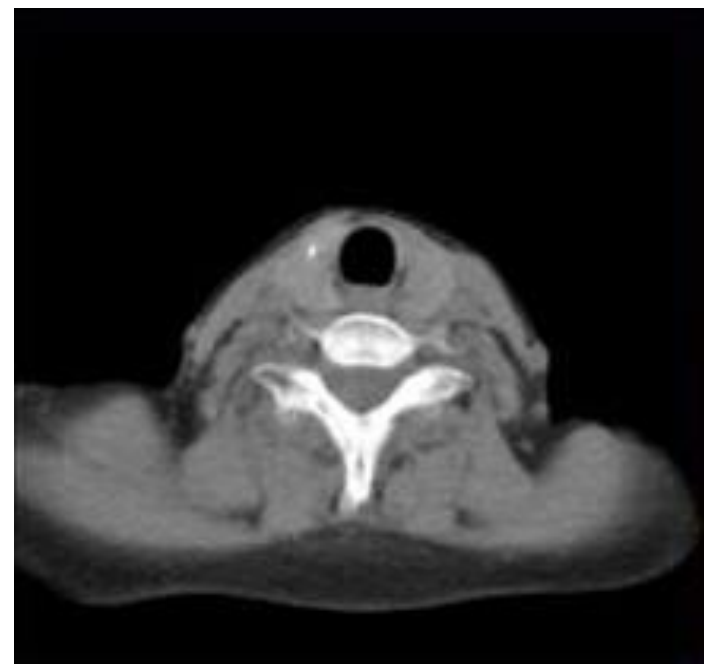


**MRI+SPECT**

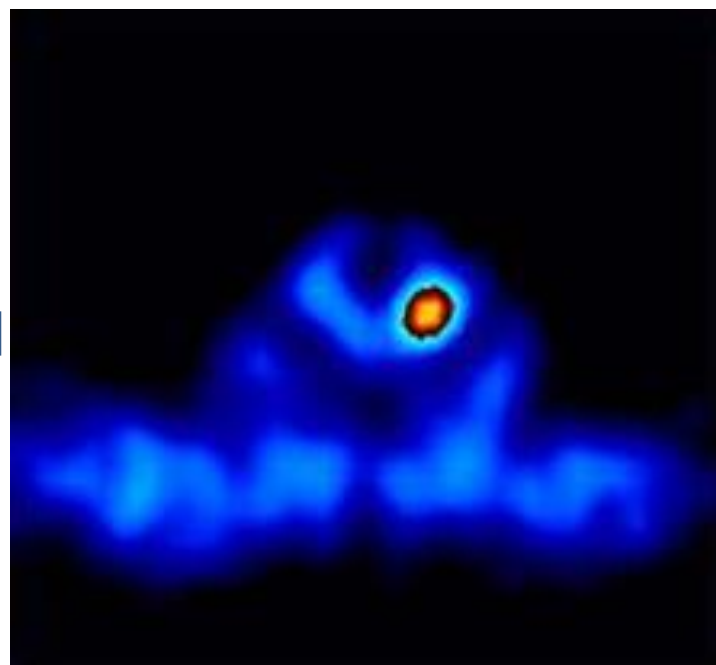


- **Development of SPECT and CT ;PET and CT fusion tools to produce SPECT/CT, PET/CT images (anatomical and functional images) → This leads to a more accurate determination of the location, volume and mass of brain tumors and lesions in relation to surrounding tissues, overcoming the disadvantages of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

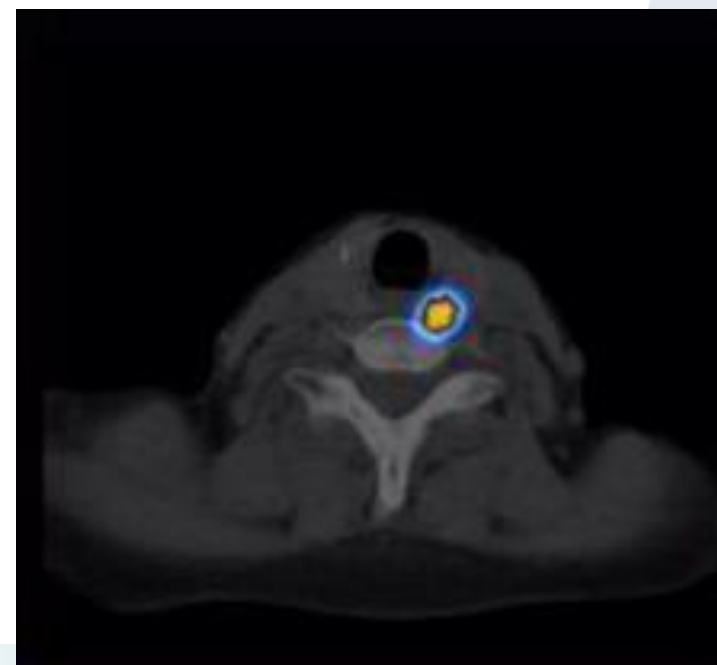
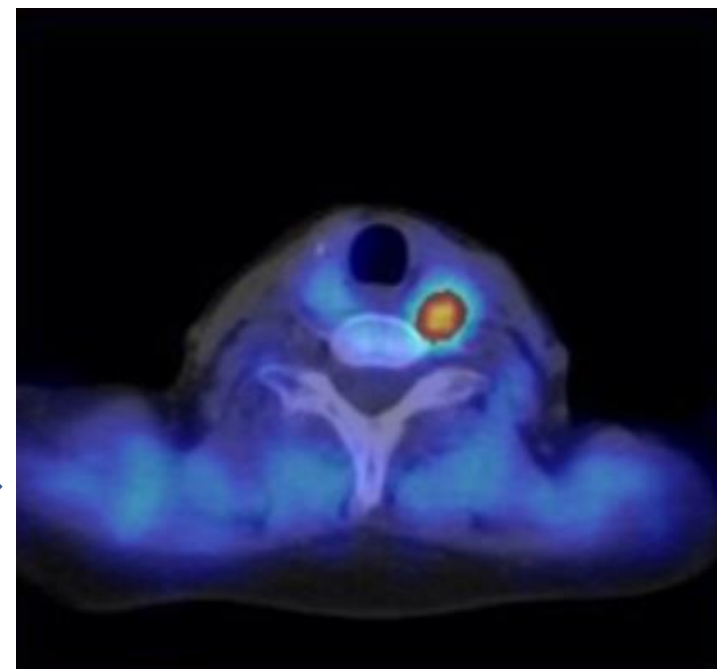
# Fusion



CT



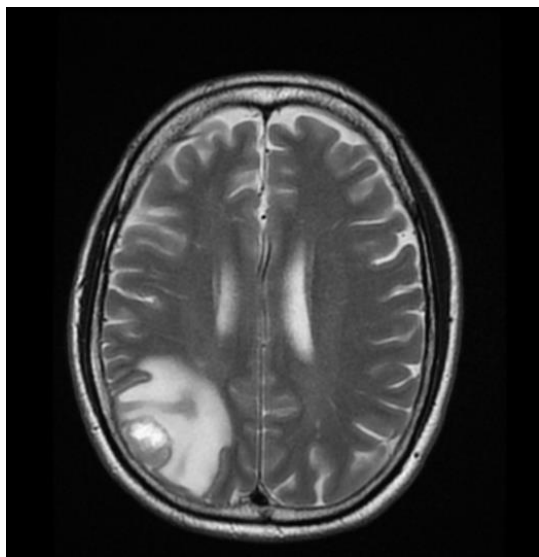
SPECT



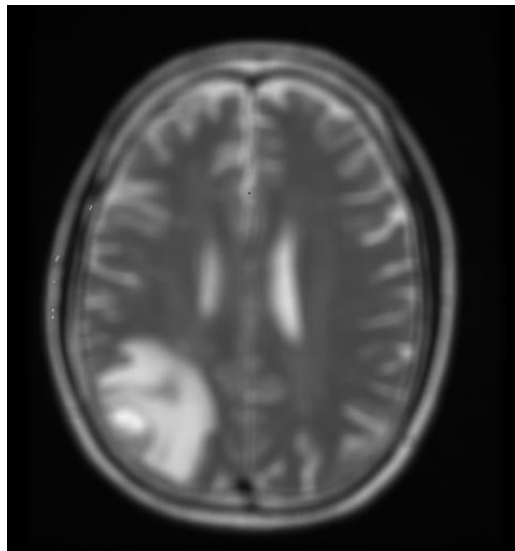
SPECT-CT



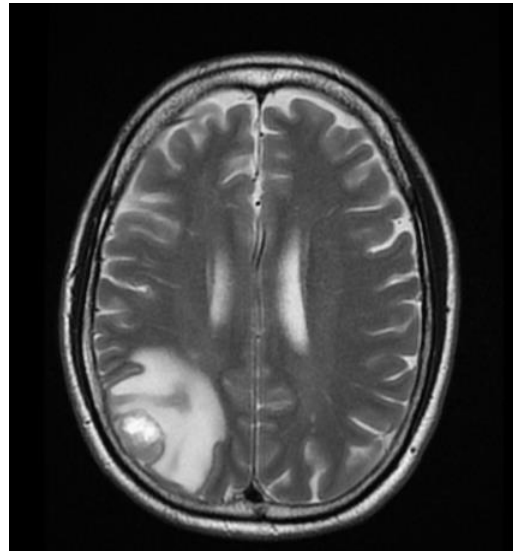
# Filters



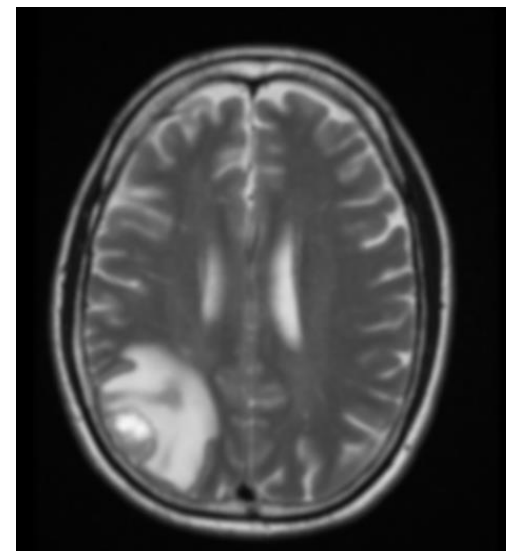
Raw



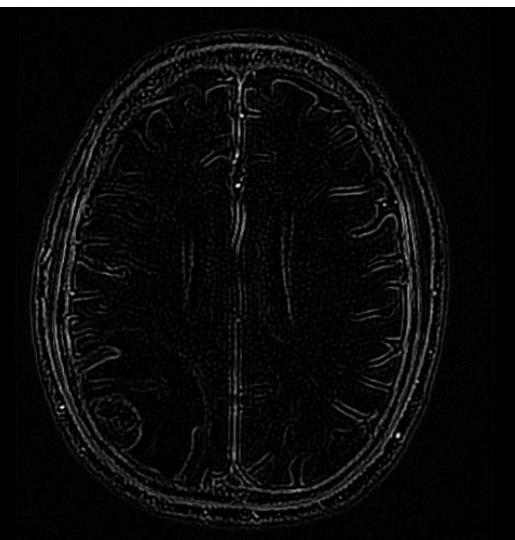
median



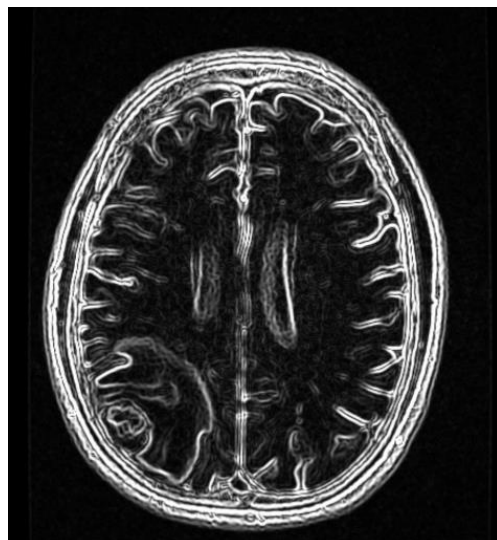
laplace



Laplace of gauss



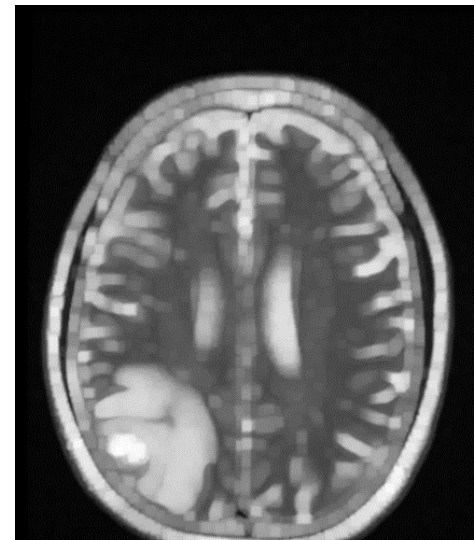
canny



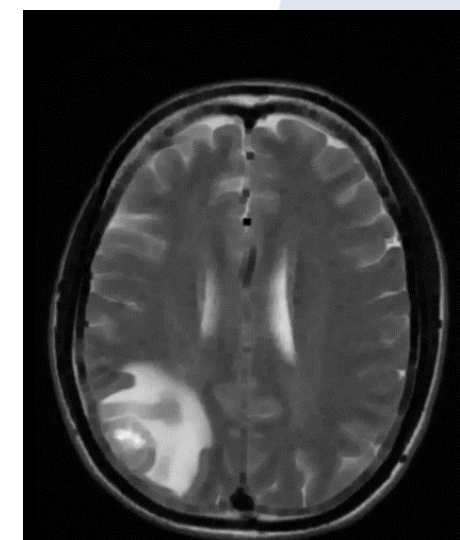
sobel



sharpen



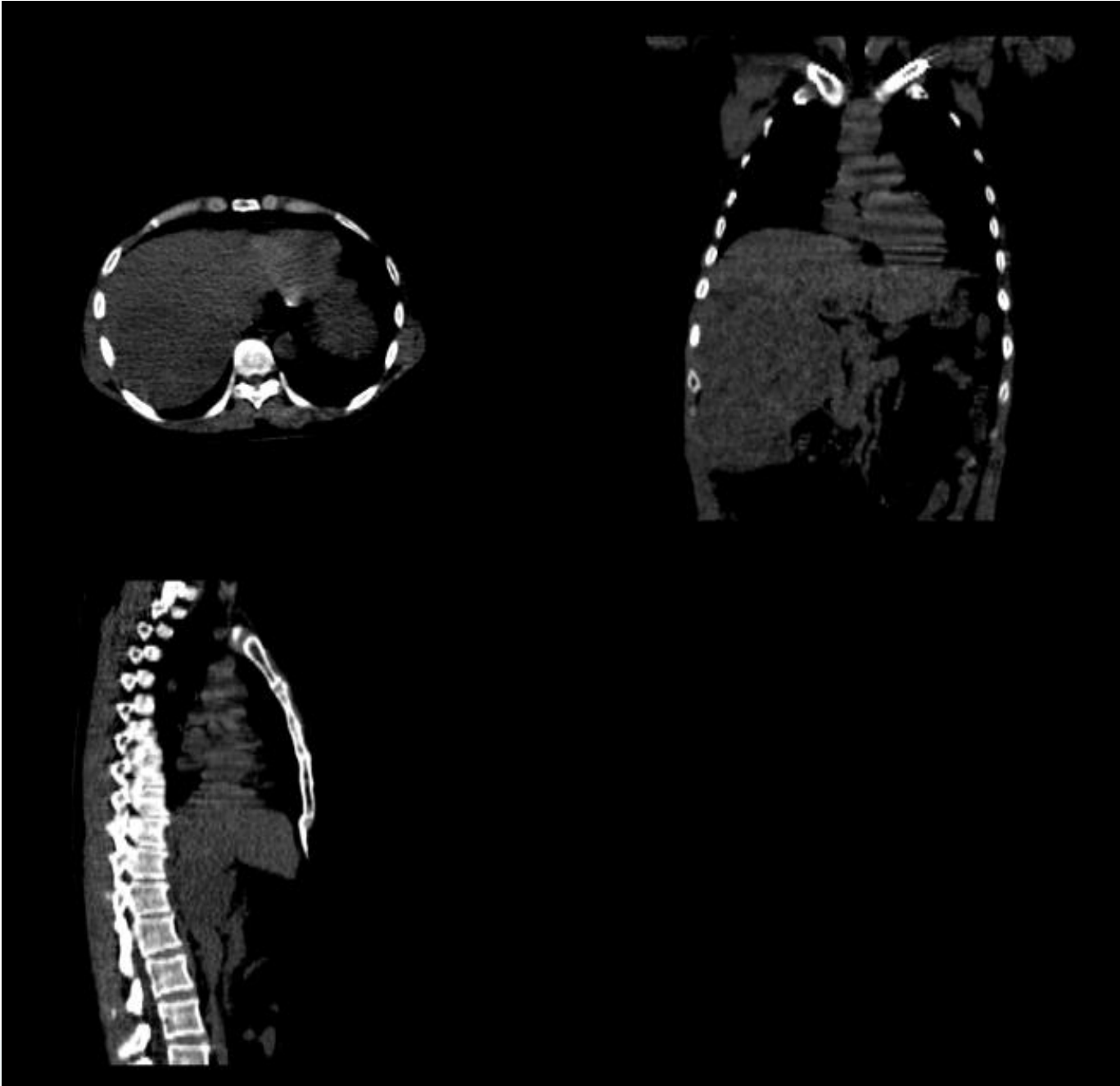
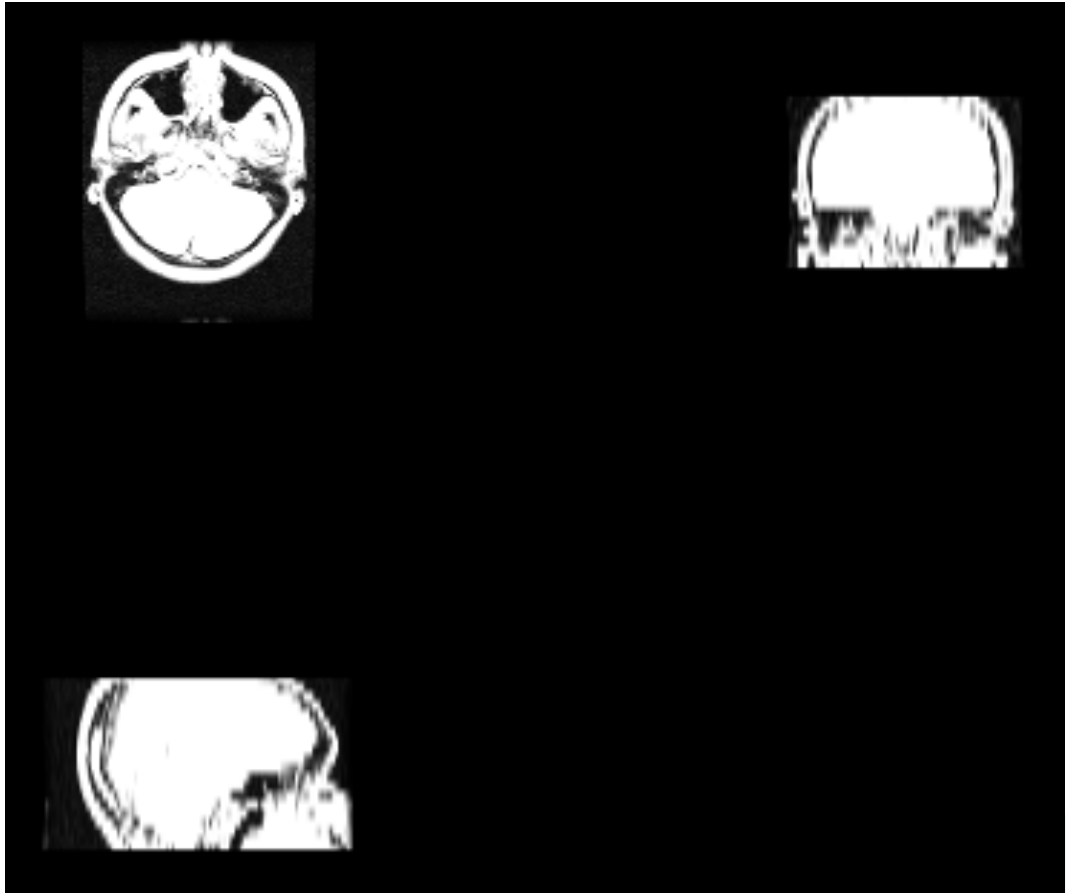
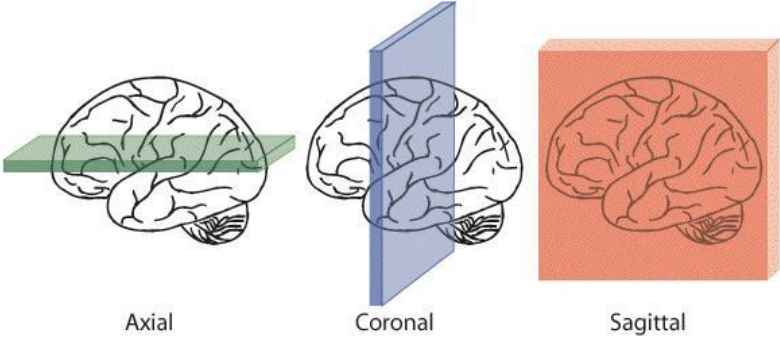
dilation



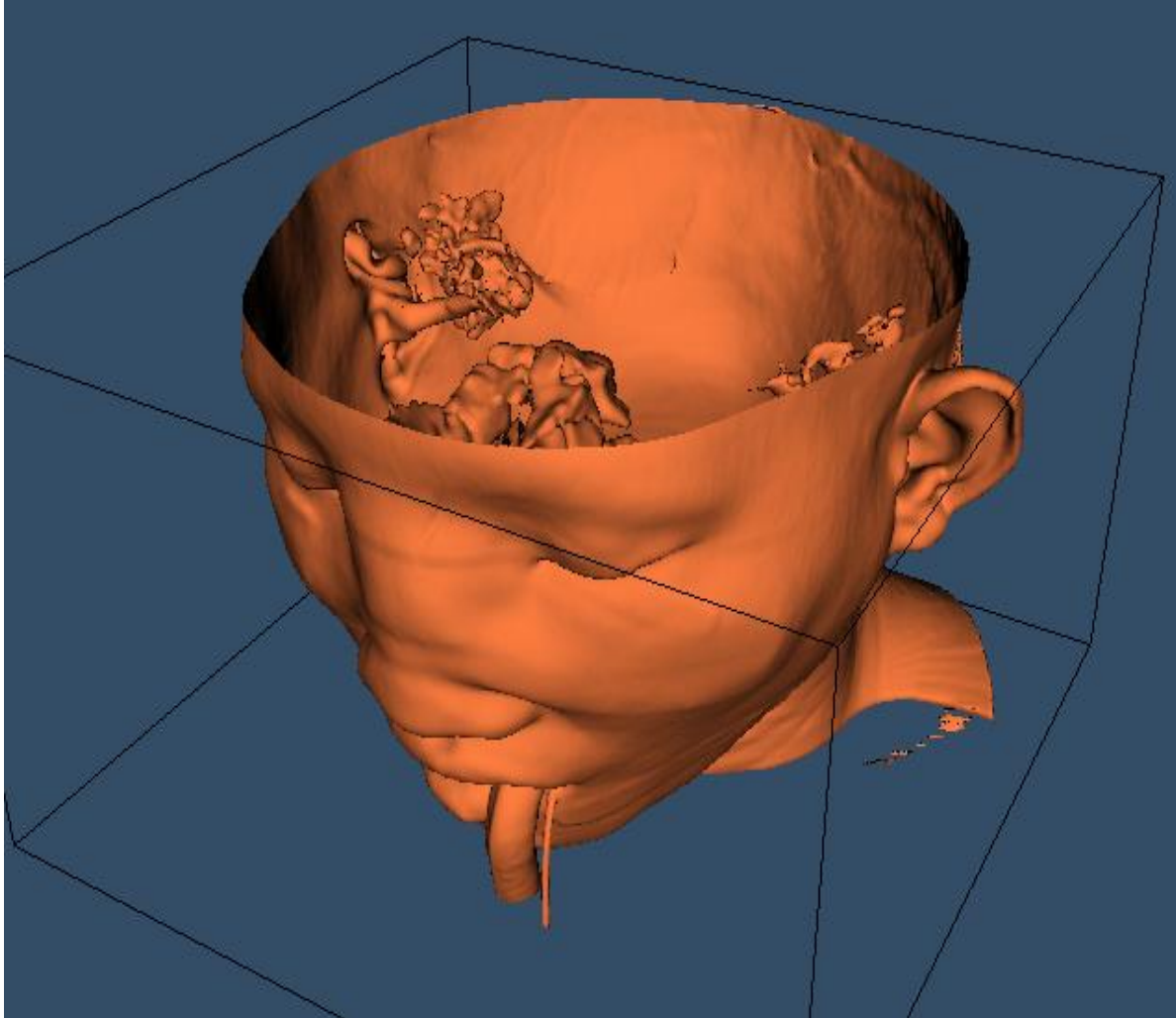
Erosion



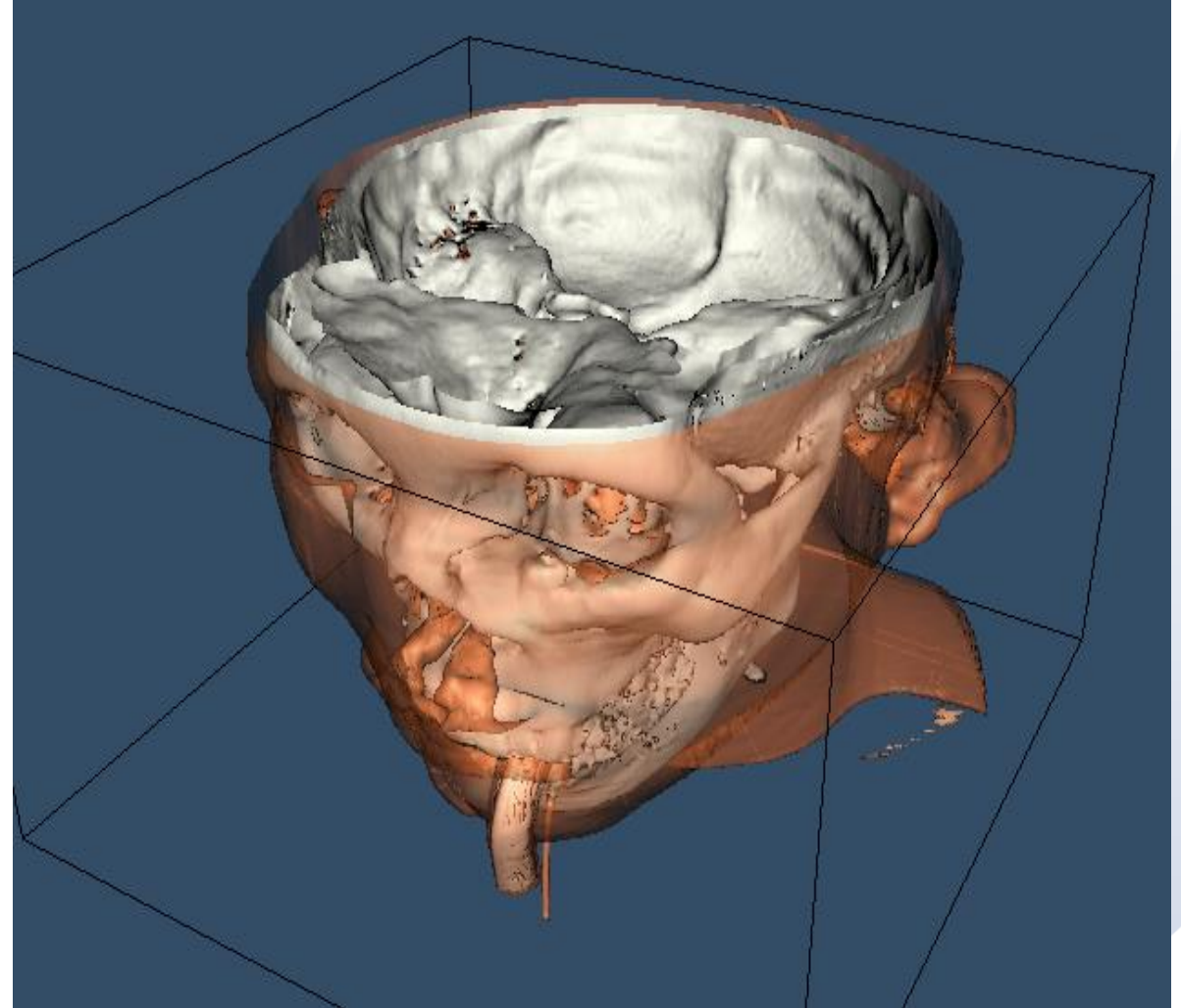
# Multiplanar reconstruction (MPR)



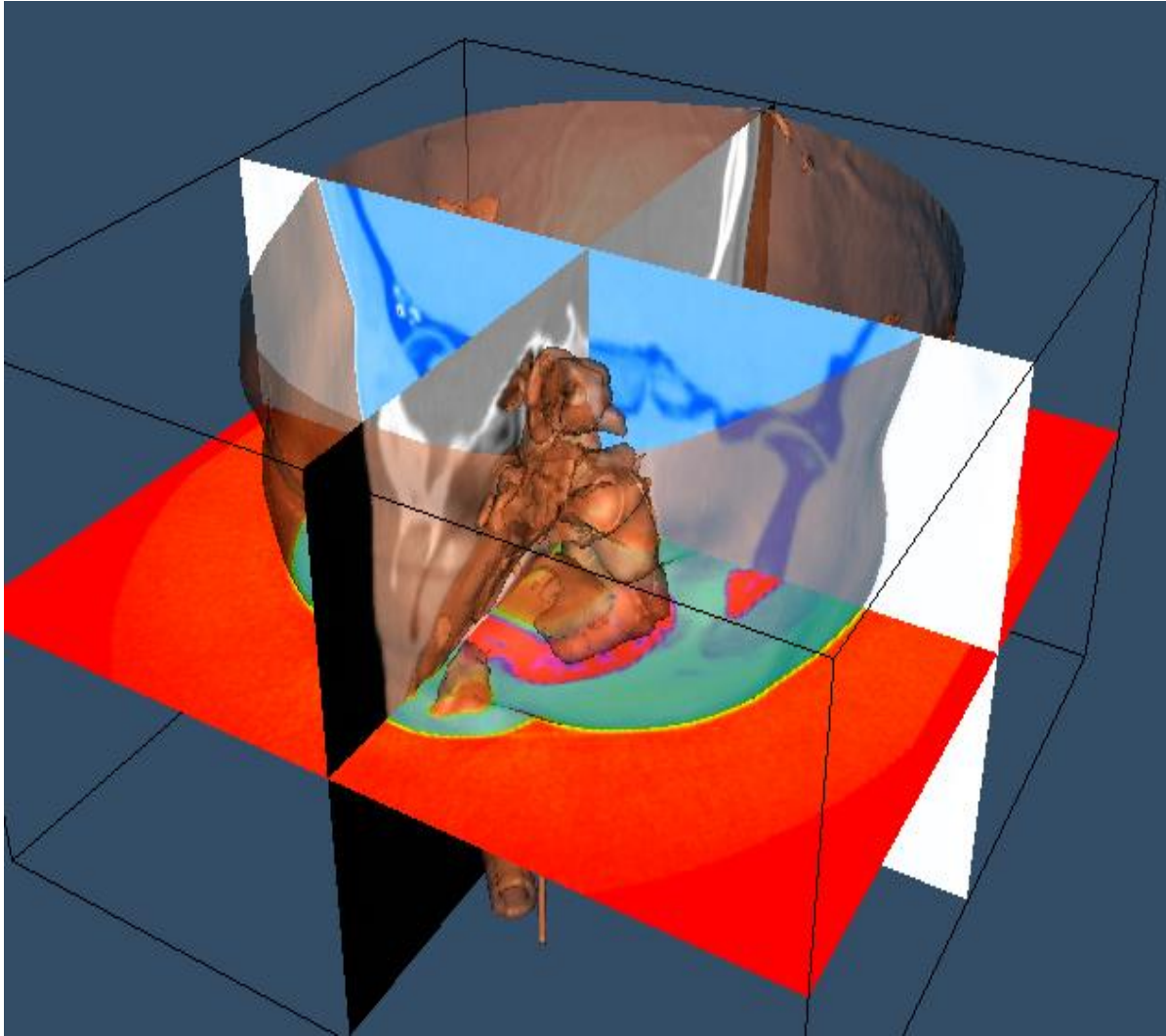
## 3D Reconstruction



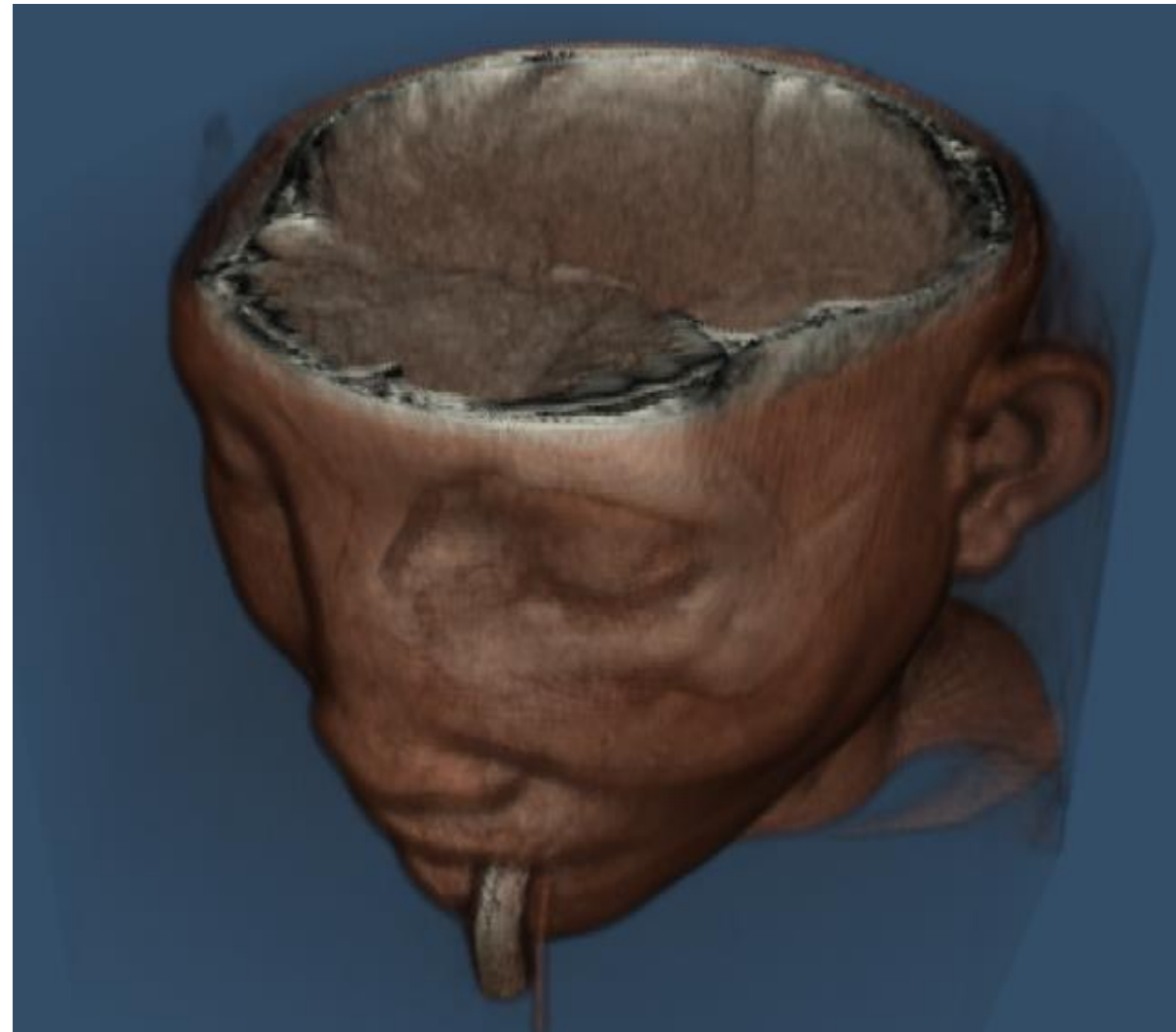
→ Reads a volume dataset, extracts an isosurface that represents the skin and displays it.



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

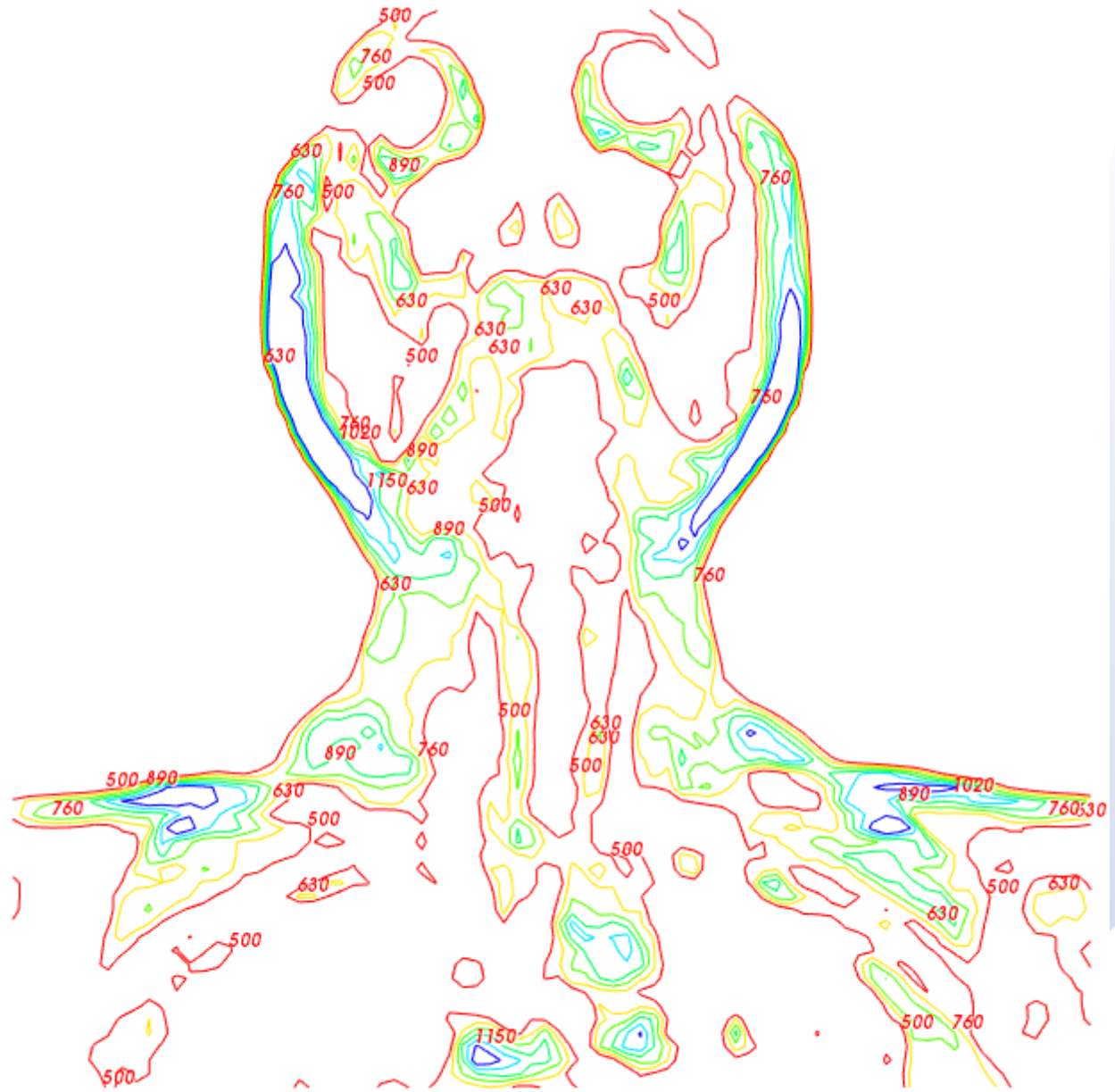


→ Reads a volume dataset, extracts two isosurfaces that represent the skin and bone, creates three orthogonal planes (sagittal, axial, coronal), and displays them.



→ 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!**