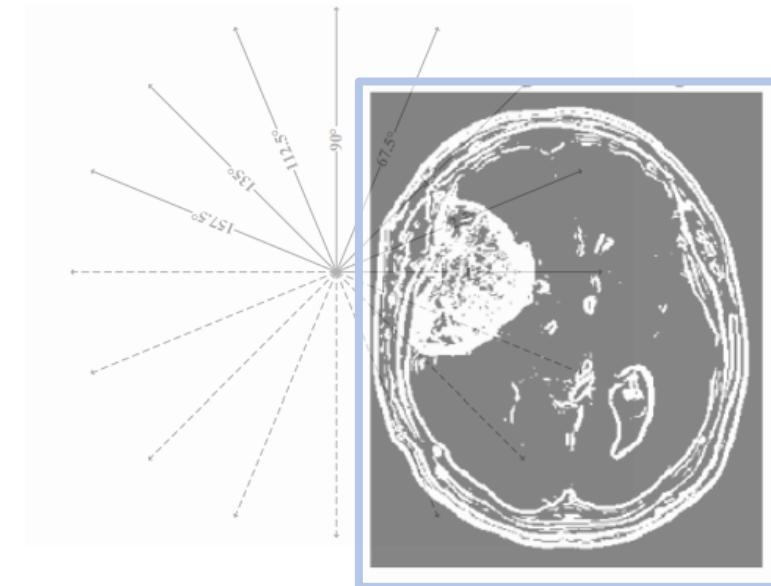# Comparative Analysis of Eight Direction Sobel Edge Detection Algorithm for Brain Tumor MRI Images

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Brain Tumor

- **Brain tumors** are caused by the abnormal and uncontrolled growth of cells inside the brain or spinal canal.

- *According to the World Health Organization (WHO) estimates, more than **400,000** children are suffering from brain tumor every year.*

Causes and Risk factors:

- Age factor
- Exposure to radiation
- Family history of brain tumors
- Smoking
- Substance abuse
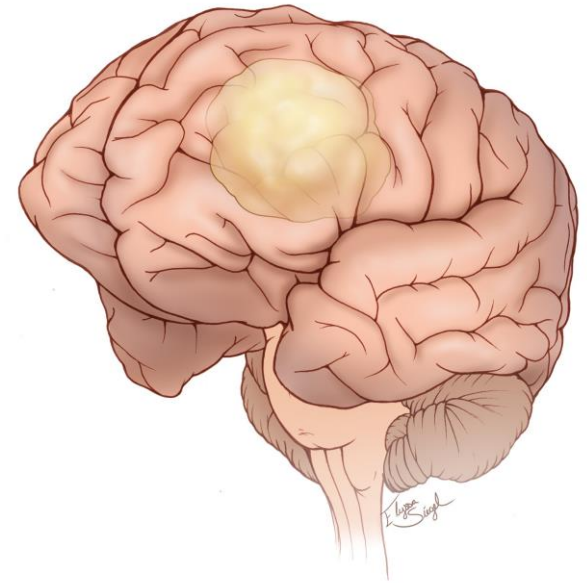
Symptoms of Brain Tumor
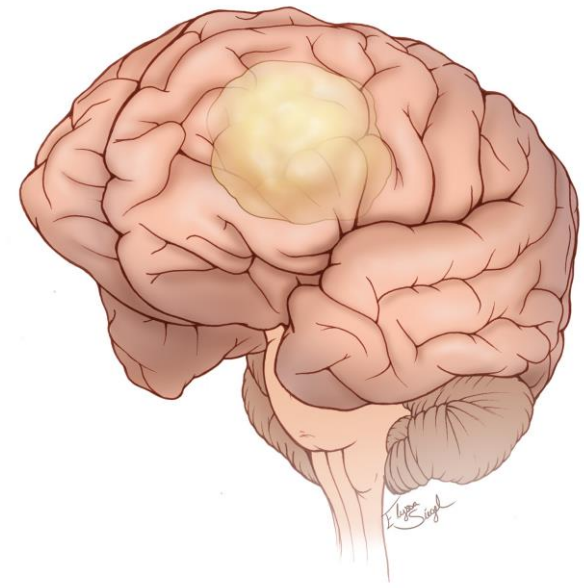
- Change in the pattern of headache
- Unexplained nausea or vomiting
- Vision problems
- Gradual loss of sensation or movement in an arm or in the leg
- Speech difficulties
- Feeling very tired
- Hearing problems

Treatment and Detection of Brain Tumors

- To reduce mortality growth rate due to brain tumor, early detection and treatment is essential.

- **But the problem is that:-**
  "Even an experienced radiologist analysing the brain tumor manually may reach to wrong decision in grading".

- **Problem Solution:-**
  "Automatically get the most significant data from brain tumor MRI images, we can use an edge detection technique".

Benefits of Edge Detection

- It filters the image to get only the significant data.
- Tremendously reduces the size of data need for further processing.
- Important variations of gray levels in an image can be identified
- Detects the geometrical and physical properties of objects in the scene of discussion.

Very Important for the effective analysis and detection of brain tumors edges from the MRI image data.

Edge Detection Process

To apply edge detection on any raw image data, few steps are necessary:

- Dataset collection.

- Noise removal from dataset through appropriate filters.

- Mean filter, Median filter, Gaussian filter, are widely used for noise removal.

- Commonly used are Sobel operator, Canny Edge Detection and Laplacian.

- Our focus is on a modified version of Sobel operator.
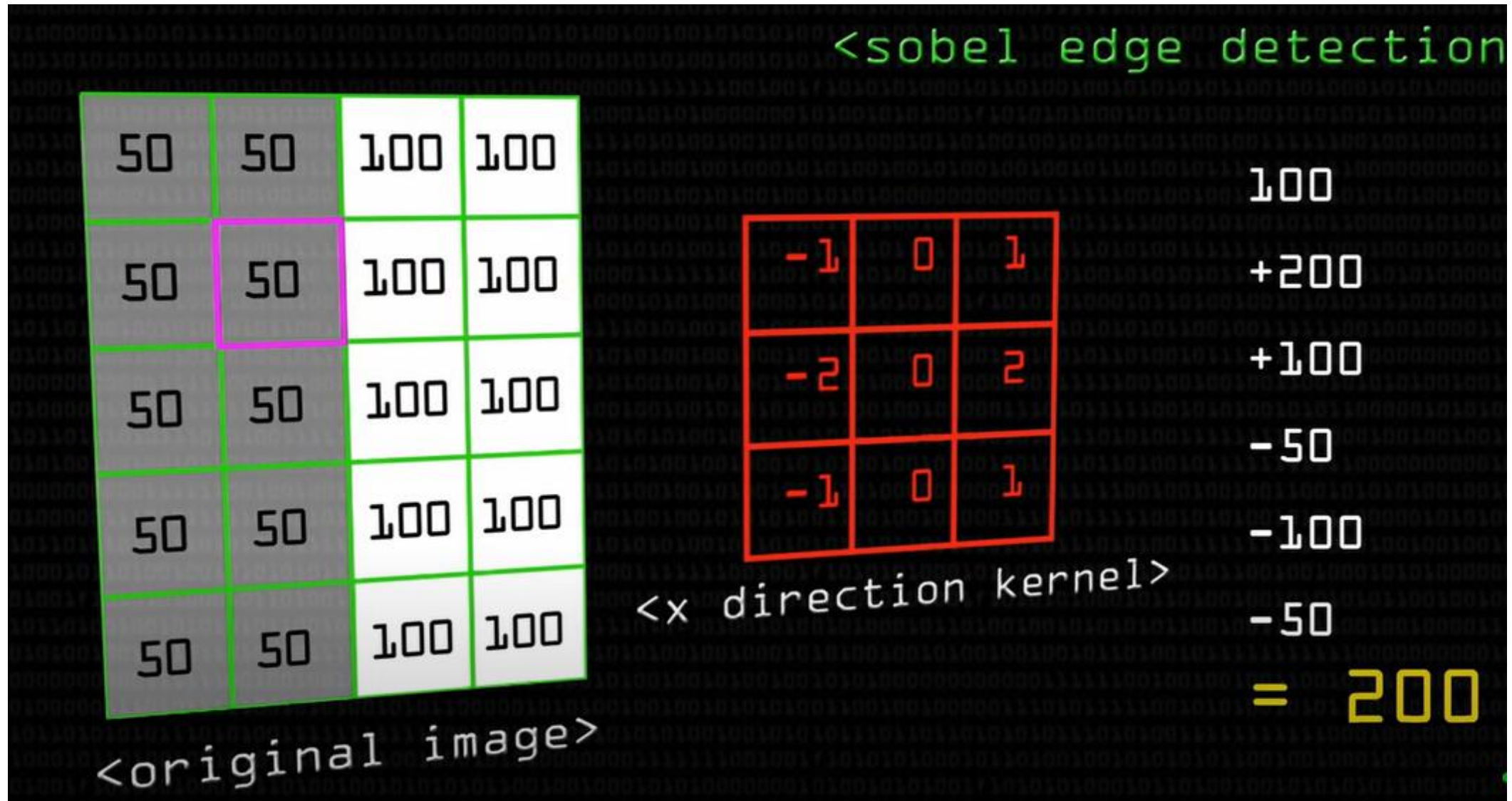
Traditional Sobel Edge Detection Operator

- The traditional Sobel edge detection operator is a discrete first order difference operator.

- The traditional Sobel edge detection operator has two 3x3 kernel matrices, in the vertical and horizontal direction, and require an image to do convolution.

- < X direction kernel > and A represent the original image

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * A$$

- < Y direction kernel > and A represent the original image

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * A$$

Working Principle of Sobel Operator

Major Limitations in Traditional Sobel Operator

As we all know that most of the edges of the images are multi-directional.

- But the traditional Sobel operator has only two direction templates.
- Only sensitive to the edges in the vertical and horizontal directions.
- Ignores the edge information in other directions of the image.
- Make the edge detection result incomplete, and massive edge information is missed.

90°

180° ← → **0°**

360°
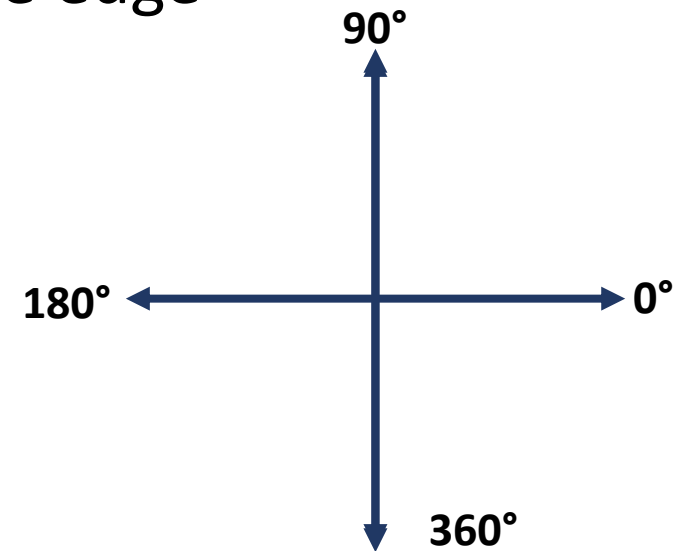
Eight Directional Sobel Operator

- The traditional Sobel operator templates is extended to 8 directional template operators.

- Extended eight directional Sobel operator uses the edge detection templates of 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5° for detection, the dashed arrow indicates the direction of symmetry.
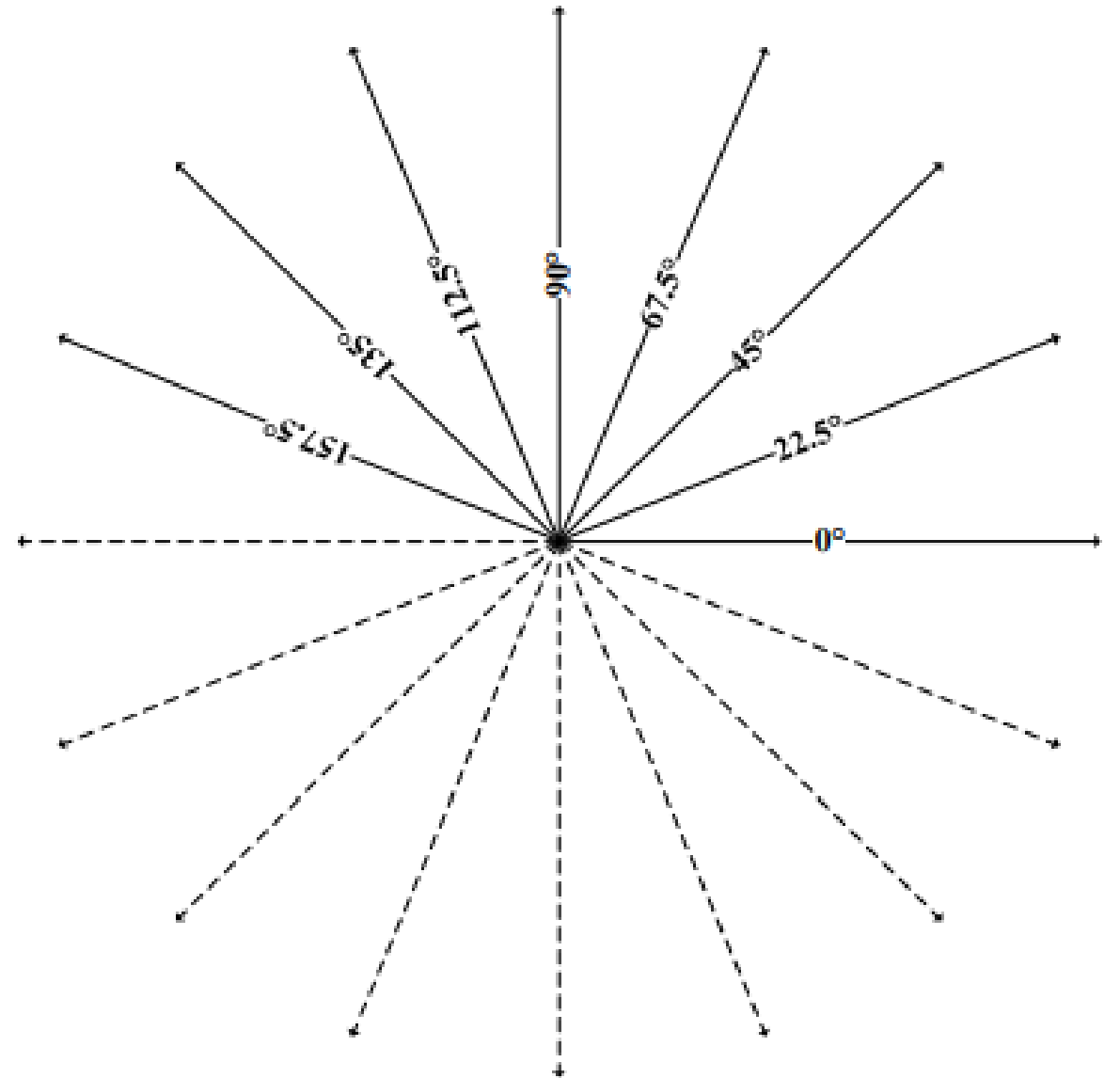
Eight Directional Kernels proposed by Researchers from **Chinese Academy of Sciences** at 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5° has shown better performance for detection.

$$G_{0^\circ} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ -1 & -2 & -4 & -2 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} * f \quad G_{90^\circ} = \begin{bmatrix} 0 & -1 & 0 & 1 & 0 \\ 0 & -2 & 0 & 2 & 0 \\ 0 & -4 & 0 & 4 & 0 \\ 0 & -2 & 0 & 2 & 0 \\ 0 & -1 & 0 & 1 & 0 \end{bmatrix} * f \quad G_{67.5^\circ} = \begin{bmatrix} 0 & 0 & -1 & 0 & 0 \\ 0 & -2 & -4 & -2 & 0 \\ 0 & -4 & 0 & 4 & 0 \\ 0 & -2 & 4 & 2 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} * f \quad G_{135^\circ} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ -1 & 0 & 4 & 2 & 0 \\ 0 & -4 & 0 & 4 & 0 \\ 0 & -2 & -4 & 0 & 1 \\ 0 & 0 & 0 & -1 & 0 \end{bmatrix} * f$$

$$G_{45^\circ} = \begin{bmatrix} 0 & 0 & 0 & -1 & 0 \\ 0 & -2 & -4 & 0 & 1 \\ 0 & -4 & 0 & 4 & 0 \\ -1 & 0 & 4 & 2 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{bmatrix} * f \quad G_{22.5^\circ} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & -2 & -4 & -2 & 0 \\ -1 & -4 & 0 & 4 & 4 \\ 0 & 2 & 4 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} * f \quad G_{112.5^\circ} = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & -2 & 4 & 2 & 0 \\ 0 & -4 & 0 & 4 & 0 \\ 0 & -2 & -4 & 2 & 0 \\ 0 & 0 & -1 & 0 & 0 \end{bmatrix} * f \quad G_{157.5^\circ} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 4 & 2 & 0 \\ -1 & -4 & 0 & 4 & 1 \\ 0 & -2 & -4 & -2 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} * f$$

Advantages of Eight Directional Sobel Operator

- The shortcoming offsets of edge information loss problem can be resolved.

- Edges in all directions are detected.

- Comparatively provide good performance with less complex functionality as compared to second-order derivations operators.

Drawbacks of Second Order Derivative Operators

Why didn't we use the second order derivatives for detection:

- Second derivatives exaggerate noise twice as much as first order and gradient based ones.

- No directional information about the edge is given.

- Doesn't measure 'how much the edge qualifies as an edge. (For Example) intensity image coming from a Sobel amplitude edge detector)

Drawbacks of Second Order Derivative Operators

- During to the gaussian smoothing: the location of the edges might be off, depending on the size of the gaussian kernel.

- Complex Functionality

- Expensive in terms of computation.

Performance Analysis of 8 Sobel Operator

Dataset: Kaggle Brain Tumor Dataset.

Metrics	Canny	Laplacian	LOG	Sobel	8 Sobel
MSE	7.6+e03	7.4+e03	7.6+e03	8.4+e03	**6.1+e03**
RMSE	87.5621	86.5603	87.6185	91.9974	**78.4808**
SNR (dB)	0.0056	0.0078	-9.6+e-16	-0.4233	**0.9567**
PSNR (dB)	9.2845	9.3844	9.2789	8.8556	**10.2355**
Time(s)	1.2394	0.6729	1.0501	0.8501	**2.7765**
Entropy	0.3404	0.0194	0	0.6741	**0.7663**

Performance Analysis of 8 Sobel Operator

- The 8-Sobel has the least **Mean Square Error** and **Root Mean Square Error**. Lower MSE indicate that the edge detected image is closer to original image.

- The **Peak Signal to Noise Ratio** value is the highest for 8-Sobel. This indicates that the quality of the edge detected image.

- The **Signal to Noise Ratio** is highest for the 8-Sobel which show output is more correct than other methods.

- **Entropy** is highest for 8-Sobel since the output has more edge detection information.

Output Result
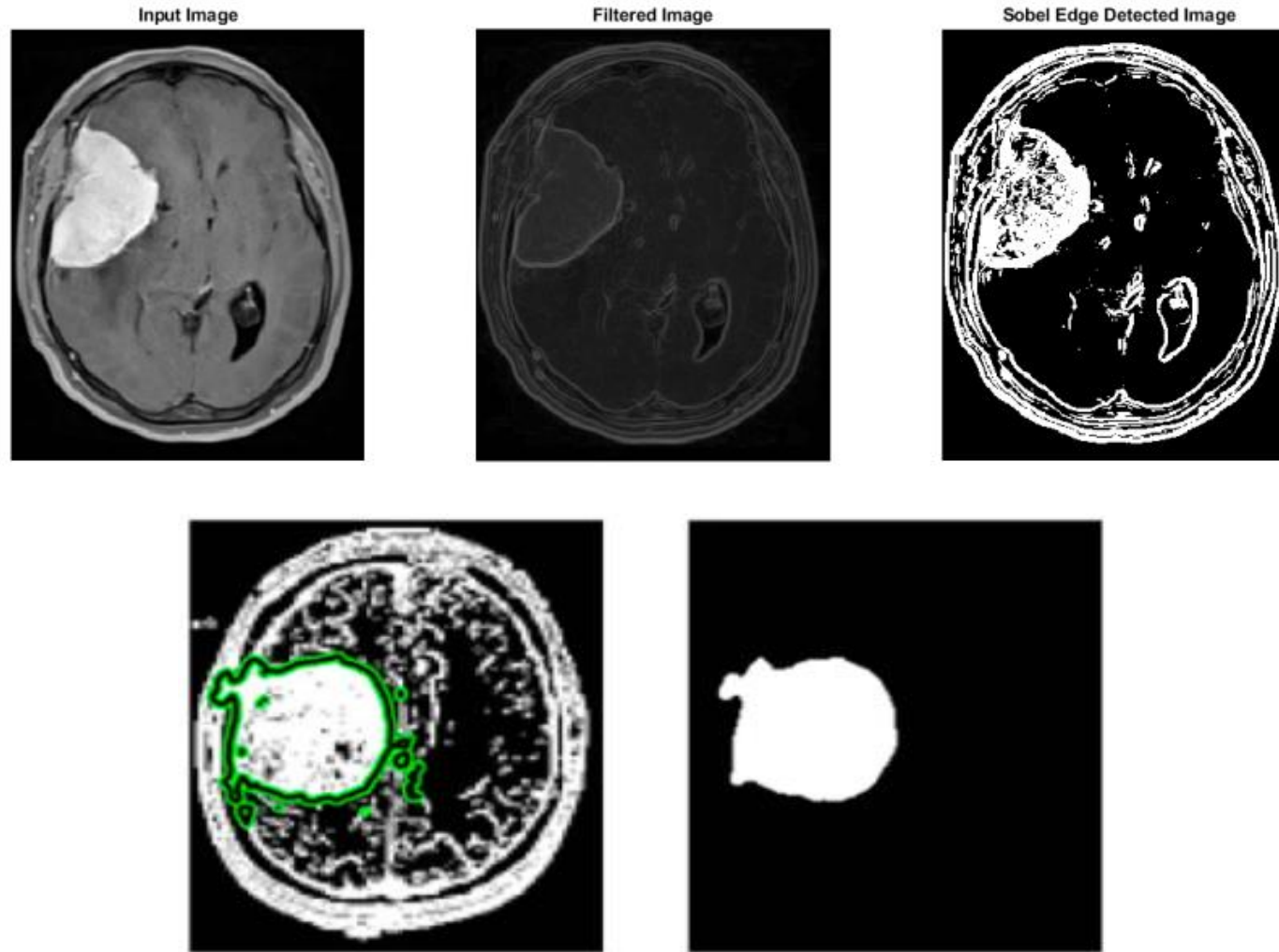
Edge Detection and Segmenting the Tumor using 8 Directional Sobel Algorithm

Conclusion and Future Scope

- Analysis shows that 8-Sobel is more suitable for detecting tumors in brain MRI images.

- Less complex functionality, Inexpensive in terms of computation.

- The scope of FPGA implementation of 8-Sobel as future work will ensure the improvement in execution speed.

- Better feature extraction models can be designed for machine learning classifiers with the 8-Sobel algorithm as an edge detector.

References

[1] A S, R. A., & Gopalan, S. (2022). Comparative Analysis of Eight Direction Sobel Edge Detection Algorithm for Brain Tumor MRI Images. Procedia Computer Science, 201, 487-494.

[2] Zhang, Kaiqiang, and Qiang Liao. "FPGA Implementation of Eight-direction Sobel Edge Detection Algorithm Based on Adaptive Threshold - IOPscience." FPGA Implementation of Eight-direction Sobel Edge Detection Algorithm Based on Adaptive Threshold - IOPscience, 1 Nov. 2020, iopscience.iop.org/article/10.1088/1742-6596/1678/1/012105.

Thank you