JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

IMPLEMENTATION OF A DOUBLE MEDIAN FILTER IN VLSI FOR NOISE REDUCTION IN BRAIN MRI IMAGES

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Abstract : The implementation of a median filter in Very Large Scale Integration (VLSI) for reducing noise in brain MRI images provides a strong method to improve the clarity and accuracy of medical imaging. Brain MRI images often have salt and pepper noise, which can hide important details needed for proper analysis. In this project, the noisy MRI images are first turned into binary text format and stored in RAM. This preprocessing makes it easier to handle and process the data within the VLSI system. The median filter module works by using a buffer to hold the incoming data and then sorting this data to find the median value, which helps remove the noise. By applying a double median filtering process to the stored data, noise is greatly reduced while keeping important image details. A line buffer is used to store temporary values, making the filtering process efficient and fast enough for real-time use. This method not only improves image quality but also uses the parallel processing power of VLSI to work quickly. A detailed testbench checks the RAM and median filter modules, showing the steps of reading binary data from an input file, filtering it, and writing the cleaned output to a new file. The resulting images have less noise and are clearer, making them better for medical analysis and interpretation. This project shows how VLSI technology can improve medical imaging techniques.

***IndexTerms* – VLSI, RAM, Median filter, MRI image.**

I. INTRODUCTION

Brain tumor detection plays a pivotal role in the field of medicine, and the utilization of MRI images has significantly enhanced this process. It is imperative to emphasize the importance of this detection technique in identifying brain tumors accurately and efficiently. MRI, an abbreviation for Magnetic Resonance Imaging, is a non-invasive imaging modality that uses a strong magnetic field and radio waves to produce detailed images of the brain. The significance of MRI in brain tumor detection lies in its ability to provide a comprehensive view of the brain's structure, as well as the presence and characteristics of any abnormal growths.

This diagnostic tool enables healthcare professionals to detect brain tumors at their earliest stages, facilitating timely intervention and treatment planning. Furthermore, MRI images assist in precisely locating the tumor, determining its size, and assessing its impact on surrounding brain tissues, ultimately guiding surgeons in their decision-making process. Thus, the integration of MRI imaging in the medical field proves essential in the early detection and subsequent management of brain tumors.

1.1 MAGNETIC RESONANCE IMAGING

Magnetic Resonance Imaging (MRI) has become an indispensable tool in the medical field, revolutionizing the way we diagnose and understand conditions of the brain. This advanced imaging technique uses a powerful magnetic field and radio waves to create detailed images of the brain, allowing healthcare professionals to visualize its structures and identify abnormalities with exceptional precision. The importance of MRI brain images lies in their ability to provide crucial information regarding the presence and progression of various neurological disorders such as tumors, strokes, and degenerative diseases.

By capturing clear and detailed images of the brain, MRI enables healthcare providers to make accurate diagnoses, plan appropriate treatment strategies, and monitor the effectiveness of interventions. The simplicity of the MRI technique, coupled with its unparalleled ability to offer insights into the complex workings of the brain, has undoubtedly cemented its position as an invaluable tool in the medical field. With ongoing advancements and a growing understanding of its capabilities, MRI continues to transform the way neurologic conditions are diagnosed and managed, enhancing patient care and improving outcomes.

Magnetic Resonance Imaging (MRI) stands as a cornerstone in contemporary medical diagnostics, offering unparalleled insights into the intricate anatomical and physiological details of the human body without the use of ionizing radiation. Despite its indisputable clinical significance, the fidelity of MRI images is inevitably compromised by the omnipresent challenge of noise. This pervasive interference manifests from a plethora of sources, spanning the electronic intricacies of the imaging apparatus to intrinsic physiological nuances of the human body undergoing examination.

Electronic noise, originating from the complex interplay of radiofrequency signals and electronic components, introduces random fluctuations that can distort image quality. Concurrently, motion artifacts induced by patient movements, whether voluntary or involuntary, contribute to the degradation of spatial resolution and overall image clarity. Furthermore, physiological processes, such as cardiac pulsations and respiratory cycles, introduce temporal variations in the acquired signals, leading to temporal artifacts that manifest as unwanted signal variations. This multifaceted nature of noise poses a formidable challenge to the field of MRI, demanding a nuanced understanding of its diverse origins and implications for diagnostic accuracy.

In essence, the deleterious effects of noise on MRI images extend beyond mere visual aesthetics, permeating into the realms of diagnostic accuracy and clinical reliability. Unchecked, noise can obscure subtle pathological findings, compromise the precision of anatomical delineations, and impede the accurate assessment of disease states. As the demand for higher image resolution and diagnostic specificity intensifies, the imperative to address and ameliorate noise-related challenges becomes increasingly pronounced. Fortunately, the scientific community has responded to this challenge with a diverse array of strategies aimed at noise characterization, quantification, and ultimately, mitigation. From advanced signal processing algorithms to sophisticated hardware modifications, researchers and engineers are continually pushing the boundaries of innovation to enhance the signal-to-noise ratio in MRI images.

1.2 NOISE

MRI images are not immune to the influence of noise. This predicament arises when random variations infiltrate the image acquisition process, leading to a degradation of image quality. Noise is a random variation of image Intensity and visible as a part of grains in the image. It may cause to arise in the image as effects of basic physics-like photon nature of light or thermal energy of heat inside the image sensors. It may produce at the time of capturing or image transmission. Noise means. It may cause to arise in the image as effects of basic physics-like photon nature of light or thermal energy the pixels in the image show different intensity values instead of true pixel values that are obtained from image. Noise removal algorithm is the process of removing or reducing the noise from the image. The noise removal algorithms reduce or remove the visibility of noise by smoothing the entire image leaving areas near contrast boundaries. But these methods can obscure fine, low contrast details.

The unparalleled sensitivity of MRI to various sources of noise presents a considerable challenge, potentially compromising the quality and reliability of acquired images. In response to this challenge, the field has witnessed a remarkable evolution in the development of noise reduction filters designed to enhance image fidelity and clinical utility. The use of filters in MRI image processing is multifaceted, encompassing a broad spectrum of methodologies and algorithms aimed at suppressing noise while preserving essential diagnostic information.

Classical linear filters, such as Gaussian and mean filters, operate on the principle of convolution, where a kernel is applied to each pixel to smooth out noise by averaging local intensities. While effective, these filters may inadvertently blur edges and compromise fine details in the image. In contrast, non-linear filters, including median and bilateral filters, provide a more sophisticated approach by selectively preserving edge information while effectively suppressing noise.

This exploration delves into noise reduction filters in MRI, examining their theoretical foundations, practical applications, and technological innovations. By analyzing these filters, we aim to enhance MRI image processing strategies, advancing this essential medical imaging modality for precise clinical diagnoses. Noise in MRI images can stem from hardware imperfections, patient movement, and environmental interference, challenging radiologists who depend on image accuracy. Advances in medical imaging have led to the development of sophisticated noise reduction filters and algorithms. These tools enhance image quality by selectively eliminating noise while preserving essential diagnostic information, thereby improving the diagnostic efficacy of MRI scans

1.3 SALT AND PEPPER NOISE

Salt and pepper noise is a type of image distortion characterized by randomly occurring bright and dark pixels in an image. It is found only in grayscale images (black and white image). These pixels resemble grains of salt and pepper, hence the name. an image having salt-and-pepper noise will have a few dark pixels in bright regions and a few bright pixels in dark regions. Salt-and-pepper noise is also called impulse noise. It can be caused by several reasons like dead pixels, analog-to-digital conversion error, bit transmission error, etc. This type of noise can significantly degrade the quality of images and impact the accuracy of image analysis algorithms.

1.3.1 Causes and Appearance

During the acquisition, transmission, or processing of an image, errors can lead to salt and pepper noise, where random pixels are assigned extreme values. This noise can be caused by external factors such as electromagnetic interference, electrical noise, and other environmental conditions. Defective pixels in imaging devices like cameras or scanners may report incorrect intensity values, contributing to this noise. Errors during image storage or data transmission can also introduce salt and pepper noise. In MRI imaging, malfunctions in scanner hardware or sensors, fluctuations in the magnetic field, and patient motion during scans can result in signal acquisition errors, leading to noise and distortion in the final image.

II. MATERIALS AND METHODOLOGY

Very Large Scale Integration (VLSI) is a transformative technology in the electronics industry, enabling the integration of thousands to millions of transistors onto a single chip. This capability is crucial for developing compact, powerful, and energy-efficient devices, thus enhancing the performance of electronic systems while reducing size and cost. VLSI is fundamental to a wide array of modern applications, from consumer electronics and medical devices to automotive systems and telecommunications.

In signal processing, noise reduction is a critical task as unwanted electrical or electromagnetic interference can significantly degrade system performance. VLSI technology is essential for implementing effective noise reduction techniques due to its ability to integrate complex algorithms and processing functions onto a single chip. This application of VLSI spans various domains: in consumer electronics, it minimizes audio and visual noise for clearer sound and sharper images; in medical devices, it ensures high precision and reliability in instruments like ECG monitors and imaging devices; and in automotive systems, it reduces electromagnetic interference for seamless operation.

In telecommunications, VLSI technology maintains signal integrity for reliable data and voice transmission, and in industrial applications, it enhances the robustness and accuracy of automation systems by mitigating noise from machinery and electrical systems. By leveraging VLSI, engineers can design integrated circuits that effectively reduce noise, ensuring optimal performance of electronic systems across diverse applications. The continuous advancement of VLSI technology promises even greater improvements in noise reduction, further pushing the boundaries of what is achievable in electronics and signal processing.

2.1 INNOVATIONS IN VLSI FOR NOISE REDUCTION

The ongoing development of VLSI technology continues to unlock new potentials in the field of noise reduction. Recent advancements have introduced more sophisticated noise-cancellation algorithms and adaptive filtering techniques that are seamlessly integrated into VLSI chips. These innovations not only enhance the efficiency of noise reduction but also reduce power consumption, making VLSI-based noise reduction solutions more viable for portable and battery-operated devices. Furthermore, the development of smaller, more powerful transistors and advanced materials has enabled the creation of high-density circuits that deliver superior performance with minimal noise interference. The integration of artificial intelligence and machine learning with VLSI technology is revolutionizing noise reduction processes. Machine learning algorithms can now be embedded directly onto VLSI chips, allowing real-time adaptation to varying noise environments.

III. METHODOLOGY

The median filter, implemented using VLSI (Very Large Scale Integration) technology, plays a crucial role in reducing noise in MRI brain images. This sophisticated approach leverages the efficiency and speed of VLSI to perform real-time filtering, ensuring that the intricate details of the brain images are preserved while unwanted noise is effectively removed. By incorporating the median filter into a VLSI design, the system can achieve high-performance processing capabilities, essential for enhancing the clarity.

3.1 BLOCK DIAGRAM

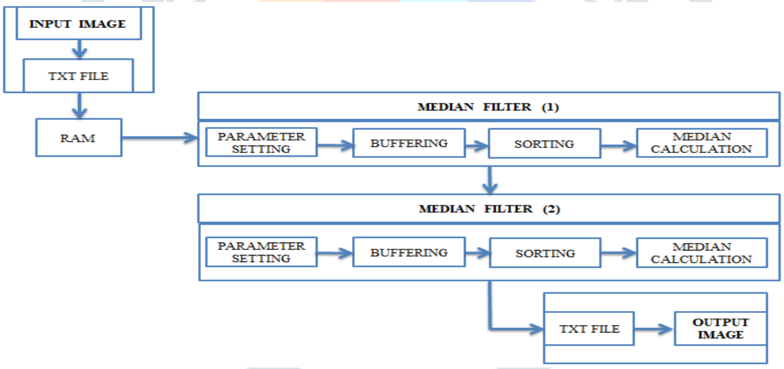


Figure 1 Block diagram

Figure 1 shows the block diagram for noise reduction in MRI brain images using a double median filter implemented in VLSI (Very-Large-Scale Integration) technology. The top module coordinates the process, beginning with the RAM module, which temporarily stores incoming MRI data. This data is then processed through two stages of median filters. The first stage median filter receives the output from the RAM module, sorting the buffered data to extract the median value, effectively reducing noise. The processed output is then fed into the second stage median filter, which performs a similar operation to further enhance the noise reduction. By leveraging the efficiency and high-speed processing capabilities of VLSI, this design ensures that MRI brain images are significantly clearer and more accurate, making it a valuable tool for medical diagnostics.

3.1.1 Parameter Setting

These are critical for defining the median filter's operation and noise reduction effectiveness.

- WIDTH = 8:
  - Input data is 8 bits wide.
  - Commonly used for pixel values in image processing applications (e.g., MRI images).
  - 8-bit width handles pixel values ranging from 0 to 255.
  - Ensures compatibility with common image formats.
- DEPTH = 5:
  - Defines the window size (5 values) used to calculate the median.
  - An odd number of values simplifies finding the median.
  - Balances noise reduction and image detail preservation.
- Impact of DEPTH:
  - Larger depth: More noise reduction but may blur details.
  - Smaller depth: Less noise reduction, possibly insufficient for MRI clarity.

- Chosen parameters:

WIDTH = 8 and DEPTH = 5 are optimized for enhancing MRI image clarity by reducing noise while maintaining image details.

3.1.2 Buffering

- Role of the Buffer:
  - Critical for noise reduction in MRI brain images.
  - Stores the most recent input values.
- Sliding Window Mechanism:
  - Maintains a sliding window of data points.
  - Essential for real-time processing of incoming data.
- Buffer Size:
  - Holds a fixed number of values (5 in this case).
  - Facilitates median calculation by storing the necessary subset of recent values.
- Median Calculation:
  - Involves sorting the buffered values and selecting the middle one.
  - Reduces noise more effectively than using the mean, as the median is less influenced by outliers.
- Noise Reduction:
  - Ensures smooth data while preserving important details in MRI images.
- Real-time Operation:
  - The buffer allows continuous operation without interruptions.
  - Ideal for dynamic and efficient real-time MRI image processing.

3.1.3 Sorting

- Importance of Sorting:

  - Essential for determining the median value.

  - A key step in reducing noise in MRI brain images.

- Buffer Accumulation:
  - The buffer holds a set of recent input values.
  - These values must be sorted to identify the median.
- Sorting Algorithm:
  - Sorting is achieved using a bubble sort algorithm.
  - The algorithm repeatedly steps through the list, compares adjacent pairs, and swaps them if they are in the wrong order.
  - This continues until the entire list is sorted.
- Median Identification:
  - Sorting organizes the data, enabling accurate identification of the middle (median) value.
  - The median is robust against extreme outliers, unlike the average.
- Noise Reduction:
  - Sorting helps isolate the central tendency of recent values.
  - This effectively smooths out noise while retaining important image details.

3.1.4 Median Calculation

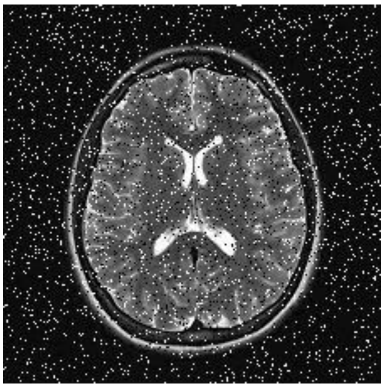
- Process of Median Calculation: After accumulating and sorting a window of recent input values, the module identifies the median (middle value in the sorted list).
- Robustness of the Median: The median is less influenced by extreme values or outliers compared to the mean.
- Effectiveness in Noise Reduction: Selecting the median value from the sorted data smooths out noise while preserving critical image details.
- Enhancement of Image Clarity: The median-filtered output reflects the central tendency of the input data.

IV. RESULTS AND DISCUSSION

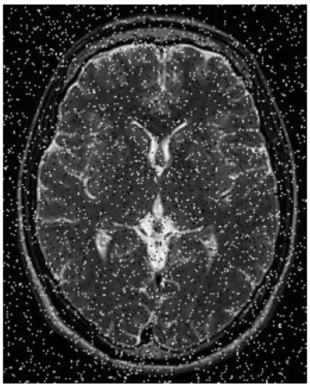
The median filter, a widely used noise reduction technique, is implemented using Very Large Scale Integration (VLSI) technology.

4.1 INPUT IMAGE

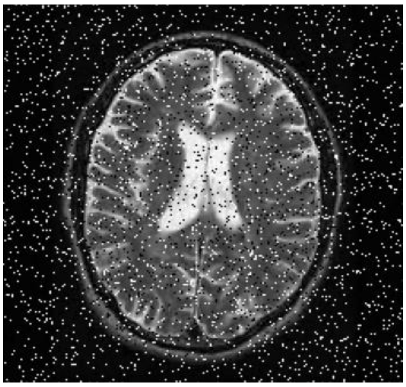
Noisy MRI brain image is given as an input image which is taken from the kaggel dataset namely the no tumor dataset. This dataset contains MRI images in JPEG format. The dataset consist of 405 images they are introduced with salt and pepper noise.



(a)



(b)



(c)

Figure 2 (a) Noisy image 1, (b) Noisy image 2,

(c) Noisy image 3

Figure 2 (a) Noisy image 1, (b) Noisy image 2, (c) Noisy image 3 shows the input noisy images. The three input images are correpted with salt and pepper noise for the further process.

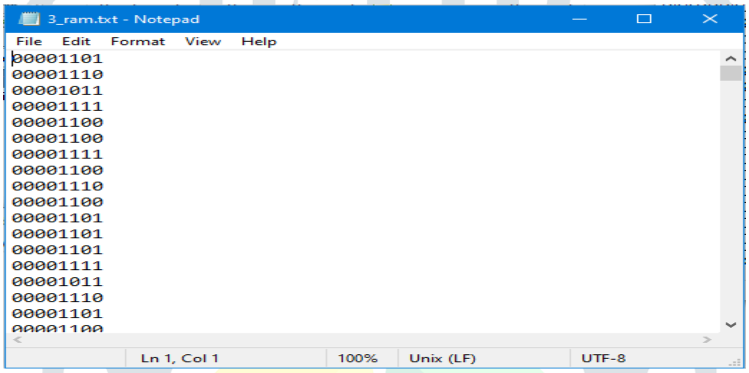


Figure 3 Binary text file of the input image (a) Noisy image 1

To read the data into RAM the input image (a) Noisy image 1is converted to binary.txt format and then it is fed into the input RAM

4.2 SIMULATION

The converted binary text of the noisy images is stored in the RAM for simulation. The simulation demonstrates the functionality of the RAM module and two median filter modules. Figure 4 displays the waveform for the simulation. By representing the noisy images as binary text, it ensures optimized memory usage and facilitates faster data processing within the VLSI system, enhancing the overall performance and reliability of the image processing application in simulation.

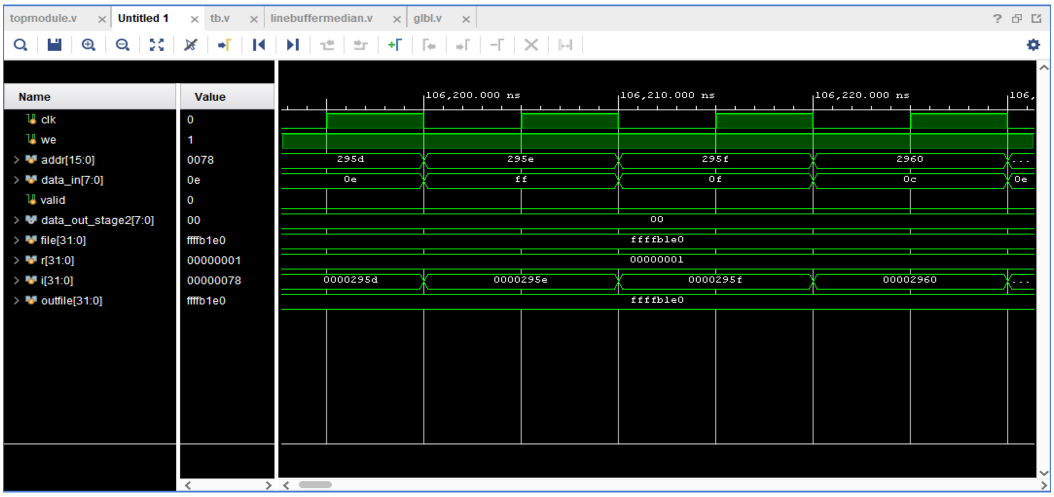


Figure 4 Waveform for the Simulation

4.3 RAM MODULE

The RAM module is a crucial component for efficient data storage and retrieval in a VLSI system. Figure 5 Waveform for the Ram Module. It handles 8-bit data inputs and outputs, and operates with a 16-bit address space, allowing precise control over where data is written or read. Controlled by a write enable signal and synchronized with a clock signal, the module ensures reliable and timely data operations. The internal memory array is designed to accommodate a large number of data entries, providing substantial storage capacity. By efficiently managing read and write operations, this RAM module significantly enhances the overall performance and reliability of the VLSI system, supporting its complex processing needs.

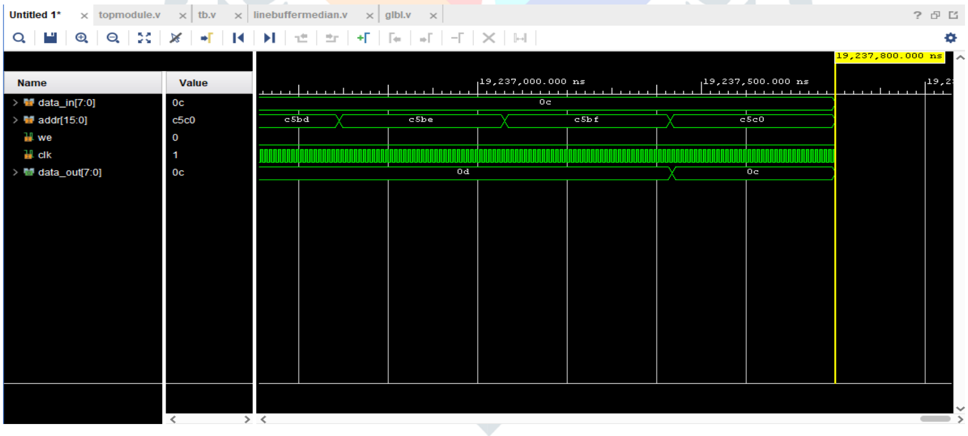


Figure 5 Waveform for the Ram module

4.4 DOUBLE MEDIAN FILTER

The median filter module is designed to reduce noise in data signals by implementing a median filtering operation. Configurable with parameters for width and depth, this module processes 8-bit data inputs, using a buffer to store incoming data and a sorting mechanism.

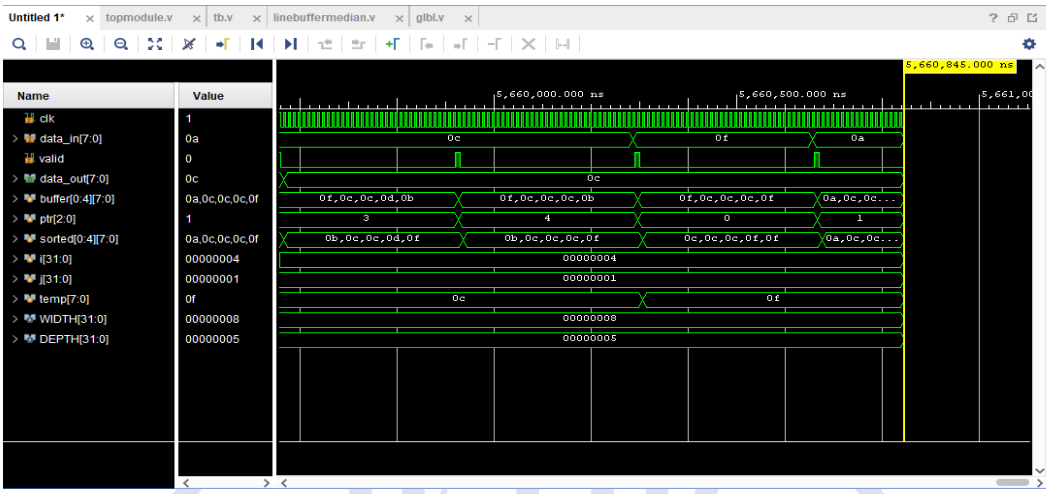


Figure 6 Waveforms for the Median filter 1

Figure 6 shows the waveforms for the Median filter 1 shows that the binary text from the RAM module enters the median filter module 1 and is stored in the buffer for further processing. The buffer contents are then copied to a sorted array, where a simple bubble sort algorithm arranges the values, with the median value being the middle value in the sorted array.

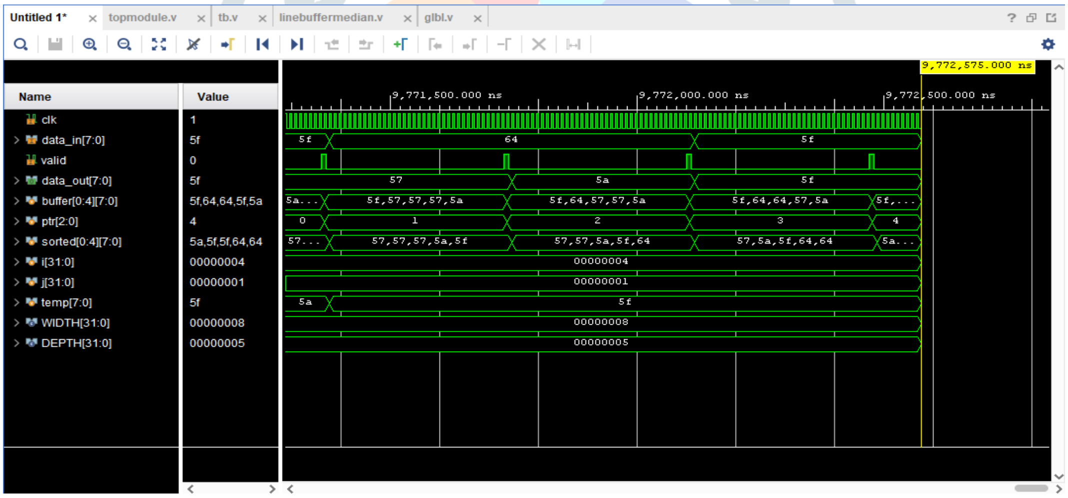


Figure 7 Waveforms for the Median filter 2

Figure 7 shows the Waveforms for the Median filter 2. To achieve effective noise reduction, the median filtering operation is applied twice, significantly enhancing the quality and reliability of the output signal. The filtered values from the median filter 1 are then sent to the second module. There, the values are sorted again, and the median values come out as the final data output.

4.5 ELABORATED DESIGN

This design includes a RAM (Random Access Memory) module and a double median filter, both of which are integral components utilized to diminish noise in MRI (Magnetic Resonance Imaging) images.

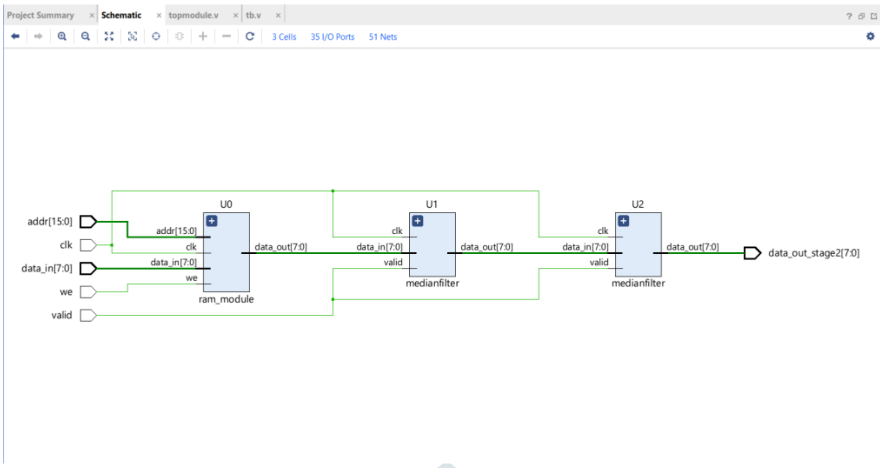
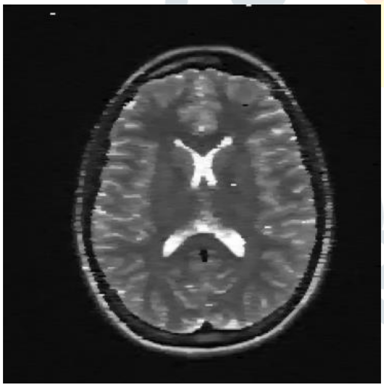


Figure 8 Elaborate design

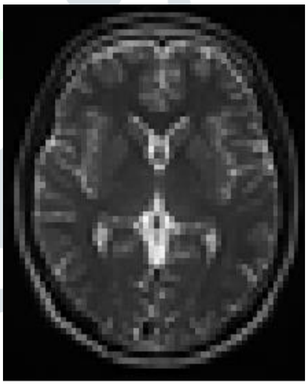
Figure 8 illustrates an elaborate design. The RAM module serves as temporary storage to manage and process the data during the noise reduction procedure. Meanwhile, the double median filter applies a two-step process to effectively eliminate noise from the MRI images, enhancing their clarity and quality.

4.6 OUTPUT FILTERED IMAGES

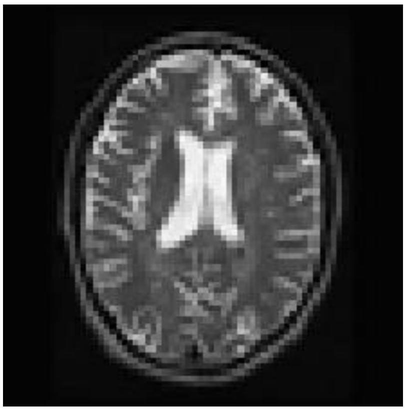
The binary text is converted back into image format. This process translates the binary data into a visual representation, effectively reconstructing the images from their binary form. Once the images are in their visual format, they can be analyzed more effectively. This allows for detailed examination and interpretation using various image analysis techniques, facilitating a deeper understanding of the filtered images' characteristics and features.



(a)



(b)



(c)

Figure 9 (a) Filtered image 1, (b) Filtered image 2,
(c) Filtered image 3

The output filtered images are displayed in Figure 9 (a) Filtered image 1, (b) Filtered image 2, (c) Filtered image 3. The images were filtered using a double median filter. The binary text is stored in the RAM, and the binary values are moved to the buffer for sorting. A bubble sort algorithm is used, and after sorting, the median value is calculated. Once the median value is calculated, the binary text is converted into an image for visual display. While the noise reduction is highly effective, the process results in some information loss in the image.

4.7 SYNTHESIZED RESULT

The synthesized design phase translates the high-level description of the convolutional layer into a gata-level representation suitable for implementation on the FPGA.

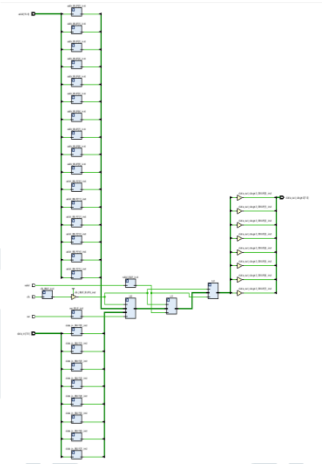


Figure 10 Synthesized design

Figure 10 illustrates a synthesized design implemented in Vivado, showcasing a complex digital circuit composed of multiple components. The design prominently features a series of flip-flops, indicating sequential logic elements used for data storage and transfer. These flip-flops are interconnected to form a shift register structure, where data is propagated through a series of stages, possibly for synchronization or serial-to-parallel data conversion. The central part of the schematic shows logic gates and multiplexers, likely responsible for conditional data routing and control signal management. This arrangement suggests a focus on efficient data handling and processing within the FPGA. The green lines represent the interconnections between these components, indicating the flow of signals throughout the circuit. This detailed layout highlights the intricacy of digital design in VLSI, emphasizing both the complexity and the precision required to achieve reliable and efficient hardware implementations.

4.8 IMPLEMENTATION RESULT

The implemetation result is a detailed schematic that illustrates intricate relationships and data points within a highly complex system. Each segment and color likely represents a distinct component or data type, and their arrangement suggests a structured analysis of interconnections or functional blocks within the system.

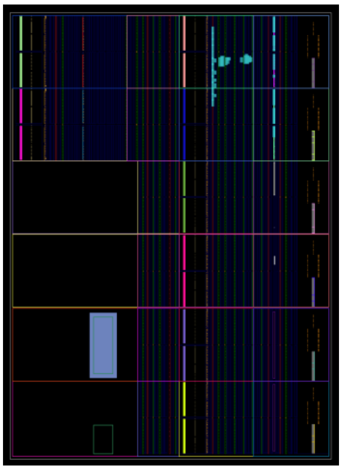


Figure 11 Implementation design

Figure 11 shows the implementation design uses varying colors and patterns to represent different types of data, where bright colors highlight active data points and darker colors indicate less active areas. It is organized into multiple segments and blocks, suggesting different modules or functional units within the system; larger blocks represent major components, while smaller ones detail sub-components. Numerous lines connecting these blocks illustrate data flow between components, indicating communication paths, dependencies, or other interactions within the system.

Table 1 Resource utilization

Resource	Utilization	Available	Utilization %
LUT	275	230400	0.12
FF	103	460800	0.02
BRAM	13	312	4.17
IO	35	360	9.72
BUFG	1	544	0.18

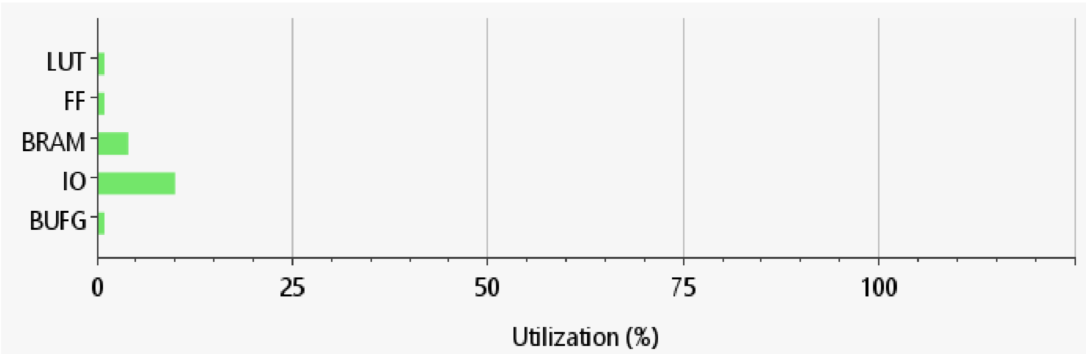


Figure 12 Resource utilization graph

Table 1 shows the resource utilization.The table lists five types of resources: Lookup Tables (LUTs), Flip-Flops (FFs), Block RAMs (BRAMs), Input/Output pins (IOs), and Global Buffers (BUFGs). For each resource type, the table shows the number of units utilized, the total number of units available, and the percentage of utilization. Specifically, the design uses 275 out of 230,400 LUTs (0.12% utilization), 103 out of 460,800 FFs (0.02% utilization), 13 out of 312 BRAMs (4.17% utilization), 35 out of 360 IOs (9.72% utilization), and 1 out of 544 BUFGs (0.18% utilization). These low utilization percentages indicate that the FPGA has sufficient capacity for additional logic and functionalities.

CONCLUSION

In conclusion, the implementation of a double median filter in VLSI technology for reducing noise in brain MRI images represents a significant advancement in medical imaging. This approach effectively addresses the challenge of salt and pepper noise inherent in MRI scans, which can obscure critical details necessary for accurate diagnosis and treatment planning. By first converting noisy MRI images into a manageable binary format and storing them in RAM, the system prepares the data for efficient processing within the VLSI framework. The double median filtering process, utilizing a line buffer for temporary storage, ensures that noise is substantially reduced while preserving essential image features. The detailed testbench verification of the RAM and median filter modules underscores the robustness and reliability of this approach, demonstrating its effectiveness in systematically cleaning noisy data and producing clearer, more interpretable MRI images. Future work will focus on extending the current double median filter approach to address other types of noise commonly found in MRI images, such as Gaussian noise and Speckle noise.

REFERENCES

1. Abdalla M.H, Zhijun P and Faustini L.I. (2017), 'Image Noise Reduction and Filtering Techniques', International Journal of Science and Research (IJSR), Vol.6, pp.2319-7064

2. Antonia M and Veska G. (2016), 'Comparative analysis of various filters for noise reduction in MRI abdominal images', International Journal "Information Technologies & Knowledge", Vol.10, pp.47-66.

3. Anwar S, Javed I.B and Abdul W.K, Imran A, Abdullah K. (2020), 'Comparative analysis of median filter and its variants for removal of impulse noise from gray scale images', Journal of King Saud University-Computer and Information Sciences, Vol.3, pp. 505-519.

4. Arulpandy and Trinita P. (2020), 'Speckle noise reduction and image segmentation based on a modified mean filter', Computer Assisted Methods in Engineering and Science, Vol. 4, pp. 221-239.

5. Bhawna D, Neetu M and Megha M. (2017), 'Analysis of different filters for noise reduction in images', Recent Developments in Control, Automation & Power Engineering, pp. 410-415.

6. Chaitali C. (1993), 'VLSI architectures for recursive median filters', IEEE International Conference on Acoustics, Speech, and Signal Processing, vol.1, pp. 413-416.

7. Jamil A, Bilal Z and Ziad A. (2018), 'Salt and Pepper Noise: Effects and Removal', International Journal on Informatics Visualization, Vol. 4, pp.252-256.

8. Jaspin J.S and Suganthi. (2020), 'An efficient denoising of impulse noise from MRI using adaptive switching modified decision based unsymmetric trimmed median filter', Biomedical Signal Processing and Control, Vol. 55, p. 101657.

9. Javad E and Alireza. (2021), 'Adaptive Removal of high-density salt-and-pepper noise (ARSPN) for robust ROI detection used in watermarking of MRI images of the brain' Computers in Biology and Medicine, Vol.137, p.10483.

10. Jayashree S, Prabhushetty and Abhayakumar. (2021), 'A comparative analysis of filters for noise reduction and smoothening of brain MRI images' In 2021 6th International Conference for Convergence in Technology, Vol.101, pp. 1-6.

11. Katra T and Anindya J (2021), 'VLSI implementation of median filter for image processing applications', Journal of Engineering Sciences (JES), Vol. 12, pp. 0377-9254.

12. Kavitha S and Hannah I. (2021), 'COVID-19 and MRI image denoising using wavelet transform and basic filtering' In IEEE International Conference on Intelligent Computing and Control Systems, pp. 792-799.

13. Vaishali S, Kishan R and Subba R. (2015), 'A review on noise reduction methods for brain MRI images' In IEEE International Conference on Signal Processing and Communication Engineering Systems, pp. 363-365.

14. Li L, Xu M and Xiao L. (2013), 'Reduction of impulse noise in MRI images using block-based adaptive median filter' In IEEE International Conference on Medical Imaging Physics and Engineering, pp. 132-134.

15. Mafi M, Martin H and Adjouadi. M. (2017), 'High impulse noise intensity removal in MRI images' In IEEE Signal Processing in Medicine and Biology Symposium Vol.20, pp. 1-6.

16. Ming Y.T, Wei C.T and Shao Y.C. (2017), 'VLSI Architecture Design of Layer-Based Bilateral and Median Filtering for 4k2k Videos at 30fps', IEEE International Symposium on Circuits and Systems (ISCAS), pp. 1-4.

17. Muna K, Rehan N and Emran H.K, Hamza E. (2019), 'Image Noise Removal Techniques: A Comparative Analysis', International Journal of Science and Applied Information Technology, Vol.8, pp.24-29.

18. Nalin K and Nachamai. (2017), 'Noise Removal and Filtering Techniques used in Medical Images', Orient. J. Comput. Sci. Technol, Vol. 10, pp.103-113.

19. Nikita J, Sarika J and Agarwal A. (2016), 'An improved approach for denoising MRI using non local means filter', In IEEE Conference on Next Generation Computing Technologies (NGCT), Vol.10, pp. 650-653.

20. Ning C.Y and Liu S.F, (2009), 'Research on removing noise in medical image based on median filter method' In IEEE Symposium on IT in Medicine & Education Vol. 1, pp. 384-388.

21. Pallav P, Abhishek S and Anushree A. (2017), 'A Review Paper of MRI Brain Image for Various Types of Noise Removal in Different Filters', International Journal of Innovative Research in Science, Engineering and Technology, Vol.6, pp. 2347-6710.

22. Ravi G and Paraskevas E. (1993), 'Design and implementation of an Efficient general purpose Median filter Network', Digital Signal Processing, Vol.3(1), pp.64-72.

23. Ravi T, Ray, Chakrabarti I and Dhar A S. (2008), 'High Throughput VLSI Architecture for One Dimensional Median Filter', International Conference on Signal Processing, Communications and Networking, pp. 339-344.

24. Ren C.D, Chen P.Y and Yeh C.H. (2014), 'A low-power architecture for the design of a one-dimensional median filter', IEEE Transactions on Circuits and Systems II: Express Briefs, Vol.62(3), pp.266-270.

25. Saritha S and Amutha P. (2017), 'Analysis of denoising filters on MRI brain images' International Journal of Imaging Systems and Technology, Vol.27, pp.201-208.

26. Suhas S and Venugopal C.R. (2017), 'MRI image preprocessing and noise removal technique using linear and nonlinear filters' In IEEE International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT), pp. 1-4.

27. Tanpia T, Maruf H.S and Hasan S, (2017), 'Study of speckle noise reduction from ultrasound b-mode images using different filtering techniques', In IEEE International Conference on Advances in Electrical Engineering (ICAEE) pp. 229-234.

28. Thirilogasundari V and Janet S.A, (2012), 'Fuzzy based salt and pepper noise removal using adaptive switching median filter', Procedia engineering, Vol.38, pp.2858-2865.

29. Tulasi G.D and Patil N, (2020), 'Analysis & evaluation of Image filtering Noise reduction technique for Microscopic Images' In IEEE International Conference on Innovative Trends in Information Technology, pp. 1-6.

30. Yugander P, Tejaswini C.H, Meenakshi J, Varma B.S. and Jagannath M, (2020), 'MR image enhancement using adaptive weighted mean filtering and homomorphic filtering' Procedia Computer Science, Vol.167, pp.677-685.