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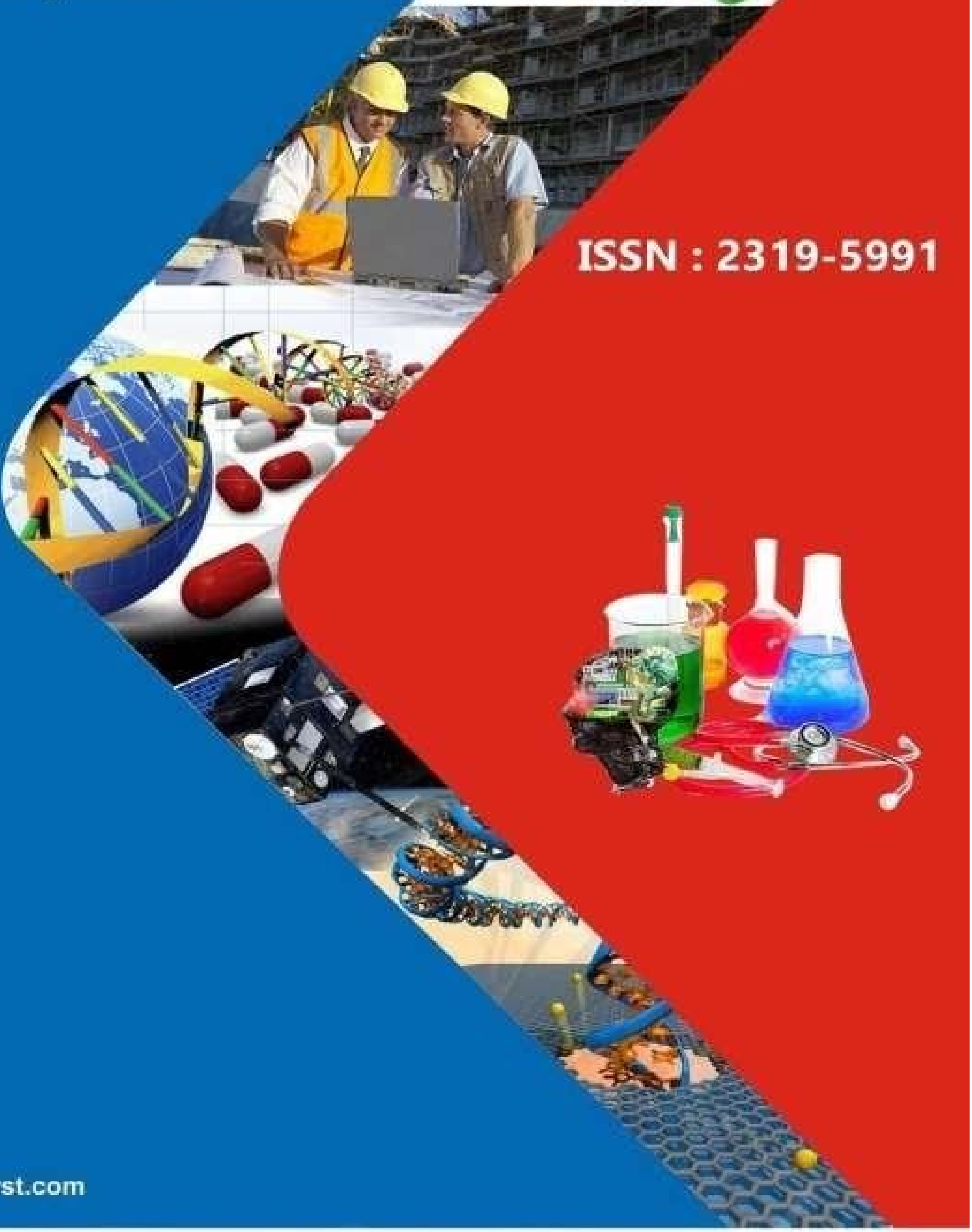

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VLSI Based Medical Image Fusion Using Translation Invariant Wavelet Transform with Average Fusion Rule

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Abstract:
The implementation of medical image fusion using VLSI design is a crucial advancement for enhancing image quality and accuracy in medical diagnostics. The global medical image processing market is projected to grow at a compound annual growth rate (CAGR) of 8.1%, reaching $47.6 billion by 2026, driven by the increasing demand for efficient diagnostic tools. Fusion techniques using wavelet transforms, particularly Discrete Wavelet Transform (DWT), have gained popularity, but they often encounter issues like poor edge preservation and loss of crucial detail, limiting their effectiveness in medical applications. In this work, we propose a novel VLSI-based implementation using Translation Invariant Wavelet Transform (TIWT) with an Average Fusion Rule. Our design incorporates a multibit adder using a 3-to-8 decoder and division using right shift, optimizing both the fusion process and overall performance. TIWT overcomes the limitations of DWT by preserving edges and eliminating artifacts that occur during image transformation. The combination of TIWT and advanced arithmetic operations allows for better detail retention in fused medical images, improving diagnostic accuracy. The proposed system achieves lower computational complexity, faster processing time, and improved fusion quality, making it ideal for real-time medical imaging applications. This approach offers three key advantages: improved edge preservation, enhanced image clarity, and reduced computational overhead. Additionally, the hardware-friendly nature of the design ensures that it was implemented efficiently in real-time systems for medical diagnostics.
Keywords: Medical Image Fusion, VLSI Design, Translation Invariant Wavelet Transform (TIWT), Average Fusion Rule, Multibit Adder, 3-to-8 Decoder, Right Shift Division, Edge Preservation, Image Clarity Enhancement, Computational Overhead Reduction, Real-Time Medical Imaging, Hardware- Friendly Design, Discrete Wavelet Transform (DWT), Image Transformation, Diagnostic Accuracy, Computational Complexity, Processing Time, Fusion Quality, Medical Diagnostics, Advanced Arithmetic Operations.

1. INTRODUCTION

Image fusion is an important branch of image processing which is being extensively worked upon by researchers. However, an image is a special form of signal which has its own complexity, diversity and unique behaviour in the following aspects. Image registration is a pre-requisite in the process of image fusion. The co-registered images highly intensify the quality of the fused image. In case of multisensory image fusion, the sensor resolutions are different. Therefore, in pixel level image fusion pre-processing of images is a necessary step. The process of image fusion largely depends on the correlation amongst the pixels in the source images. In the process of image fusion, the discreet level of information by each pixel of an image at a specific instance of time, state, position or circumstances is mapped upon respective information from each pixel of another image of the same object at a different instance or state. The varied design and construction of each type of optical sensors put some limitations on the type of information acquired by them. Therefore, the process of image fusion develops a composite image which suffices for the data which is not made available by an individual optical sensor.

The source of information to be fused was made available from a single source for different intervals of time or from multiple numbers of sensors over a common timeslot. The revolutionary advancement in designing of innovative image fusion tools has sustained due to various signal processing techniques and analysis theory methods which include spatial filters, artificial intelligence machine learning techniques and most importantly multi-scale transforms. Followed by the decomposition of image features or coefficients using suitable transform method, they are combined using appropriate fusion rules e.g. pixel-level averaging rule, weighted averaging rule and min-max rule. With the help of these image integration tools the image pixels are combined into a highly representational format. The block diagram of a pixel level image fusion process employing wavelet transform and pixel-level averaging fusion rule is illustrated to give a basic insight into image fusion system.

2. LITERATURE SURVEY

Pavan Kumar Reddy, Y. Sunanda et.al [1] implemented the process of integrating various source photos into a single image that is more informative than all the source images is known as image fusion. It is an efficient way of retrieving the information from the multiple sources into single image. The main purpose of image fusion is to not only decrease amount of data but also construct images that are more appropriate and comprehensible for human and machine perceptions. This literature describes morphology and empirical mode decomposition (EMD) based image fusion strategy. The goal of this technique is to minimise the spatial distortions caused by noisy attributes of pixel-wise maps and to construct fusion images of high quality. Initially, we design a multi-channel, bidimensional empirical mode decomposition (EMD) algorithm that divides the image data into IMFs of different scales and a residue utilising morphological dilation as well as erosion filters. **Parvathy,Velmurugan Subbiah et.al [2]** proposed the fusion of medical images. It was an essential and effective technique for disease analysis. The current study proposed a Non Sub sampled Contourlet Transform (NSCT) image fusion technique in which Neuro Fuzzy with Binary Cuckoo Search (NFBCS) and Salp Swarm Optimisation (SSO) methods were utilised. The researchers successfully fused the images retrieved from Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) and created a single merged image which becomes a new integrated diagnostic method. At the beginning, two unique sets of images such as MRI and CT were considered for the fusion procedure. These pairs of images are used in NSCT to generate the image and divided it into high frequency module and low-frequency module. Mixing policies are used here to generate and combine high- and low-frequencies **S.Sridevi et.al [3]** Implemented diagnosis of ailments require accurate information from same modality images or different modality images like Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Positron Emission Tomography (PET) etc which was obtained by Image fusion technique In Image fusion, there are various methods implemented based on Discrete wavelet transformation. The image after fusion will have significant and accurate information from different images than the individual images. The main advantage of image fusion is that, it increases the quality of the particular image and

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also reduces redundancy and randomness. In this literature, transform method and sparse representation method are implemented for Image fusion of MRI, PET and CT images of brain regions to obtain a better entropy. Discrete Wavelet Transform (DWT) method is applied to obtain low pass and high pass patches. The low pass patches undergo Sparse representation (SR) to form the fused patch objective patch. **Rao, R. Varaprasada et.al [4]** designed image content analysis plays a major role in image classification, retrieval, and indexing together with object and scene recognition. Numerous image content descriptors are proposed in the literature, but their high computational costs and lower-performance scores make them inappropriate for content-based medical image retrieval (CBMIR) for large medical image datasets. To overcome these drawbacks, a novel hybrid Scattering Coefficients - Bag of Visual Words – Discrete Wavelet Transform (SC-BoVW- DWT) relevance fusion algorithm is proposed for effective CBMIR. For preprocessing, resizing and contrast limited adaptive histogram equalization (CLAHE) are carried out. Then scattering transform (ST), BoVW and DWT are applied to extract texture features, visual features, and low-level features of the preprocessed images respectively. A hybrid Grey Wolf Optimization - Particle Swarm Optimization (GWO-PSO) approach is used for optimal feature selection. Finally, image fusion (IF) is carried out with a relevance fusion based Euclidean distance technique. Experiments based on three standard medical computer tomography image databases namely, EXACT-09, TCIA-CT and NEMA-CT, are carried out **Iqbal, Saeed et.al [5]** designed medical image retrieval is essential to modern medical treatment because it enables doctors to diagnose and treat a variety of illnesses. In this study, they present an innovative technique for selecting the methodology of medical images by combining textural and visual information. Knowing the imaging process behind an idea, such as a chest X-ray, skin dermatology, or breast histopathology image, was extremely helpful to healthcare professionals since it can aid in image investigation and provide important information about the imaging technique used. We use deep learning-based feature engineering to do this, using both the textural and visual components of healthcare images. They extract detailed visual information from the images using a predefined Convolutional Neural Network (CNN). The Global-Local Pyramid Pattern (GLPP), Zernike moments, and Haralick are also used to physically separate the pertinent parts from the images' other visual and factual aspects. These essential characteristics, such as image modality and imaging technique-specific characteristics, provide additional information about the technology. They employ a feature fusion method that incorporates the depictions obtained from the two modalities in order to combine the textural and visual elements. This fusion process, which improves the discrimination capacity of the feature vectors, makes accurate modality classification possible **Nair, Rekha R., and Tripty Singh et.al [6]** proposed medical images usually display various attributes of data on human viscera and abnormal tissue in different modalities. The fusion of images, ensures effective deployment of all relevant information from several modalities into a single image. Finally, the paper leads to a novel multi-modal medical image fusion method based on Non-Subsampled Shearlet Transform (NSST) called Denoised Optimum B-Spline Shearlet Image Fusion(DOBSIF) that is based on real-time and standard radiological datasets. The proposed, novel registration based fusion technique DOBSIF, is compared with existing state-of-art techniques like PCA, DWT, SWT etc., and in comparison the proposed DOBSIF works effectively for both the color and grayscale images. To improve the fusion function, a novel pre- fusion method is carried out with the help of the Whale Optimization Algorithm(WOA), using the ideal B-spline-based registration method and in addition a novel Weighted Energy fusion rule is applied to derive relevant information from the source images.

Singh, Vineeta et.al [7] designed medical image fusion approaches was sub-categorized as single-mode as well as multimodal fusion strategies. The limitations of single-mode fusion approaches was resolved by introducing a multimodal fusion approach. Multimodal medical image fusion approach is formed by integrating two or more medical images of similar or dissimilar modalities aims to enhance the image quality and to preserve the image information. Hence, this literature introduced a new way to meld multimodal medical images via utilizing developed weighted fusion model relied on Dual Tree Complex Wavelet Transform (DTCWT) for fusing the multimodal medical image. Here, the two medical images was considered for image fusion process and we have implied DTCWT to the medical images for generating four sub-bands partition of the source medical images. The Renyientropy-based weighted fusion model was used to combine the weighted coefficient of DTCWT of images.**Dikshit, Anushka et.al [8]** developed enhancement increases accuracy and efficiency of radiologist interpretation of mammogram images. However, most modalities exhibit inadequate contrast, weak tissue boundaries, etc. Thus, in this literature, contrast limited adaptive histogram equalization (CLAHE) is done to improve contrast of mammographic images in order to ease the further processing and get accurate results. In most of the cases, the acquired enhanced image lacks some important features of the original mammogram which gets removed as noise by the enhancement technique leading to contradictions in the interpretation of the mammographic image. To extract better features from the mammogram images, discrete wavelet transform-based image fusion technique is implemented which fuses the original and the enhanced mammographic image together, leading to restoration of features of both the mammographic images. The performance is evaluated using dedicated metrics such as enhancement measure (EME) and entropy (E).

3. PROPOSED METHODOLOGY

Medical image fusion combines different types of medical images to create a more detailed and comprehensive picture of what's happening inside the body. Think of it like putting together puzzle pieces to see the full picture. VLSI technology, which packs lots of computing power into a tiny chip, plays a big role in this process. It helps to make the fusion happen quickly and accurately. This technology is great because it can handle a lot of information at once, making it possible for doctors to make decisions faster. Plus, it doesn't use too much power, so it was used in portable devices that doctors can take anywhere. By using VLSI technology, medical image fusion wascome more accessible and useful for doctors and patients, leading to better healthcare overall. Medical image fusion using VLSI technology is a cutting-edge approach that revolutionizes how medical images are processed and analyzed.

In the context of medical image fusion, VLSI technology plays a crucial role in seamlessly combining information from multiple imaging modalities, such as MRI, CT, PET, SPECT, and ultrasound, to create a unified and enhanced representation of the underlying anatomy. One of the key advantages of using VLSI technology for medical image fusion is its ability to handle large volumes of imaging data with remarkable efficiency and speed. The parallel processing architecture of VLSI circuits enables complex fusion algorithms to be executed in real-time, facilitating swift decision-making in clinical settings. This real-time processing capability is particularly valuable in situations where rapid diagnosis and treatment planning are essential, such as in emergency medicine or intraoperative imaging. Furthermore, VLSI-based medical image fusion systems offer high computational efficiency, allowing for the execution of sophisticated algorithms while maintaining low power consumption. This efficiency is critical for the development of portable and battery-operated medical imaging devices that was used in various clinical settings, including resource- limited environments or remote locations where access to traditional imaging equipment was limited. The compact form factor of VLSI chips also enables the development of miniaturized and wearable medical devices, opening up new possibilities for continuous monitoring and personalized healthcare. Additionally, VLSI technology offers scalability, allowing for seamless integration with existing medical imaging infrastructure and accommodating future advancements in imaging technology.

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Wavelet transforms are mathematical tools used in signal processing and image analysis to decompose signals or images into different frequency components, allowing for a multi- resolution analysis. Translation-invariant wavelet transforms, also known as stationary wavelet transforms, maintain translation invariance across scales, which is crucial for applications such as image processing where shifts or translations occur. When performed with low-pass and high-pass

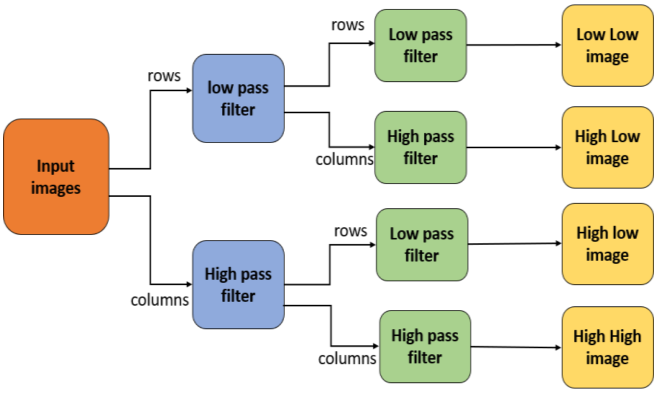


Figure 1 : Translation invariant wavelet transforms

filters without down sampling, this operation generates four outputs: LL (approximation), LH (horizontal detail), HL (vertical detail), and HH (diagonal detail). Let's delve into the intricacies of this operation. Firstly, let's understand the role of filters in the wavelet transform. In wavelet analysis, signals or images are passed through two types of filters: low-pass and high-pass filters. Low-pass filters allow low- frequency components to pass through, while attenuating high- frequency components. High-pass filters, conversely, permit high- frequency components to pass through while suppressing low- frequency components. This filtering process separates the input signal or image into different frequency bands. Medical image fusion is a complex process that involves combining information from multiple medical images into a single, more informative representation. This fusion technique is widely used in the field of medical imaging to enhance the quality and diagnostic value of images, aiding healthcare professionals in making more accurate diagnoses and treatment decisions.

The picture of an object from an MRI scan and another from a CT scan. The operation starts by using a special mathematical technique called Translation Invariant Wavelet Transform on both pictures. This helps break down the information in a way that captures important features. Next, a fusion rule is applied, specifically the average fusion rule. This rule takes corresponding pieces of information from both the MRI and CT transformed images and combines them by calculating their average.

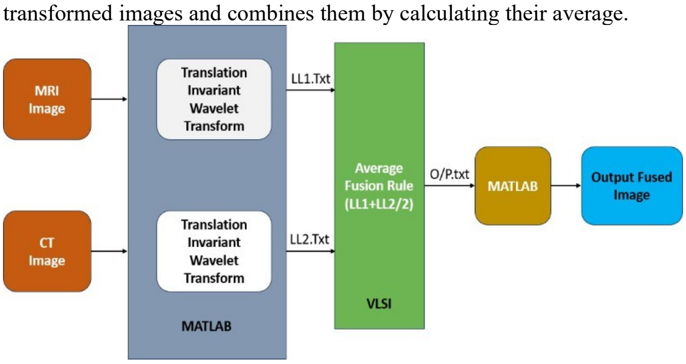


Figure 2: Overall process of medical image fusion

This process helps create a new image that incorporates important details from both the MRI and CT scans, providing a more comprehensive and informative fused image.

Applications:

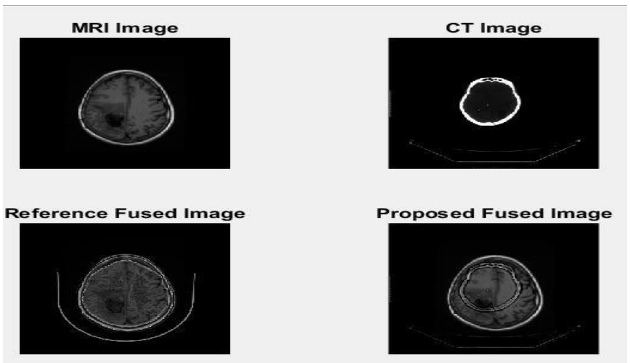
- **MRI Machines:** Enhances speed and accuracy of image processing in MRI scans, providing better diagnosis of neurological, musculoskeletal, and other conditions.
- **CT Scanners:** Speeds up processing of vast amounts of data for diagnosing complex conditions like cancer and cardiovascular diseases.
- **Ultrasound Systems:** Provides real-time, high-clarity imaging for applications like pregnancy monitoring and abdominal diagnosis.
- **Surgical Planning:** Aids in precise pre-operative planning by providing detailed anatomical views.
- **Cancer Treatment:** Integrates data from various imaging techniques to better target tumors during radiation therapy and monitor treatment effectiveness.

Advantages:

- Precision in Diagnosis: Provides more accurate images by combining data from multiple medical machines.
- Swift Results: High-speed processing enables quick decision-making.
- Energy Efficiency: Low energy consumption makes it suitable for portable medical devices. Compatibility Across Machines: Adapts to various imaging devices and health scenarios. Adaptability to Advancements: Easily integrates new image fusion techniques as medical technology progresses.
- Enhanced Visualization: Provides clearer and more detailed images for better analysis.
- Data Security and Privacy: Ensures strong security measures for keeping patient data safe.
- Seamless Integration: Easily integrates into existing hospital systems, making it user-friendly.
- Cost-Effective Solutions: Makes advanced medical technology accessible to a broader range of healthcare facilities.
- Improved Patient Care: Provides better diagnostic accuracy, leading to enhanced patient care.

4. EXPERIMENTAL ANALYSIS

The experimental analysis of the proposed medical image fusion technique involves evaluating the performance of the developed system using various quality metrics. The approach employs Translation Invariant Wavelet Transform (TIWT) with an Average Fusion Rule to combine MRI and CT images. After preprocessing, the images are resized, converted to grayscale if



necessary, and decomposed using TIWT into various frequency bands. The fusion is carried out by averaging the low-frequency components while retaining the high-frequency details to enhance clarity. The fused image is then reconstructed using the inverse wavelet transform

Figure 3: Result of Sample image-1.

The performance of the proposed method is assessed using

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several metrics, including Edge Intensity, Entropy, Mutual Information, PSNR (Peak Signal-to-Noise Ratio), RMSE (Root Mean Square Error), SSIM (Structural Similarity Index), and Variance. The results demonstrate that the proposed fusion method effectively improves image quality by enhancing edges,

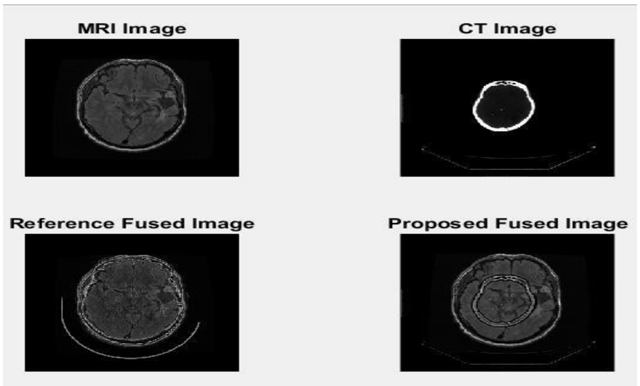

Figure 4: Result of Sample image-2.

increasing entropy, and providing better structural similarity. Furthermore, the TIWT approach with the Average Fusion Rule shows improved computational efficiency compared to other existing methods, making it suitable for real-time applications. The experimental results confirm the robustness and efficiency of the proposed technique, indicating its potential for enhancing diagnostic accuracy in medical imaging

5. CONCLUSION

Medical image fusion using VLSI technology is a cutting-edge approach aimed at enhancing the quality and accuracy of diagnostic imaging. By merging different types of medical images, such as MRI and CT scans, this technique provides a more comprehensive and detailed view of the internal structures of the body. The use of VLSI technology, which focuses on designing small and efficient electronic circuits, is particularly beneficial for implementing real-time medical image fusion systems. VLSI's parallel processing architecture enables the rapid execution of complex fusion algorithms, making it ideal for time-critical applications such as emergency diagnosis and surgical procedures.

The primary advantage of employing VLSI in medical image fusion is its ability to process large volumes of imaging data quickly and accurately. The hardware design is optimized to minimize power consumption, allowing for portable and battery-operated medical devices that can be used in resource-limited or remote locations. Moreover, VLSI's compact design facilitates the development of wearable devices, enabling continuous monitoring and personalized healthcare.

The fusion process typically involves the use of Translation Invariant Wavelet Transform (TIWT) along with an Average Fusion Rule to enhance image clarity and preserve important details. TIWT overcomes limitations associated with Discrete Wavelet Transform (DWT), such as loss of edge information and artifacts during image transformation. This approach ensures better edge preservation, improved clarity, and reduced computational overhead, making it suitable for real-time medical imaging applications.

Furthermore, ongoing research is aimed at enhancing the efficiency of VLSI-based medical image fusion systems by optimizing fusion algorithms and integrating them with advanced techniques like deep learning. The goal is to improve diagnostic accuracy, streamline medical workflows, and enhance patient care by providing clinicians with clearer and more reliable diagnostic images .

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