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VLSI Implementation of chest X-Ray image segmentation using hybrid clustering

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Abstract:

Chest X-ray imaging plays a critical role in diagnosing pulmonary diseases, with approximately 30 million chest X-ray procedures performed annually worldwide. Despite its prevalence, traditional image segmentation techniques, particularly threshold segmentation, often struggle with variability in lighting and contrast, leading to suboptimal performance in accurately delineating anatomical structures. These limitations necessitate a more robust approach to segmentation that can effectively handle diverse imaging conditions while maintaining high accuracy. This work presents a novel hybrid k-means clustering method for the segmentation of chest X-ray images, leveraging the strengths of both k-means clustering techniques. By integrating these approaches, the proposed method enhances segmentation accuracy and robustness, particularly in regions with overlapping features. hybrid algorithm effectively reduces sensitivity to noise and variability in image quality, significantly improving the delineation of structures of interest. Furthermore, the VLSI implementation of this algorithm ensures high-speed processing, making it suitable for real-time medical imaging applications. The advantages of the proposed system include improved accuracy, reduced computation time, robustness to noise, enhanced scalability, and effective integration into existing imaging systems.

Keywords: VLSI implementation, image segmentation, chest x-ray image segmentation, Hybrid clustering, K- mean clustering, image processing, segmentation accuracy, real time imaging system, resource optimization in VLSI design.

1. INTRODUCTION

The increasing demand for rapid and accurate diagnosis in the healthcare industry has made medical image processing a critical area of research. Among various medical imaging techniques, X-ray imaging is widely used to diagnose conditions related to the chest, such as pneumonia, tuberculosis, lung cancer, and other pulmonary diseases. However, the accurate interpretation of Chest X-ray images requires robust image segmentation techniques that can extract regions of interest (ROIs) from the image. These segmented regions typically correspond to critical anatomical structures such as the lungs, heart, rib cage, and abnormalities that need to be identified for proper diagnosis. Traditionally, **image segmentation** techniques rely on software-based algorithms that require significant computational resources, limiting their efficiency and applicability in real-time scenarios. Recent advancements in **Very Large Scale Integration (VLSI)** technology have paved the way for the implementation of high-performance, hardware-accelerated systems. These systems are capable of performing **image processing tasks** much faster and more efficiently than software running on general-purpose processors. **VLSI-based systems**, including **Field-Programmable Gate Arrays (FPGAs)** and **Application-Specific Integrated Circuits (ASICs)**, provide the necessary parallelism and high throughput for real-time medical image analysis.

2. LITERATURE SURVEY

Song, J., Gu, et.al [1] developed the emergence of new technologies given rise to a huge amount of data in different fields such as public transportation, community services, scientific research, etc. Due to the aging population, healthcare is becoming more important in our daily life to reduce public burdens. For example, manually archived massive electronic medical files, such as X-ray image segmentation is impossible. However, precise classification is essential for further work, such as diagnosis. In this literature, they applied a spectral clustering algorithm to classified chest disease X-ray images. They also employed the "pure" K-means algorithm for comparison. Three types of indexes are used to quantify the performances of both algorithms. Their analysis result shows that spectral clustering can successfully classify chest X-ray images based on the previous of disease spots on the lungs and the performance is superior to "pure" K-means clustering.

Al-Zyoud, Walid, et.al [2] suggested the COVID-19 was a severe acute respiratory syndrome that has caused a major ongoing pandemic worldwide. Imaging systems such as conventional chest X-ray (CXR) and computed tomography (CT) was proved essential for patients due to the lack of information about the complications that result from this disease. In study, the aim was to develop and evaluate a method for automatic diagnosis of COVID-19 using binary segmentation of chest X-ray images. The study used frontal chest X-ray images of 27 infected and 19 uninfected individuals from Kaggle COVID19 Radiography Database, and applied binary segmentation and quartering in MATLAB to analyze the images. The binary images of the lung split into four quarters; Q1 = right upper quarter, Q2 = left upper quarter, Q3 = right lower, and Q4 = left lower. The results showed that COVID- 19 patients had a higher percentage of attenuation in the lower lobes of the lungs (p-value

< 0.00001) compared to healthy individuals, which is likely due to ground-glass opacities and consolidations caused by the infection. The ratios of white pixels in the four quarters of the X-ray images were calculated, and it was found that the left lower quarter had the highest number of white pixels but without a statistical significance compared to right lower quarter (p-value = 0.102792). This supported the theory that COVID-19 primarily affects the lower and lateral fields of the lungs, and suggests that the virus is accumulated mostly in the lower left quarter of the lungs. Overall, this study contributes to the understanding of the impact of COVID-19 on the respiratory system and can help in the development of accurate diagnostic methods.

Agrawal, Tarun, et.al [3] proposed the Chest radiography (X-ray) was the most common diagnostic method for pulmonary disorders. A trained radiologist is required for interpreting the radiographs. But sometimes, even experienced radiologists can misinterpret the findings. This leads to the need for computer-aided detection diagnosis. For decades, researchers was automatically detecting pulmonary disorders using the traditional computer vision (CV) methods. Now the availability of large annotated datasets and computing hardware has made it possible for deep learning to dominate the area. It was now the modus operandi for feature extraction, segmentation, detection, and classification tasks in medical imaging analysis. This literature focuses on the research conducted using chest X-rays for the lung segmentation and detection/classification of pulmonary disorders on publicly available datasets. The studies performed using the Generative Adversarial Network (GAN) models for segmentation and classification on chest X-rays are also included in this study. GAN had gained the interest of the CV community as it can help with medical data scarcity. In study, they have also included the research conducted before the popularity of deep learning models to have a clear picture of the field. Many surveys have been published, but none of them is dedicated to chest X- rays. This study help the reader to know about the existing techniques, approaches, and their significance.

Chakraborty, Gouri Shankar, et.al [4] developed the Covid-19 diagnosis systems has been improved with the emerging development of deep learning techniques. Covid-19 was widely known for the deadly effects and its high transmission rate. To overcome the challenges, different deep learning-based detection methods have been introduced through which the disease easily be identified in patient's body. But only identification of the disease is not sufficient to assist physicians for further diagnosis. Infection identification process with severity measurement from medical image can put an advancement in current Covid-19 diagnosis systems. This work presents a novel infection detection approach based on image segmentation technique that was used to localize the infection. The proposed system is able to predict segmented lung and mask images with visual representation so that it makes the diagnosis task easier for the physicians. Res Net-U-N et, VGG16-U-Net and a modified U-Net model have been implemented in the proposed work where the modified U-Net performed better with 0.968 IOU, 98.60% accuracy and 0.9567 of dice coefficient. An advanced module using OpenCV has been designed that can calculate the area of the predicted lung and infection mask images separately and then the infection percentage was calculated accurately.

Lee, Beom J., et.al [5] proposed the World Health Organization, Artificial Intelligence (AI) technology Assisted in COVID-19 management. However, existing image segmentation using AI suffered from a lack of accuracy and explainability, which prevented its adoption in actual clinical practice. In this literature, they investigated an attention-based image segmentation method for COVID-19 CT imaging with enhanced interpretation capabilities. Specifically, they developed U-Net architecture-based for segmentation with attention coefficients to produce a salient feature map. they used the DICE score and accuracy to perform a comprehensive model evaluation. they compared to other well-known methods such as Light U-Net, COPLE- Net, and Res U-Net and demonstrated that attention U-Net was superior for COVID-19 segmentation tasks in terms of performance and explainability. they also developed the tool as a web-application with a graphic user interface with the goal to translated this AI-driven clinical decision-support system for real-world clinical use.

Liu, Leon, et.al [6] developed Computer vision in medical diagnosis achieved a high level of success in diagnosing diseases with high accuracy. However, conventional classifiers that produced an image- to-label result provide insufficient information for medical professionals to judge and raise concerns over the trust and reliability of a model with results that cannot be explained. Class activation maps are a method of providing insight into a convolutional neural network's feature maps that lead to its classification but in the case of lung diseases, the region of concern is only the lungs. Therefore, the proposed model combines image segmentation models and classifiers to crop out only the lung region of a chest X-ray's class activation map to provide a visualization that improves the explainability and trust of an AI's diagnosis by focusing on a model's weights within the region of concern. The proposed U-Net model achieves 97.72% accuracy and a dice coefficient of 0.9691 on testing data from the COVID-QU-Ex Dataset which includes both diseased and healthy lungs.

Wahyuningrum, Rima Tri, et.al [7] developed the Medical Image segmentation was a crucial stage in computer vision and image processing to help the later-stage diagnosis process become more accurate. Because medical image segmentation, such as X-ray, can extract tissue, organs, and pathological structures. However, medical image processing, primarily in the segmentation process, has significant challenges regarding feature representation. Because medical images have different characteristics than other images related to contrast, blur, and noise. This study proposes the use of lung segmentation on chest X-ray images based on deep learning with the FCA-Net (Fully Convolutional Attention Network) architecture. In addition, attention modules, namely spatial attention and channel attention, are added to the Res2Net encoder so that it is expected to be able to represent features better. This research was conducted on chest X-ray images from Qatar University contained in the Kaggle repository. A chest x-ray image measuring 256 × 256 pixels and as many as 1500 images were then divided into 10% testing data and 90% training data. The training data will then be processed in K-Fold Cross validation from K = 2 until K = 10. The experiment was conducted with scenarios that used spatial attention, channel attention, and a combination of spatial and channel attention. The best test results in this study were using a variety of spatial attention and channel attention in the division of K-Fold with a value of K = 5 with a DSC (Dice Similarity Coefficient) value in the testing data of 97.24% and IOU (Intersection over Union) in the testing data of 94.66%. This accuracy result is better than the U Net++, DeepLabV3+, and Seg Netarchitectures.

Gopatoti, Anandbabu, et.al [8] developed the COVID-19 from chest X-ray radiography (CXR) images is faster than PCR sputum testing, the accuracy of detecting COVID-19 from CXR images is lacking in the existing deep learning models. This study aims to classify COVID- 19 and normal patients from CXR images using semantic segmentation networks for detecting and labeling COVID-19 infected lung lobes in CXR images. For semantically segmenting infected lung lobes in CXR images for COVID-19 early detection, three structurally different deep learning (DL) networks such as Seg Net, U-Net and hybrid CNN with Seg Net plus U-Net, are proposed and investigated. Further, the optimized CXR image semantic segmentation networks such as GWO Seg Net, GWO U-Net, and GWO hybrid CNN are developed with the grey wolf optimization (GWO) algorithm. The proposed DL networks are trained, tested, and validated without and with optimization on the openly available dataset that contains 2,572 COVID-19 CXR images including 2,174 training images and 398 testing images. The DL networks and their GWO optimized networks are also compared with other state-of-the-art models used to detect COVID-19 CXR images. optimized CXR image semantic segmentation networks for COVID-
19 image detection developed in this study achieved detection accuracy higher than 92%. The result shows the superiority of optimized Seg Net in segmenting COVID-19 infected lung lobes and classifying with an accuracy of 98.08% compared to optimized U-Net and hybrid CNN. The optimized DL networks has potential to be utilized to more objectively and accurately identify COVID-19 disease using semantic segmentation of COVID-19 CXR images of the lungs.

Gómez, Oscar, et.al [9] developed the Chest X-ray images (CXRs) was the most common radiological examination tool for screening and diagnosis of cardiac and pulmonary diseases. The automatic segmentation of anatomical structures in CXRs is critical for many clinical applications. However, existing deep models work on severelydown-sampled images (commonly 256×256 pixels), reducing the quality of the contours of the resulting segmentation and negatively affecting the possibilities of such methods to be effectively used in a real environment. In this literature, they studied multi-organ (clavicles, lungs, and hearts) segmentation, one of the most important problems in semantic understanding of CXRs. they completely avoided down- sampling in images up to 1024×1024 (as in the JSRT dataset), and we diminish its impact in higher resolutions via network architecture simplification without a significant loss in the accuracy. To do so, they proposed four different convolutional models by introducing structural changes to the baselines employed (U-Net and Inverted Net) as well as by integrating several techniques barely used by CXRs segmentation algorithms, such as instance normalization and convolution. they also compare single-class and multi-class strategies to elucidate which approach was the most convenient for this problem. Their best proposal, X-Net+, outperforms nine state-of-the-art methods on clavicles and lungs obtaining a Dice similarity coefficient of 0.938 and 0.978, respectively, employing a tenfold cross-validation protocol. The same architecture yielded comparable results to the state of the art in heart segmentation with a Dice value of 0.938. Finally, its reduced version, RX-Net+, obtains similar results but with a significant reduction in memory usage and training time.

Gite, Shilpa, et.al [10] developed the proactive diagnosis of diseases with artificial intelligence (AI) and its aligned technologies has been an exciting research area in the last decade. Doctors usually detect tuberculosis (TB) by checking the lungs' X-rays. Classification using deep learning algorithms is successfully able to achieve accuracy almost similar to a doctor in detecting TB. It was found that the probability of detecting TB increases if classification algorithms was implemented on segmented lungs instead of the whole X-ray. The paper's novelty lies in detailed analysis and discussion of U- Net++ results and implementation of U-Net++ in lung segmentation using X-ray. A thorough comparison of U-Net++ with three other benchmark segmentation architectures and segmentation in diagnosing TB or other pulmonary lung diseases is also made in this literature. To the best of our knowledge, no prior research tried to implement U- Net++ for lung segmentation. Most of the literatures did not even use segmentation before classification, which causes data leakage. Very few used segmentations before classification, but they only used U- Net, which U-Net ++can easily replace because accuracy and mean of U-Net++ are greater than U-Net accuracy and mean, discussed in results, which can minimize data leakage. The authors achieved more than 98% lung segmentation accuracy and mean 0.95 using U-Net++, and the efficacy of such comparative analysis was validated.

3. PROPOSED METHODOLOGY

The proposed methodology for VLSI implementation of Chest X-ray image segmentation using hybrid clustering combines the efficiency of traditional clustering algorithms with the hardware acceleration capabilities of VLSI (Very-Large Scale Integration) technology. In this approach, the hybrid clustering algorithm integrates K-means and Fuzzy C-means (FCM) techniques to improve segmentation accuracy. K-means is initially used for fast segmentation of well-defined regions in the image, such as the lungs or background. Then, Fuzzy C-means refines the segmentation by considering the degree of membership for each pixel, effectively handling fuzzy or overlapping boundaries between regions like the lungs and the heart. To achieve real-time processing, this hybrid algorithm is implemented using VLSI hardware such as FPGA (Field-Programmable Gate Array) or ASIC (Application-Specific Integrated Circuit). These hardware platforms allow for parallel processing and pipelining, significantly improving the processing speed and reducing latency compared to traditional software-based approaches. Additionally, the VLSI design optimizes memory usage and power consumption, making the system suitable for portable medical devices that require low power consumption. The final segmented image can be used for further analysis, such as automated disease detection, making the system highly applicable inclinical settings.

VLSI Implementation of chest x-Ray image segmentation using hybrid clustering. The block diagram illustrates a process starting with the input of a chest X-ray image, followed by its reading into MATLAB for further analysis. Once the image is imported, MATLAB performs preprocessing tasks to enhance its quality and reduce noise.Subsequently, the preprocessed image undergoes conversion into textformat within

MATLAB. This step involves extracting relevant features or characteristics from the image and representing them as text data, potentially aiding in further computational analysis or integration with other systems.

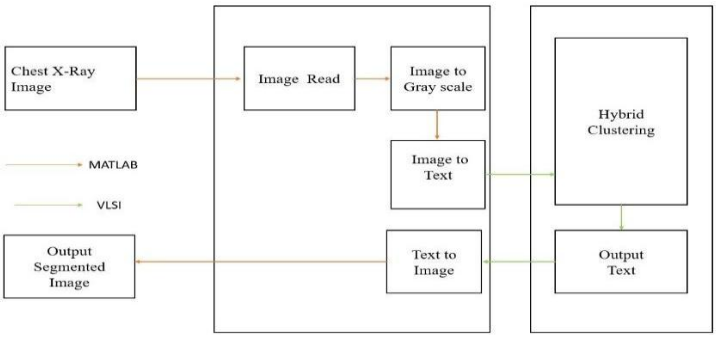

Figure 4.2: Block Diagram of Proposed System

The block diagram illustrates a process starting with the input of a chest X-ray image, followed by its reading into MATLAB for further analysis. Once the image is imported, MATLAB performs preprocessing tasks to enhance its quality and reduce noise. Subsequently, the preprocessed image undergoes conversion into text format within MATLAB. This step involves extracting relevant features or characteristics from the image and representing them as textdata, potentially aiding in further computational analysis or integration with other systems.

Applications:

Covid-19 detection: Chest X-rays and CT scans are used to identify characteristic signs of COVID-19 pneumonia, such as ground-glass opacities and consolidations.

Lung Cancer Screening and Diagnosis: Chest X-rays, CT scans, and MRI imaging are employed for the detection and diagnosis of lung cancer.

Chronic Obstructive Pulmonary Disease (COPD): Chest X-rays and CT scans help in assessing the extent of lung damage in COPD patients.

Pulmonary Embolism Detection: CT pulmonary angiography (CTPA) is the primary imaging modality for diagnosing pulmonary embolism (PE). Computer algorithms can aid in identifying emboli within the pulmonary vasculature, assisting radiologists in accurate diagnosis and risk stratification.

Interstitial Lung Disease (ILD): High-resolution CT (HRCT) is the imaging modality of choice for evaluating ILD, such as idiopathic pulmonary fibrosis (IPF). Automated quantitative analysis tools can assess disease severity, track changes in lung fibrosis, and predict prognosis in ILD patients.

Advantages:

Improved Accuracy: Hybrid clustering methods often out Perform individual clustering algorithms by leveraging their strengths and compensating for each other's weaknesses. This results in more accurate segmentation of lung regions in chest X-ray images, crucial for accurate diagnosis and treatment planning.

Robustness To Variability: Hybrid clustering techniques are generally more robust to variations in image quality, patient positioning, and other factors that can affect the performance of segmentation algorithms. This robustness ensures consistent and reliable results across diverse datasets.

Adaptability To Complex Patterns: Hybrid clustering can effectively adapt to the complex and diverse patterns present in chest X-ray images. By combining multiple clustering algorithms, the method can handle various textures, shapes, and intensities commonly encountered in medical images, making it suitable for a wide range of cases.

Enhanced Noise Reduction: Hybrid clustering methods often incorporate noise reduction mechanisms, such as feature selection and outlier detection, which contribute to more accurate segmentation results. This is particularly important in medical imaging where noise can interfere with the identification of critical structures.

Optimized Computational Efficiency: Hybrid clustering algorithms was designed to optimize computational efficiency by selecting the most appropriate clustering method based on the characteristics of the input data. This ensures that the segmentation process is efficient without compromising accuracy.

Increased Flexibility: Hybrid clustering allows for flexibility in combining different clustering algorithms or modifying the fusion strategy. This flexibility enables customization based on the specific requirements of the chest X-ray images, making the segmentation process more adaptable to different clinical scenarios.

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4. EXPERIMENTAL ANALYSIS

The experimental analysis for the VLSI implementation of Chest X- ray image segmentation using hybrid clustering involves evaluating various performance metrics, including segmentation accuracy, processing time, power consumption, and hardware efficiency.

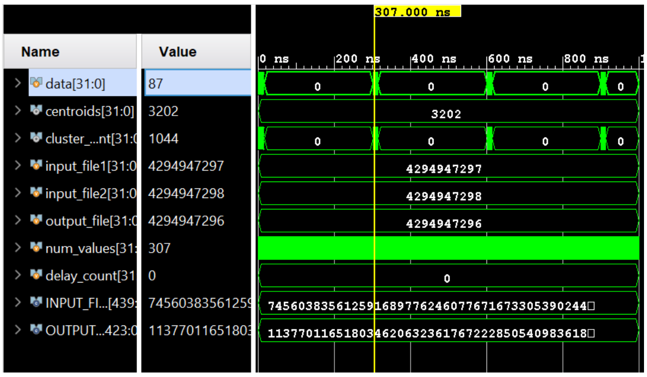

Figure 1: proposed simulation output

Resource	Estimation	Available	Utilization...
LUT	136	134600	0.10
IO	67	500	13.40

Figure 2: Area output

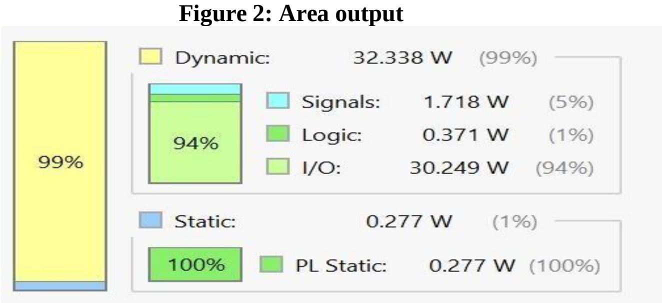

Figure 3: Power output

5. CONCLUSION

The VLSI implementation of chest X-ray image segmentation using hybrid clustering represents a significant advancement in medical imaging technology, poised to revolutionize diagnostic processes in healthcare. By combining the power of VLSI chips with innovative hybrid clustering techniques, this approach offers a promising solution for automatically segmenting chest X-ray images into meaningful regions for medical analysis. The integration of hybrid clustering algorithms, such as k-means, hierarchical clustering, and density- based clustering, allows for more accurate and robust segmentation, catering to the complex and variable characteristics of chest X-ray images. This groundbreaking implementation harnesses the parallel processing capabilities of VLSI chips to efficiently perform the computationally intensive tasks involved in image segmentation. By distributing the workload across multiple processing units on the VLSI chip, the segmentation process was accelerated, enabling real-time or near-real-time analysis of chest X-ray images. This not only enhances the efficiency of medical diagnosis but also facilitates timely interventions and treatments for patients, potentially leading to improved patient outcomes and healthcare delivery.

Moreover, the VLSI implementation of Chest X-ray image segmentation using hybrid clustering holds promise for integration into portable and wearable medical devices, ushering in a new era of point-of-care diagnostics and remote monitoring. The compact form factor and low power consumption of VLSI chips make them ideal fordeployment in handheld or wearable devices, bringing advanced medical imaging capabilities closer to patients and healthcare providers. This democratization of medical imaging technology has the potential to expand access to quality healthcare services, particularly in remote or underserved areas, where access to traditional medical facilities was limited. In addition to its practical applications in medical diagnostics, the VLSI implementation of chest X-ray image segmentation using hybrid clustering represents a significant step forward in interdisciplinary collaboration between engineering and medicine. By leveraging cutting-edge technologies and methodologies from both fields, this approach demonstrates the power of interdisciplinary research in addressing complex challenges in healthcare. Furthermore, ongoing research and development efforts in this area hold promise for further improvements in segmentation accuracy, processing speed, and integration into clinical workflows, paving the way for continued advancements in medical imaging technology and patient care. Ultimately, the VLSI implementation of chest X-ray image segmentation using hybrid clustering stands as a testament to the transformative potential of technology in enhancing healthcare outcomes and improving quality of life for patients around the world.

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