DOI: 10.35598/mcfpga.2023.017

Methods for Processing Medical Images on FPGA

Valeriia Chumak
ORCID 0000-0002-2403-020X
Department of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
valeriia.chumak@nure.ua

Kateryna Stetsenko
Department of Computer-Integrated Technologies, Automation and Mechatronics
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
kateryna.stetsenko2@nure.ua

***Abstract*—This article provides an overview of image processing methods in the field of medical imaging using Field-Programmable Gate Arrays (FPGA). The article analyzes various methods for the analysis of medical images, with a focus on the utilization of FPGA for efficient processing.**

In recent decades, medical image processing has become an integral part of diagnosis, monitoring, and treatment in the medical industry. With the continuous development of new technologies and the increasing volume of medical image data, it has become critically important to have efficient analysis and processing methods that can ensure high accuracy and performance.

Keywords—Canny algorithm, FPGA, Haralick algorithm, image processing, LBP, Renyi dimension, Sobel algorithm

I. Introduction

The relevance of this work is determined by the fact that medical images are a fundamental element of medical diagnosis and treatment, as they reveal the internal anatomy of patients. The analysis of methods for medical image processing on FPGA involves examining and evaluating various techniques and algorithms tailored specifically for medical imaging tasks. This analysis encompasses areas such as image enhancement, segmentation, registration, feature extraction, and classification. The goal is to assess the effectiveness, efficiency, and applicability of these methods in addressing the unique challenges posed by medical image data [1-8].

The aim of this work is to summarize and analyze existing methods for processing and analyzing medical images in order to improve them and practically apply them in medicine. It involves the examination and analysis of key methods for the segmentation of medical images, including comparisons of their effectiveness and accuracy. The practical application of developed methods and algorithms on real medical images aims to enhance diagnostic accuracy and improve the quality of patient care.

By exploring and evaluating various image processing techniques, this work aims to contribute to the advancement of medical imaging technologies and their effective utilization in clinical practice. The findings and insights gained from this study can potentially enhance the accuracy and efficiency of medical diagnoses, leading to improved patient outcomes and overall healthcare quality [1-8].

II. Analysis of Methods for Medical Image Processing on FPGA

Key aspects of the analysis include evaluating the computational efficiency of FPGA-based implementations, assessing the accuracy and robustness of the processing methods, and considering the resource utilization of the FPGA device. As a result of the research, five commonly used methods have been identified:

A. The Canny algorithm:

The Canny algorithm is one of the most widely used image processing algorithms for edge detection. It consists of several stages: image smoothing, calculation of brightness gradients, noise suppression, thresholding, and edge linking.

In the first stage, the algorithm starts by smoothing the image to reduce noise and prepare it for further analysis. Typically, a Gaussian filter is applied to blur the image.

In the second stage, using the smoothed image, gradients of intensity are computed at each pixel. This indicates the rate of change of intensity and helps identify potential edges. Differential filters like the Sobel or Prewitt filters are often used for this purpose..

In the third stage, in order to eliminate insignificant gradients caused by noise, a thresholding technique is applied. Gradients below a certain threshold are considered noise and discarded.

In the fourth stage, a threshold value is determined to separate significant edges from the rest of the image. This threshold can be a static value or dynamically computed based on statistical properties of the image.

In the fifth stage, The individual gradient responses that correspond to edges are connected to form continuous edge segments. Various approaches such as edge grouping algorithms or edge tracing algorithms can be used for this step.

This algorithm is used for edge detection in images and for determining the shape of objects in an image.

B. The Sobel algorithm:

The Sobel algorithm is a popular method for processing medical images to detect edges and contours of objects. It is based on computing the gradients of brightness in the image and consists of the following steps:

- Preprocessing of the image: Before applying the Sobel algorithm, preprocessing of the image is often performed to smooth out noise and improve image quality. This may involve applying smoothing filters, such as a Gaussian filter.
- Computing brightness gradients: In this step, two Sobel operators are applied - one for computing the vertical gradient and another for computing the horizontal gradient at each point in the image. The Sobel operators are used to highlight changes in brightness between neighboring pixels.
- Computing absolute gradient values and directions: After computing the vertical and horizontal gradients, the absolute gradient values are calculated for each point. The direction of the gradient is also determined, which helps determine the orientation of the edge.
- Applying a threshold value: To extract significant edges and suppress noise, thresholding is applied. Pixels with absolute gradient values below a certain threshold are considered noise and discarded, while pixels with higher values are preserved as object edges.
- Edge linking: Finally, the detected edges are linked to form continuous object contours in the image. This can be achieved through operations like connected component labeling or edge tracing.

C. Renyi dimension:

Renyi dimension is determined by estimating the entropy or information distribution within the image. It measures the degree of non-uniformity or variability of pixel intensities in the image. A higher Rényi dimension indicates more complex structures or images with a greater number of details and textures.

For processing medical images on FPGA, the Rényi dimension algorithm can be implemented by computing the informational content of pixels or using specific formulas for entropy estimation. FPGA provides high computational power and the ability for parallel processing, enabling efficient calculation of the Rényi dimension on medical images in real-time.

Applying Renyi dimension for processing medical images on FPGA can aid in analyzing structural features, detecting important details, and highlighting regions of interest in the images. This can be beneficial for diagnosis, measurement of object sizes, or assessing the complexity of pathological changes.

D. Local Binary Pattern, LBP:

The Local Binary Pattern (LBP) method is a technique for comparing the intensity of pixels at a specific pixel with their neighbors, which provides information about local texture features. The LBP method is based on comparing the pixel intensities at a central pixel with its neighbors. Typically, this comparison is performed using binary encoding. The application of LBP allows for the extraction of various local texture features such as spots, lines, and circles.

The LBP method can be used to determine certain image characteristics, such as texture energy, contrast, and smoothness. Its application in practical medicine can aid in the diagnosis and monitoring of diseases such as breast cancer, lung cancer, hepatitis, tuberculosis, and others.

E. The Haralick algorithm:

This is a method for analyzing texture in an image based on its statistical properties. The main idea is to identify a set of statistical characteristics of the texture in the image and use them for image classification. The Haralick method can be used to describe textures in images and determine their characteristics. Statistical features such as energy, contrast, homogeneity, and others are utilized to describe textures.

The application of the Haralick method can be beneficial in the processing of medical images, such as X-ray images, magnetic resonance imaging (MRI), and other fields related to image processing. One of the advantages of the Haralick method is its ability to assess textures from various directions and scales.

REFERENCES

[1] V. Semenets, V. Chumak, I. Svyd, O. Zubkov, O. Vorgul, N.a Boiko. Designing the Structure of a General-Purpose Telemedicine Complex. // III International Scientific and Practical Conference Theoretical and Applied Aspects of Device Development on Microcontrollers and FPGAs (MC&FPGA), Kharkiv, Ukraine, 2021, pp. 47-48, doi: 10.35598/mcfpga.2021.016.

[2] В.С. Чумак, И.В. Свид. Перспектива использования продукта FPGA в медицинских системах. // XIII Міжнародна науково-практична конференція магістрантів та аспірантів «Теоретичні та практичні дослідження молодих науковців» (19–22 листопада 2019 року): матеріали конференції. – Харків : НТУ «ХПІ», 2019. – С. 288-289.

[3] I. Svyd, O. Vorgul, V. Semenets, O. Zubkov, V. Chumak, N. Boiko. Special Features of the Educational Component “Design of Devices on Microcontrollers and FPGA”. // II International Scientific and Practical Conference Theoretical and Applied Aspects of Device Development on Microcontrollers and FPGAs (MC&FPGA), Kharkiv, Ukraine, 2020, pp. 55-57. doi: 10.35598/mcfpga.2020.017

[4] В. Чумак, І. Свид. Створення модуля VHDL-опису при проектуванні цифрових систем на ПЛІС в Xilinx ISE Design Suite. // Перспективні напрямки сучасної електроніки, інформаційних і комп'ютерних систем (MEICS-2019). Тези доповідей на IV Всеукраїнській науково-практичній конференції: 27-29 листопада 2019 р., м. Дніпро. – Дніпро, Дніпровський національний університет імені Олеся Гончара, Кременчук: ПП Щербатих О. В., 2019. – С. 94-95.

[5] Луценко О. В. Використання FPGA для реалізації штучної нейронної мережі / О. В. Луценко, В. С. Чумак // Автоматизація, електроніка та робототехніка. Стратегії розвитку та інноваційні технології : матеріали IV форуму, 24–25 листопада 2022 р. – Харків : ХНУРЕ, 2022. – С. 26-27.

[6] Чумак В. С. Реализация структуры нейронных сетей на FPGA / Чумак В.С., Свид І.В. // Наука, технології, інновації: тенденції розвитку в Україні та світі: матеріали міжнародної студентської наукової конференції, 17 квітня, 2020 рік. – Харків, Україна: Молодіжна наукова ліга. –Т.2– С. 30-32.

[7] Чумак В. С. Применение FPGA при реализации искусственной нейронной сети для информационных систем. Науковий керівник: Свид І. В. // Авіація, промисловість, суспільство : матеріали II Міжнар. наук.-практ. конф., (м. Кременчук, 12 трав. 2021 р.) : у 2 ч. / МВС України, Харків. нац. ун-т внутр. справ, Кременчуц. льотний коледж. – Харків : ХНУВС, 2021. – Ч. 1. – С. 109-111.

[8] Чумак, В. С., Аврунін, О. Г., Чугуй, Є. А., & Свид, І. В. (2021). Аналіз принципів побудови телемедичних комплексів широкого призначення. АСУ та прилади автоматики, 177, 80–85.