Investigation and Simulation of Different Medical Image Processing Algorithms to Improve Image Quality Using Simulink MATLAB

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Abstract

After the discovery of X-rays with the increasing use of digital imaging systems, medical image processing has become more important. Medical image processing helps specialists in diagnosing diseases. In addition to major digital techniques such as computed tomography (CT) or magnetic resonance imaging (MRI), analog imaging techniques such as endoscopy or radiography are now equipped with digital sensors. By processing images using different methods, the procedure applied to patients can be improved. Algorithms play a key role in noise filtering, segmentation, extraction, and characterization that diagnose diseases. MATLAB software and image processing toolbox provide a wide range of advanced image processing functions and interactive tools for enhancing and analyzing digital images. In this article, using several algorithms designed in MATLAB, the quality of images is examined and a more appropriate algorithm is selected.

Keywords: Image Processing, Medical Images, Operator, Simulink MATLAB.

1. INTRODUCTION

Digital image processing has a vital role in the analysis and interpretation of remotely sensed data, especially digitally obtained remote sensing and satellite data, which with the help of digital image processing to the best of these images are used [1,2].

The common term "medical image processing" is to obtain a processed digital image for medical applications [3,4]. Medical image processing covers five main areas as shown in Fig. 1, which are [5]:

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A. Formation: The image includes all the steps from taking an image to forming a digital matrix image.

B. Image Enhancement: In contrast to image analysis, also called high-level image processing, low-level image processing or image enhancement involves manual or automatic methods performed without prior knowledge of the specific content of images. This type of algorithm has similar effects regardless of what is shown in the image.

C. Image visualization: refers to the types of manipulations of this matrix, the result of which is the optimal output of the image.

D. Image analysis: includes all processing steps that are used for quantitative measurement as well as abstract interpretation of medical images. This step requires prior knowledge of the nature and content of the images, which must be integrated into high-level abstraction algorithms. Therefore, the image analysis process is very specific and advanced algorithms can rarely be transferred directly to other applications.

E. Image management: includes all methods that provide storage, communication, transferring, archiving, and access (retrieval) of image data for you. A simple gray-scale radiograph may require several megabytes of storage capacity and use compression techniques. Telemedicine is also part of image management.

Commonly used image processing algorithms include image enhancement, inversion, and image segmentation. In particular, biomedical image enhancement (BIE) is one of the most important and difficult methods in digital image processing research [6,7].

Tools for improving the output quality of the system include calibration, stabilization, optimization, transformation, and filtering [8,9]. The main purpose of BIE is to improve the visual appearance of an image or to provide a "better display of deformation" for future image processing. Digital image enhancement methods improve the visual quality of images. The main purpose of image enhancement is to process an image to get a better result than the original image for specific applications. Image processing is one of the most basic and significant solutions. The accuracy and reliability of its results directly affect the diagnosis and treatment of specific and chronic diseases.

Implementing image enhancement algorithms in a field programmable gate array (FPGA) has advantages such as the use of large memory and amplifier [10,11]. The image inversion algorithm is used to obtain information hidden in dark pixels, which is mentioned in this article. The most important part of medical image processing is image segmentation. Many image segmentation methods have been used in medical applications to segment body tissues and organs. Some applications include border detection in coronary angiography, surgical scheduling, surgical simulation, tumor diagnosis and segmentation, brain growth study, functional mapping, automatic blood cell classification, diagnosis Mass in mammogram, image recording, heart splitting and analysis of cardiac images, and so on. Image segmentation is a vital process in the early detection of abnormalities and treatment planning. Fragmentation algorithms have been used to extract
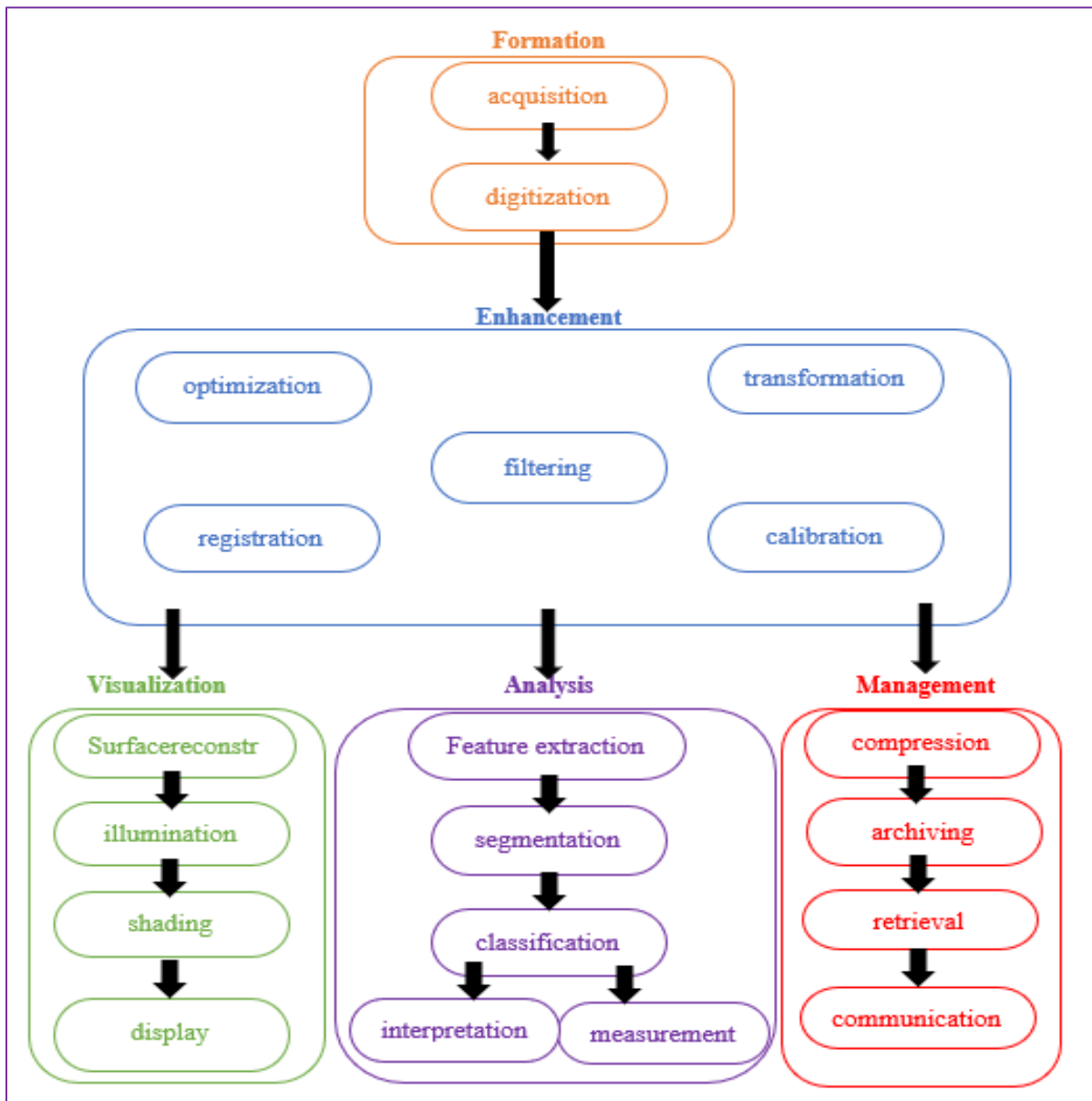
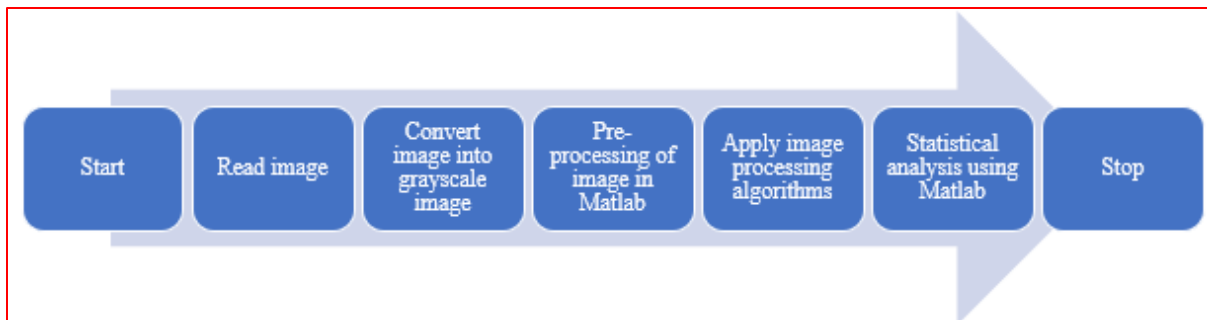**Fig. 1. Steps of image processing design.**

Fig. 2. The path of designing image processing algorithms in MATLAB software.

anatomical structures and anomalies from medical images. In general, classifications are divided into three categories: point, line, and edge detection.

MATLAB software is a high-level technical language and an interactive environment for data analysis and mathematical calculation functions such as signal processing, optimization, solving partial differential equations, etc. [12,13]. It provides interactive tools including thresholds, correlations, Fourier analysis, filtering, initial statistics, curve connections, matrix analysis, and drawing functions. Image processing operations allow noise reduction and image amplification, image conversion, map color manipulation, color system conversion, area processing, and geometric operations. The toolbox functions implemented in MATLAB software can be used to apply the desired algorithms [14,15].

Image processing is widely used in various methods of disease diagnosis (human, animal, plant) and helps specialists in choosing the appropriate treatment [16,17]. In most diagnostic applications, the image is improved by various methods of filtering and segmentation, as well as separation of target areas. The input image is classified in the final step. Methods of diagnosing the disease are based on these steps and common methods [18]. For example, many diseases can be diagnosed by using human nail image as input and nail color analysis. Another example is the diagnosis of skin diseases and cancer by turning the image of the desired area on grayscale and applying various filters to eliminate noise, as well as applying the

desired algorithms to diagnose the disease. One of the most important applications of image processing with software such as MATLAB is the detection of brain tumors using magnetic resonance imaging (MRI). This diagnostic method includes noise removal, segmentation, and morphological operations based on image processing [19,20]. Examining various researches in the field of diagnosis of diseases and tumors, it can be concluded that the diagnosis of the edges of the studied object is very important for diagnostic applications [21,22].

Medical image processing using various methods helps to diagnose the disease. The MATLAB software image processing toolbox can be used to improve and analyze digital images. In this article, using several algorithms designed in MATLAB, the quality of images is examined and a more appropriate algorithm is selected.

2. IMAGE PROCESSING ALGORITHM IN MATLAB SOFTWARE

Medical image analysis is the process of extracting useful information from medical images that often uses computational methods [23,24]. Some of the applications of medical image analysis are visualization and exploration of 2D images and 3D volumes, segmentation, classification, 3D recording and reconstruction of image data. Input images for these analyzes can be obtained from medical imaging techniques such as X-rays (2D and 3D), sonography, computed tomography (CT), MRI, nuclear imaging (PET and SPECT), and microscopy achieved [25,26]. MATLAB has a scalable environment and is used to analyze and

access data to build medical image analysis algorithms. Medical image analysis can be used to automate or simplify tasks such as counting and identifying cells in a microscopic image. For example, cancerous abnormalities can be analyzed in cells. By computational analysis, the tumor tissues can be distinguished from the dead or the amount

of oxygen saturation in the blood vessels can be measured. With medical image analysis, a three-dimensional MRI image can be reconstructed to calculate organ function and other diagnostic procedures. Medical image analysis algorithms can be used on large amounts of data such as digital health data
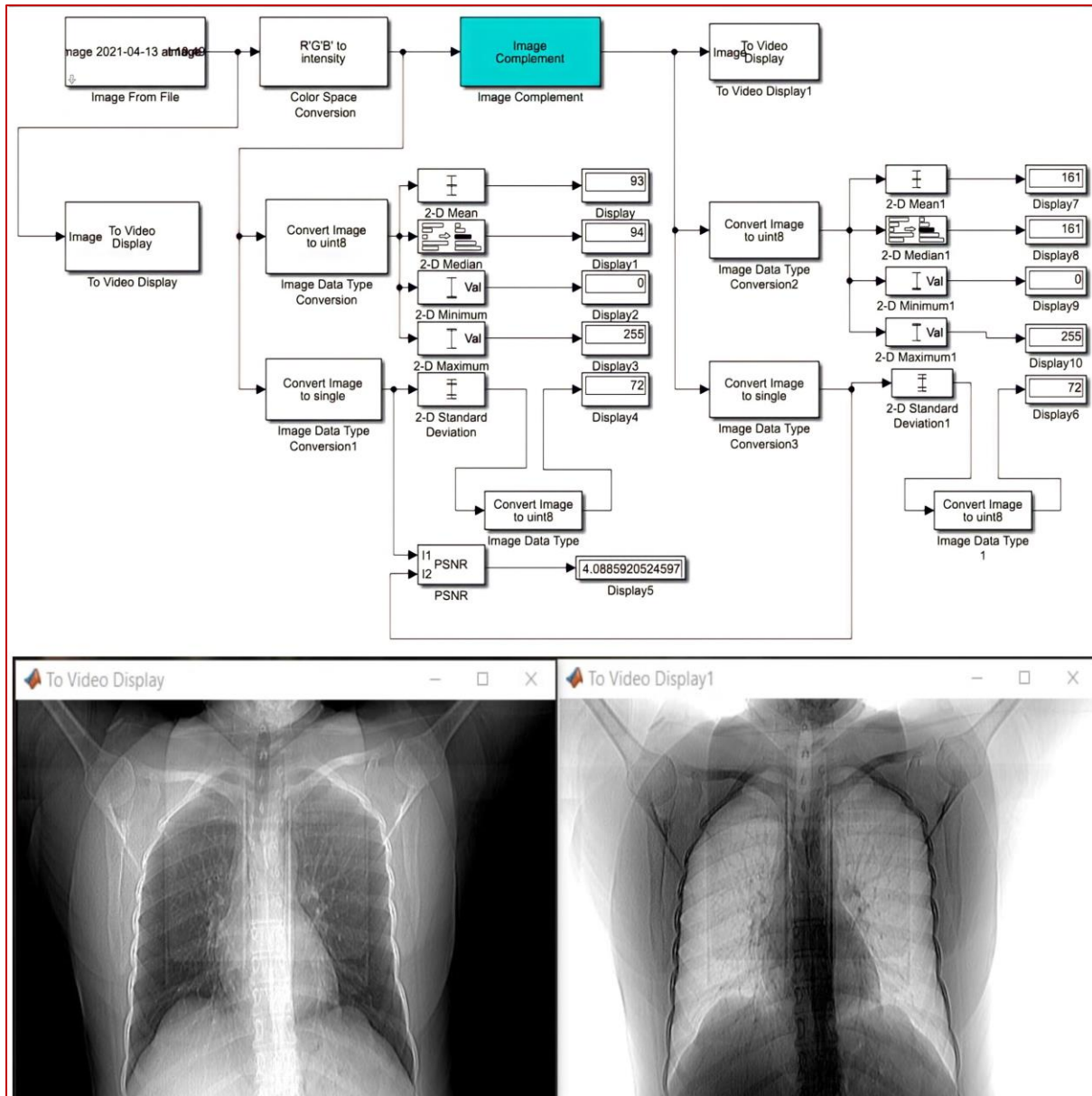

Fig. 3. Image inversion model using image complement in MATLAB Simulink environment (The CT scan image is from the chest of a 52-year-old patient at the Imaging Center of Khorshid Hospital in Isfahan).

collected from wearable gadgets. These algorithms can be used to manage diseases and health risks as well as promote health and wellness. With MATLAB software, two-dimensional images and three-dimensional volumes can be illustrated and analyzed. It also processes very large and high-resolution images. Simulink MATLAB is a widespread platform in MATLAB that does not require coding. In this paper, the performance of selected algorithms using MATLAB Simulink is investigated. Fig. 2 shows the design path of image processing algorithms in MATLAB software [27].

3. PEAK SIGNAL-TO-NOISE RATIO

The peak signal-to-noise ratio (PSNR) is a parameter for the ratio between the maximum possible power of a signal and the destructive noise power that affects its view accuracy.

Given that many signals have a very wide dynamic range, PSNR is expressed as a logarithmic value using the decibel scale.

The PSNR is used to quantify the quality of images and compressed videos [28].

The PSNR measure depends on the Root Mean Square Error (RMSE) among the interest image and the reference one. It can be expressed as [29]:

$$PSNR = 10 \times \log(\frac{f_{max}^2}{RMSE^2}) \qquad (1)$$

where f_{max} defines the maximum image pixel score.

4. ANALYSIS OF THE FUNCTION OF THE STUDIED ALGORITHMS

In this article, in general, the three algorithms of image inversion, image enhancement, and image segmentation, which are done in several different ways, are examined and according to the results and the most appropriate filter numbers and figures algorithms are specified.

4.1. Visual Analysis

First, using MATLAB Simulink, the effect of the algorithms for processing medical images is visually reviewed and then to ensure the obtained data using statistical parameters such as mean, median, Standard deviation, minimum, and maximum, they are compared with each other. First, the image inversion algorithm is investigated. As a simple definition, in the inversion of the image, light areas become dark and dark areas become light. In Fig. 3, the image inversion algorithm is implemented in Simulink.

The medical image enhancement algorithm plays a very important role and targets problems such as low contrast and high-level noise for accurate diagnosis of specific diseases as well as data related to research and analysis. There is a wide range of methods to improve the image. Contrast enhancement, density layering, edge reinforcement, and optical filtering are some of the most commonly used methods.

The Median Filter (MF) is typically used to reduce noise in the image, this filter usually has a better performance than the averaging filter in maintaining useful detail in the image. The median filter, like the middle filter, considers each pixel of the image individually and looks at the neighbors next to that pixel to decide if it represents the environment. Instead of simply replacing the pixel value with the average of the

neighboring pixel values, replace it with the middle of the values.

The median first sorts all the pixel values from the surroundings in numerical order and then replaces the intended pixel with the calculated middle pixel value. Fig. 4 shows the median filter block that replaces the complementary image block in Fig. 3 as well as the input and output image of the algorithm.

Contrast adjustment techniques to enhance the image Expand the range of brightness values in the image to get the image as desired by the dimmer. The density in a scene varies and expands over a wider range. This method makes it easy for the analyst to distinguish between areas that initially had little difference in density. This method is very useful for improving dark
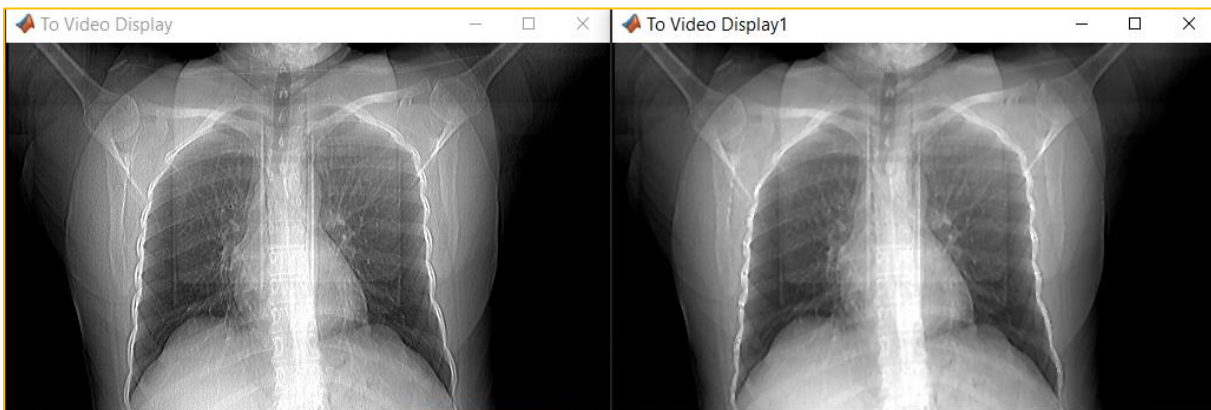
images [30]. Fig. 5 shows the contrast adjustment block that replaces the complementary image block in Fig. 1 as well as the input and output image of the algorithm.

In addition to segmentation of medical images, the thresholding method has been used to improve and enhance the images.

The thresholding method is used to create a binary image of a grayscale image. This method is in line with the same main goal of image improvement, which means changing the properties of the image in order to make it more accurate for applications intended by experts [31]. Fig. 6 shows the automatic threshold block that replaces the complementary image block in Fig. 1 as well as the input and output image of the algorithm.
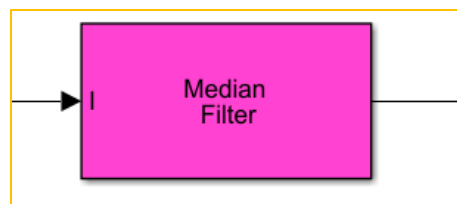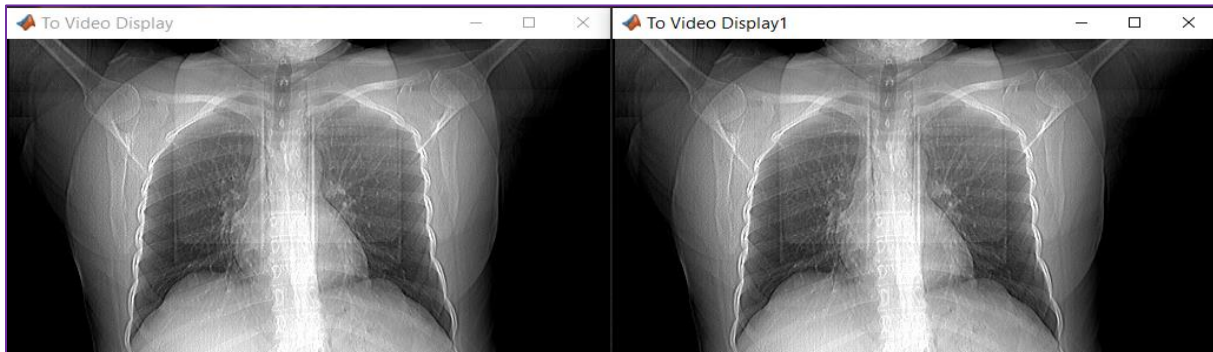

(a) Intermediate filter diagram block

(b) Input and output image using image enhancement model

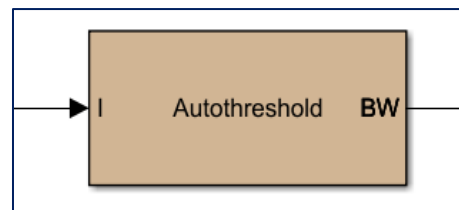**Fig. 4. The result of the image using the middle filter.**
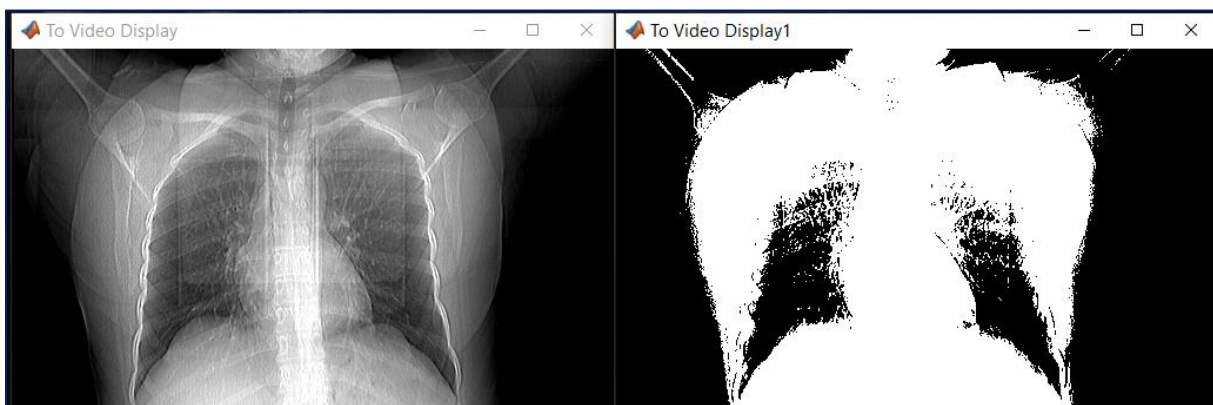
(a) Contrast adjustment block diagram

(b) Input and output image using image enhancement model

Fig. 5. The result of the image using the contrast adjustment.

(a) Automatic transition threshold block diagram

(b) Input and output image using image enhancement model

Fig. 6. Image result by auto-threshold.

The most important part of medical image processing is image segmentation. Image segmentation is the process of segmenting a digital image into several regions or sets of pixels. Image segmentation is a method with automatic or semi-automatic process for extracting the region of interest (ROI). Many image-splitting methods have

been used in medical applications to segment body tissues and organs [32,33]. Some applications include coronary artery bypass graft angiography, surgical scheduling, surgical simulation, tumor diagnosis and segmentation, brain growth study, functional mapping, automatic classification of blood cells, ward Heart classification and analysis of heart images, and so on. The segmentation algorithm is divided into four categories, which are: area-based methods, classification methods, and hybrid methods.

The boundary between two areas with different gray balance properties is called the edge. Edge Detection (ED) is one of the main methods used in segmentation. (There is also a point and line recognition method). There are various operators such as Sobel, Robert, Prewitt and Canny, etc. that are used to design the edge detection algorithm. This article reviews Sobel and Canny operators.
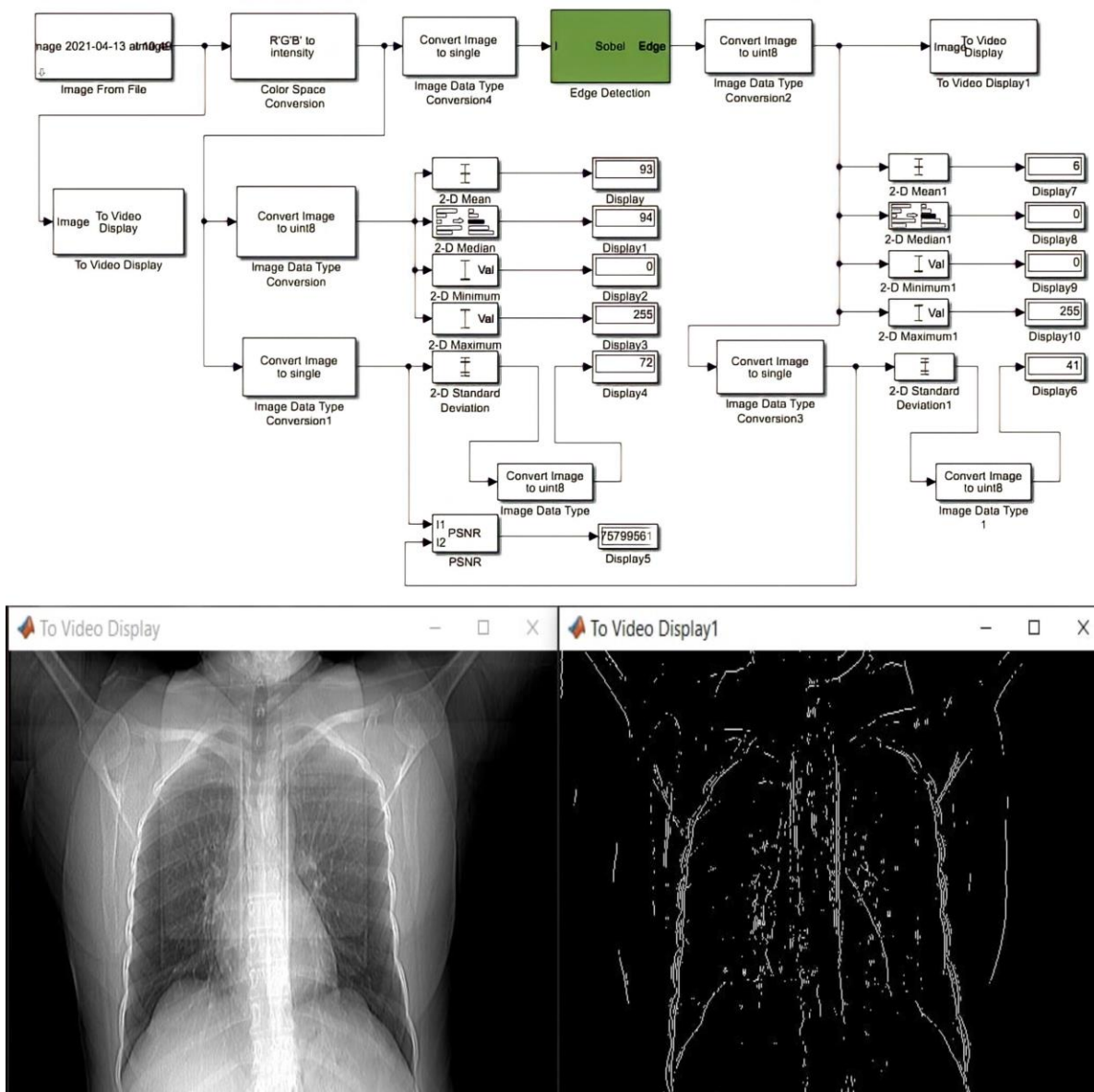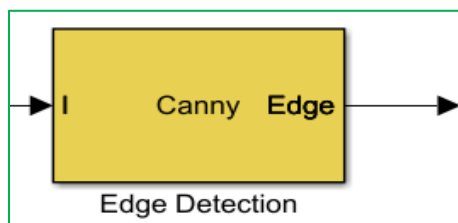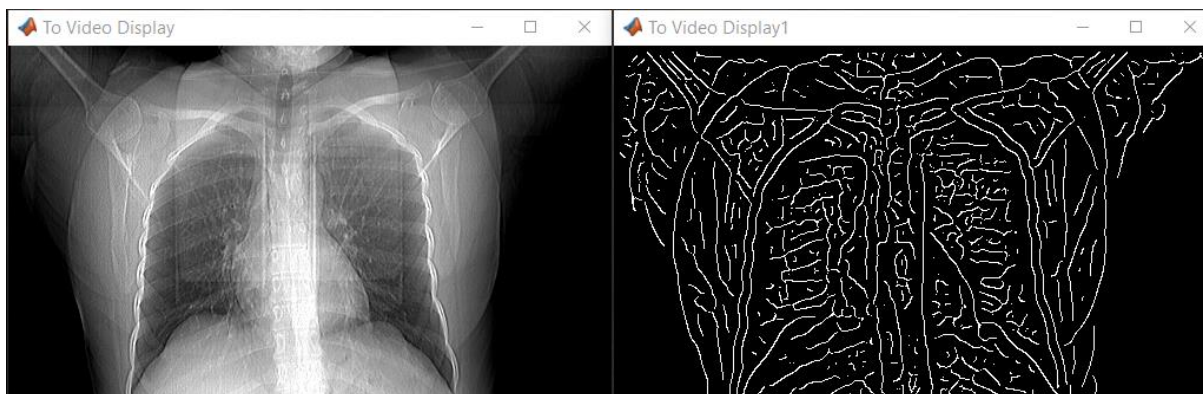

Fig. 7. Diagram block in MATLAB Simulink and the result of edge detection with Sobel.

(a) Edge detector operator block

(b) Input and output image using edge detection model

Fig. 8. Simulation result by Canny operator.

The Sobel operator is used in image processing methods, especially edge detection. The Sobel operator is based on combining the image with a small, separable filter with the integer value in the x and y directions, so it is relatively inexpensive computationally. Fig. 7 shows the method of edge detection using the Sobel operator

The Canny Detector is an edge detection operator that uses a multi-step algorithm to detect a wide range of edges in images. The operator can also effectively detect the edges of the image with added noise. Fig. 8 shows the operator block of the Canny edge detector, which replaces the Sobel operator block in Fig. 7, as well as the input and output image of the algorithm.

The named operators have different results both visually and statistically. Analysts use different operators to detect the edge according to their intended purpose.

As seen in the visual analysis of the algorithms, many of the visual data obtained have similar results. Although visual analysis is important for detecting applied algorithms, they must also be statistically compared to ensure results.

4.2. Statistical Analysis

In order to statistically analyze this section, a number of statistical parameters such as mean, standard deviation are used to determine the applied algorithm.

As shown in Table 1, statistical parameters are used to identify and evaluate the algorithms used in image processing.

Table 1. *Statistical analysis of image processing algorithms.*

Row	Image processing algorithms	Average	Standard deviation	Minimum	Maximum	PSNR
1	Input image	93	72	0	255	-
2	Image inversion	161	72	0	255	4.08
3	Improve the image using the median filter	93	72	0	255	41.7
4	Image enhancement using contrast adjustment	93	72	0	255	52.67
5	Automatic image thresholding	127	127	0	255	9.75
6	Sobel edge detector	8	46	0	255	6.78
7	Canny edge detector	10	50	0	255	6.62

According to the information provided by these parameters, a more appropriate algorithm can be selected than other algorithms. From these parameters, the mean indicates the average number of pixels and the standard deviation also calculates the amount of change in the number of pixels. The minimum and maximum ranges are the same for all algorithms and are zero to 255. The last column of the PSNR table represents the term signal-to-noise ratio of 8, which means the signal-to-noise ratio and shows analysts the quality of the image. If we compare the PSNR value of the algorithms, this parameter for the image correction algorithm using the contrast setting is 52.67, while for the same algorithm using the PSNR middle filter is 31.7, which indicates that the image is processed by improving the image by using a contrast adjustment; also, by comparing the PSNR value for the two Sobel and Canny edge detection operators, which are 6.78 and 6.62, respectively. it can be concluded that between these two operators, Sobel has a slightly better output. With this statistical information and their analysis, analysts and experts select and use a more appropriate algorithm for the application.

5. CONCLUTION

Medical imaging devices are used to diagnose and prevent disease in people, which is mainly due to the noise generated by the image output of the device which is not of good quality and makes the work difficult for the analyst and specialist. Therefore, image processing algorithms are used to improve image quality and enhance the output. In this paper, by designing a number of algorithms using MATLAB software in Simulink space, medical image processing is mentioned. In general, image inversion, image enhancement, and image segmentation algorithms were used, each of which has its own application in medicine. By visual inspection in Simulink and then statistical analysis, the peak signal-to-noise ratios of the algorithms were compared with each other, and it was concluded that to improve the contrast adjustment images compared to the

median filter, better results are given to researchers. Better results are obtained in recognizing the edge of the Soble operator with a slight difference from the Canny operator. In the field of image processing, MATLAB software is an accurate, efficient, and flexible tool that is very easy to work with and get results from.

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