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Tubercolusis Segmentation Based on X-ray Images

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A B S T R A C T

Tuberculosis or TB is an infectious disease caused by the bacterium Mycobacterium tuberculosis. This disease typically affects the lungs but can also impact other organs such as the kidneys, bones, and brain. TB is highly contagious and can spread through the air when an infected person coughs or sneezes. The main challenge in early detection through automated chest X-ray image analysis is the segmentation of the X-ray images. Lesions are identified by experts and doctors to determine the lesion volume and whether the pixel resolution is normal or not. A comparison is made between the area of modifications using Red, Green, Blue (RGB) color channel operations and grayscale, employing three edge detection methods: SobelX, Felzenszwalb, and Canny for lesion volume segmentation. To aid anatomical pathology experts in diagnosing tuberculosis, segmentation of chest X-ray image volumes is performed using color channel operations and edge detection. The volume or lesion values obtained are then compared. Research results indicate that color channel operations with modified summation of Red, Green, and Blue (RGB) channels along with Canny edge detection yield the highest segmented RGB image (Otsu's thresholding) with a value of 230,466.0 pixels and a lesion volume of 14,818.625 mm^3.

1. Introduction

One serious health problem worldwide is tuberculosis. Tuberculosis is a disease caused by the bacterium Mycobacterium tuberculosis, which affects the respiratory system, particularly the lungs. This highly contagious disease can spread through the air when an infected person coughs, sneezes, or even talks.

According to the World Health Organization (WHO) data in 2020, an estimated 10 million deaths out of 8,005,176,000 people [1] were associated with tuberculosis worldwide each year. This disease is also the leading cause of death globally, with approximately 1.5 million people dying from TB annually.

Despite being a global issue, tuberculosis is more commonly found in developing countries, especially in low and middle-income nations [2], [3]. Contributing risk factors to the spread of this disease include poor socio-economic conditions, limited access to healthcare, and low awareness and education levels regarding tuberculosis. Throughout the course of the infection, various patterns of lung lesions can simultaneously appear in the same host [4].

Tuberculosis can affect the respiratory system, causing symptoms such as productive cough, fever, weight loss, fatigue, and chest pain. If left untreated, the disease can progress severely and spread to other organs such as the kidneys, bones, or brain.

To address the tuberculosis problem, the World Health Organization (WHO) and its member countries have taken various preventive and treatment measures. These include efforts to raise awareness about TB, expanding access to treatment services, and developing new medications. However, despite efforts to control this disease, complex challenges persist. For instance, the increasing resistance to tuberculosis drugs, especially in the case of multidrug-resistant tuberculosis (TB-MDR), adds difficulty to the treatment and control of the disease.

In addressing this issue, global collaboration among countries and organizations involved in tuberculosis management is crucial. Only through cooperation and shared commitment can the disease be effectively controlled and eliminated worldwide for the sake of survival [5], [6], [7], [8].

The focus of this research is on pulmonary tuberculosis. Disorders in the lungs pose a significant threat as they can affect the human respiratory system and lead to fatal consequences if not treated seriously. This can result in difficulty breathing, impaired activity, and oxygen deficiency, which, if not promptly addressed, can lead to death [9].

In the medical field, one way to identify abnormalities in the lungs is by examining images obtained from X-ray photographs of the lungs.

2. Research Method

2.1. Data

The dataset consists of 3,500 normal cases and 750 cases of tuberculosis. The data distribution is provided in Table 1. This research evaluates the chest X-ray segmentation from this dataset, which has already been manually segmented for all images by pathology experts and doctors [10]. The study employs image segmentation using the Sobel X, Felzenszwalb, and Canny edge detection methods, where researchers analyze pixel levels and lesion volumes using methods with a dataset-oriented scientific approach in Table 1.

Table 1. Data set

Data Set	Amount of Data
Normal	3500
Tubercolusis	750
Total Data	4250

2.2. Metode

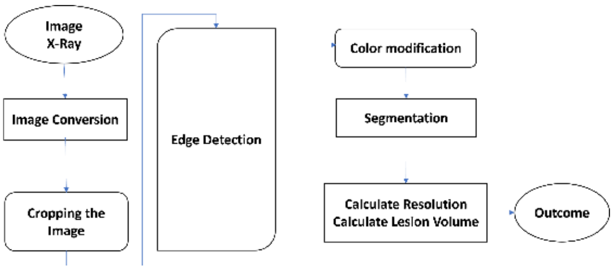

Figure 1. Research Methodology Scheme

The method used is image segmentation, employing Sobel X, Felzenszwalb, and Canny edge detection methods, where researchers analyze pixel levels and lesion volumes. These methods can be utilized to measure lesion sizes in lung images or other medical images. However, there are several considerations to be taken into account, such as the lesion detection rate. The program relies on thresholding and contour search to detect lesions, and the success rate in lesion detection is highly dependent on the characteristics of the medical images used. Some medical images have low contrast levels or features of lesions that are challenging to identify. Lesion detection methods in medical images often require more sophisticated approaches, such as the use of deep learning or image resolution segmentation algorithms.

The Canny edge detection method obtains the highest pixel values for lesion sizes and is a technique in machine learning inspired by the structure and function of the human biological neural network in chest X-rays. Testing the method with images, as illustrated below, involves filtering, color image processing techniques, separating color channels, eliminating noise, and producing better initial accuracy as shown in Figure 1. The initial step involves converting the original image to a grayscale image [11], [12], [13], [14], [15], [16], [17].

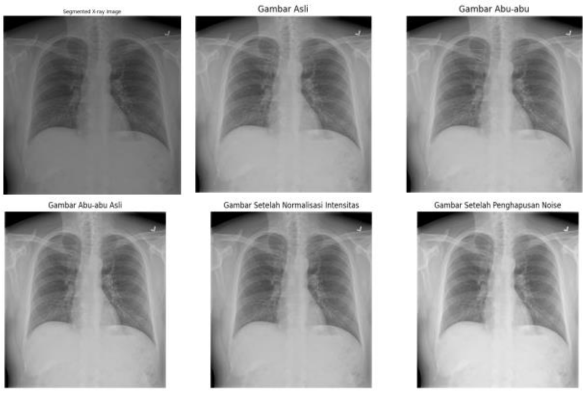

Figure 2. X-Ray Lung Images

2.3. Operation Konvensi Citra color RGB and Grayscale.

The image processing conducted based on the research method involves several stages, including the image processing steps after noise removal cropping, which aims to extract the image and perform grayscale and RGB color channel operations without noise in Figure 2. A selected cropping process results in a single chest image in Figure 3.

Figure 3. Citra X-Ray Chest Without Noise

2.4. Edge Detection Process

The next step involves edge detection. The use of edge detectors such as Roberts, Prewitt, and Sobel is common for diagnosing various images, including brain tumor images [18], [19] and others. In this study, three edge detection methods are employed: Sobel X detection, Felzenszwalb, and Canny edge detection.

2.4.1. The Sobel edge detection

The Sobel edge detection formula for chest X-ray images can be explained as follows. Let II be the pixel intensity in the grayscale image, and GxGx and GyGy are the gradients or partial derivatives with respect to the xx and yy axes, respectively. The Sobel operator calculates the gradient using a 3x3 kernel or convolution matrix, as shown in Equation (1) and Equation (2).

$$Gx = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 1 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$

$$Gy = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix} \quad (1)$$

The Sobel edge detection process can be explained by the following Formula (2).

$$M = \sqrt{G_{x^2} + G_{y^2}}$$

$$O = \arctan\left(\frac{G_y}{G_x}\right) \quad (2)$$

Where M is gradient magnitude indicating the strength of intensity change, and O is gradient direction indicating the direction of intensity change.

2.4.2. Felzenszwalb

Felzenszwalb is typically used for image segmentation, where the goal is to partition the image into several regions or segments based on similarity in features. The method is not solely focused on edge detection but rather on forming segments that encompass areas with uniform features.

2.4.3. Canny Edge Detection

Canny Edge Detection is one of the commonly used techniques in image processing to find significant edges or boundaries. The Canny edge detection formula involves convolution with a Gaussian Filter, convolving the image with a Gaussian kernel to reduce noise and smooth the image Equation (3).

$$G(x,y) = \frac{1}{2\pi\alpha^{2^2}} - (x^2 + y^2) / (2x^2) \quad (3)$$

2.5. Color Modification

Color modification at this stage involves adjustments to the RGB values. There are the original image, grayscale image, and original RGB image in Figure 4.

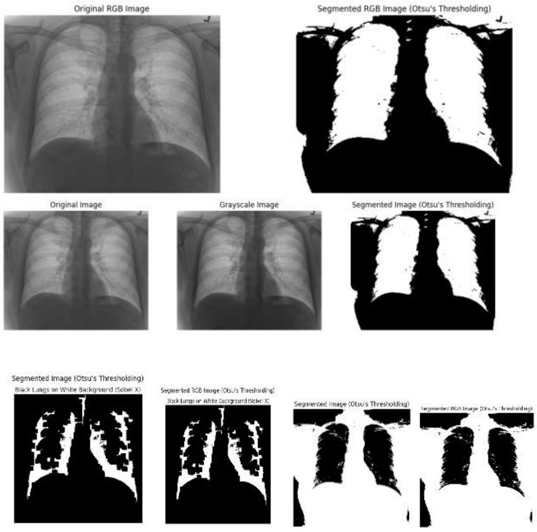

Figure 4. Chest X-Ray Image Segmentation with Canny, Sobel, and Felzenswalb

2.6. Calculate Resolution and Calculate Lesion Volume.

Calculate Resolution and Calculate Lesion Volume Compute the area value, which is the total number of pixels in the calculated region using the size parameter. Also, calculate the lesion volume in the binary image. By testing the Canny detection model with images, as illustrated below, where we previously filtered, applied color image processing techniques, separated color channels, eliminated noise, and performed segmentation, resulting in better accuracy as shown in the image below. The accuracy values for the resolution of the segmented RGB image (Otsu's Thresholding) are 230,466.0 pixels, and the lesion volume in the image is 14,818.625 mm^3 in Tabel 2.

Table 2. Research Methods Used and Results

No Method	GrayScale Image (Pixels)	SRGB Image (Pixels)	Gray Scale Lesi (mm^3)	RBG Lesi (mm^3)
1. No Noise	150000	173382	13345.375	15465.000
2. Sobel X	151956	170826	7386.750	8166.125
3. Felzenswalb	138750	184458	6796.750	8961.000
4. Canny Detection	132020	230466	9002.000	14818.625

The original X-ray image processed through the chain code method with dilation, erosion, opening, and closing operations results in the image shown in Figure 5.

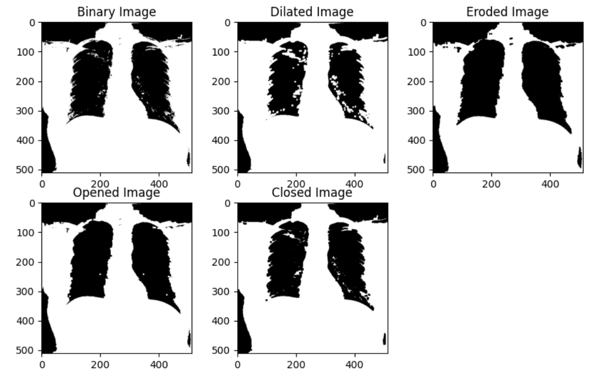

Figure 5. Original X-Ray Image to Chain Code Method

The original X-ray image processed through the chain code method with dilation, erosion, opening, and closing operations results in the image shown in Figure 6.

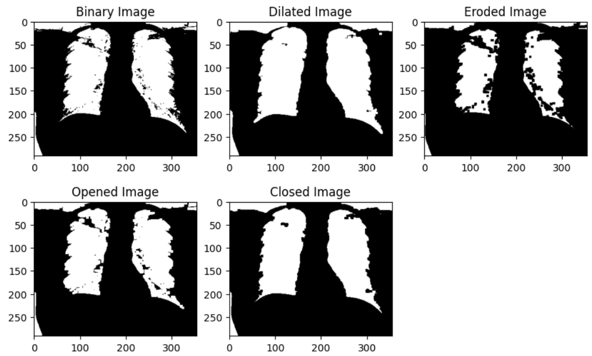

Figure 6. X-Ray Image from Canny Edge Detection to Chain Code Method

3. Discussion

Regarding tuberculosis (TB), several key aspects relevant to the management and understanding of the disease can be involved. This includes challenges in early TB detection, considering its often nonspecific symptoms. Early identification allows for prompt and accurate treatment, crucial for achieving positive outcomes. The use of X-ray images and segmentation techniques in the diagnostic process is well-explained. The method details the use of image segmentation techniques, such as Canny edge detection, Sobel X, and Felzenszwalb, to enhance the clarity of X-ray images for tuberculosis diagnosis. A more in-depth discussion about the strengths and limitations of each segmentation method can provide insights into their effectiveness in different scenarios. This could involve strategies to enhance public and healthcare professional understanding of early symptoms and examinations. Antibiotic resistance in TB treatment is a major concern. Discussions can involve efforts to reduce antibiotic resistance and ensure effective treatment. The role of vaccination, especially the BCG vaccine, in preventing TB is crucial. Further understanding of the effectiveness of vaccination and research related to the development of new vaccines can be an essential part. The relationship between TB and HIV/AIDS infection is a noteworthy aspect. Detailing strategies to address both diseases simultaneously and how TB control efforts can be integrated with HIV/AIDS programs is essential. This should encompass the importance of research and development to identify faster diagnostic methods, more effective treatments, and better vaccines. This forms the basis for strategic planning and the implementation of more effective programs in global TB management. Effectively addressing the importance of TB diagnosis, the role of image segmentation, and the global impact of this disease. Further explanations of segmentation methods, comparisons with existing techniques, and insights into future research areas will add depth to the discussion.

4. Conclusion

TB is an infectious disease caused by the bacterium Mycobacterium tuberculosis. It can affect various organs, particularly the lungs, and presents symptoms such as persistent cough, weight loss, fever, night sweats, and prolonged fatigue. Some risk factors that may increase the likelihood of contracting TB include a weakened immune system (as seen in individuals with AIDS, diabetes, or those on immunosuppressive drugs) and living or working in environments with high TB transmission rates. X-ray is one of the diagnostic tools used to detect TB. In this study, image segmentation was conducted to aid in the diagnostic process. The segmentation method involved edge detection using techniques such as Canny Edge Detection, Sobel X, and Felzenswalb. The segmentation method using Canny Edge Detection with segmented RGB image (Otsu's Thresholding) resulted in an accuracy value of 230,466.0 pixels for image resolution and a lesion volume of 14,818.625 mm^3. Color modifications were made at certain stages, including modifications to RGB values, grayscale images, and original RGB images. The segmentation stage involves breaking the image based on changes in image edges, aiming to measure resolution and perform the process of filling lesion volume holes. The results of this research can assist healthcare professionals, especially doctors, in interpreting chest X-ray results for TB more effectively and accurately. Image segmentation through edge detection and color modifications can facilitate the interpretation of X-ray results and support early diagnosis processes. This study contributes to the development of segmentation methods to support TB diagnosis through chest X-ray image analysis. It emphasizes that TB control requires a holistic approach involving various sectors, including health, education, and the environment. This strategy should encompass early detection, effective treatment, and prevention of transmission. Investing in research and development of new drugs, vaccines, and diagnostic methods is crucial to overcoming TB. These efforts will help improve the effectiveness of global treatment and prevention.

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